19 EUROPEAN SCIENCE EDUCATION RESEARCH ASSOCIATION

13TH CONFERENCE 26TH - 30TH AUGUST 2019 BOLOGNA ITALY

CONFERENCE PROCEEDINGS

ALMA MATER STUDIORUM
UNIVERSITÀ DI BOLOGNA

The Beauty and Pleasure of Understanding: Engaging with Contemporary Challenges Through Science Education (Proceedings of ESERA 2019)

ISBN 978-88-945874-0-1

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The Proceedings of ESERA 2019 is an electronic publication for revised and extended papers presented at the ESERA 2019 conference in Bologna, Italy during the 26-30 August, 2019. All papers in the eProceedings correspond to communications submitted and accepted for the ESERA 2019 conference. All proposals to the conference went through a double-blind review process by two or three reviewers prior to being accepted to the conference. A total of 1314 proposals (out of which 65 were symposia) were presented at the conference and in total 238 papers are included in the eProceedings.

The authors were asked to produce updated versions of their papers and take into account the discussion that took place after the presentation and the suggestions received from other participants at the conference. On the whole, the eProceedings presents a comprehensive overview of ongoing studies in Science Education Research in Europe and beyond. This book represents the current interests and areas of emphasis in the ESERA community at the end of 2019.

The eProceedings book contains eighteen parts that represent papers presented across 18 strands at the ESERA 2019 conference. The strand chairs for ESERA 2019 co-edited the corresponding part for each strand 1 to 18. All formats of presentation (single oral, interactive poster, ICT demonstration/workshop and symposium) used during the conference were eligible to be submitted to the eProceedings.

The co-editors carried out a review of the updated versions of the papers that were submitted after the conference at the end of 2019. ESERA, the editors and co-editors do not necessarily endorse or share the ideas and views presented in or implied by the papers included in this book.

The appropriate APA style for referencing this eProceedings is as follows:

Levrini, O. & Tasquier, G. (Eds.) (2020). Electronic Proceedings of the ESERA 2019 Conference. The Beauty and Pleasure of Understanding: Engaging With Contemporary Challenges Through Science Education, Bologna: ALMA MATER STUDIORUM – University of Bologna. ISBN 978-88-945874-0-1

The appropriate APA style for referencing individual papers in the eProceedings is as follows:

[Author(s)]. (2019). [Title of article]. In Levrini, O. & Tasquier, G. (Eds.),

Electronic Proceedings of the ESERA 2019 Conference. The beauty and pleasure of understanding: engaging with contemporary challenges through science education, Part [part/strand number] (co-ed. [Editors of the strand chapter]), (pp. [page numbers]). Bologna: ALMA MATER STUDIORUM – University of Bologna. 978-88-945874-0-1978-88-945874-0-1

WITHIN THE PROCEEDINGS:

Part 1: Learning science: Conceptual understanding

Part 2: Learning science: Cognitive, affective, and social aspects

Part 3: Science teaching processes

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PART 1: STRAND 1

Learning Science: Conceptual Understanding

Co-editors: *Anna De Ambrosis & Odilla Finlayson*

CONTENTS

STRAND 1: INTRODUCTION

LEARNING SCIENCE – CONCEPTUAL UNDERSTANDING

Strand 1 focusses on the processes of learning science that develop understanding. The emphasis here is on the research that examines how students develop conceptual understanding and the processes and strategies used to determine and further this. This is a central focus of research in science education as it encompasses all disciplines and educational levels.

This strand is therefore wide and varied as it comprises of theories, models, and empirical results on conceptual understanding, conceptual change and development of competences; methodology for investigating students' processes of concept formation and concept use; and strategies to promote conceptual development. Seventeen papers are now included in the e-proceedings under this strand, highlighting many aspects of developing conceptual understanding.

Understanding of specific concepts and identification of underlying misconceptions are targeted by several authors e.g. in the area of hydrostatics (Kiss and Velmovska), cosmology (Colantonio et al.), temperature-thermal sensation (Ezquerra-Romano et al.), kinematics (Kekule), costal physics (Bliesmer and Komorek), genes (Tsopoglou-Gkina and Papadopoulou) and quantum physics (Giliberti et al.).

The impact of inquiry-based approaches on students' conceptual understanding and scientific knowledge at different ages and cultural levels is analysed from a vertical and interdisciplinary curriculum perspective in the paper by Fazio et al.

The use of visualisation techniques including modelling have been used by many authors to elicit students' understanding and to help to connect ideas e.g. drawings linking to formal reasoning as applied to understanding of atomic structure (Zarkadis et al.), and static electricity (Stefanidou et al.). Four archetypes for interpretation of mental models is proposed by Ubben and Heusler. Moutet discusses the use of the extended Mathematical Working Space (MWS) framework to analyze the tasks to be performed by students and carried out by them in a teaching sequence dealing with solution chemistry.

Use of concept maps to aid in multilevel thinking of representations in chemistry is discussed by Hamnell-Pamment and this includes discussion with peers – a theme that is also researched by Hundertmark et al. (analysing discursive processes in a collaborative learning situation) and Heeg et al., within a peer-interaction model. The educational value of communication within diverse cultures, peoples and contexts, also with the help of technology, is analysed by Chartofylaka, and Forissier, who investigate what type of elements of cultural understanding emerge after the completion of a collaborative experience between young learners from different contexts. Questioning strategies are highlighted by Trimble et al.

The research papers presented here in the e-proceedings for Strand 1 represent the varied and diverse range of papers in this strand. Many of the papers focus on specific disciplinary concepts, evaluating and addressing areas of difficulty. It is interesting to note the varied approaches taken and there is not a 'one pedagogy that fits all'. The varied aspects of the papers in this strand provide us with many ideas to address conceptual understanding within various context and hopefully will stimulate further research in these areas.

Anna De Ambrosis Vigna & Odilla Finlayson

THE LEVEL OF UNDERSTANDING OF SELECTED CONCEPTS IN PHYSICS OF STUDENTS FROM DIFFERENT COUNTRIES

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Children start to perceive the world that surrounds them since the beginning of their lives. They start school with basic knowledge and there begins their education which includes classes of physics, too. During physics classes teachers encounter students' ideas about certain phenomenon every day. It would be ideal if teachers were aware of the students' ideas and should take their ideas to the account when introducing new physical knowledge. Based on this assumption we decided to focus on students' ideas in teaching physics in our study. Our main topic is the students' ideas connected with concepts and phenomena in Hydrostatics. Based on the analysis of movies sent by students to the Festival of Movies about Physics, and on the outcomes of another surveys and researches, we believe that students have incorrect ideas about certain concepts and phenomena in this thematic unit. To assess students' ideas, we have compiled a hydrostatics concepts and phenomena test. This test was filled in by students of primary schools from Slovakia and Hungary. The answers from students, who were part of our survey, were marked based on which country they come from and they were also compared with each other. We found out that involved students in both countries have incorrect ideas about different concepts and phenomena in Hydrostatics. One of these incorrect ideas relates to the behaviour of certain objects in liquids - involved students consider mass of the certain objects crucial when deciding how they act while submerged in liquids. According to the results of our survey we are able to conclude that involved primary school students from Hungary were less likely to have incorrect ideas about the topic than the involved Slovak students. As far as correct answers are concerned, we found no greater difference between the involved groups. In the following, we plan, based on the students' answers, the examination of students' quality of argumentation.

Keywords: Conceptual Understanding, Incorrect Ideas, Primary School

INTRODUCTION

The ideas which students have about the world around them when entering primary school can possibly match the theories already accepted in science, but they can also contradict them too. But how could we describe these ideas of the students?

How could we define the concept of preconception and misconception? Unfortunately, we cannot speak about unified terminology. According to Mandíková and Trna (2011), the reason for this is "the relative novelty of the concept and the relatively spontaneous research on this issue, without the existence of a generally accepted, basic theoretical research."

In the English literature (National Research Council, 1997), (Alwan, 2011) and (Read, 2014) we can find phrases as preconception, preconceived notion, alternative conception/framework, conceptual framework, intuitive theory, naive conception/theory, non-scientific belief, wrong physical concept, conceptual misunderstanding, misconception.

In the German literature (Weber, 2004), (Wilhelm, 2007) one can find the following phrases: Präkonzept, Alltagsvorstellung, Schülervorstellung, Schülervorverständnis, Fehlvorstellungen, Misskonzept.

In the Slovak and Czech literature (Haverlíková, 2013), (Mandíková and Trna, 2011), (Průcha, 2013) there are also different expressions and their different definitions and explanations.

The definition of preconception according to Mandíková and Trna (2011) is the following: "Preconceptions are the conception and interpretation of those objects and phenomena, which, from childhood onwards, are formed based on the direct observation of the surrounding world, that is, on the manipulation of the objects of the world and the instinctive generalization of one's own experience."

Haverlíková (2013) identifies preconceptions as primary ideas. She claims that "Preconceptions begin to evolve from the moment the individual interacts with the surrounding world. These are individual ideas, that emerge from a personal perspective based on experience from the past." Furthermore, she claims that the preconceptions are not always in line with the scientific views. However, we still cannot consider them incorrect. They are based on the individual's experience of everyday life, which means they are sufficient to solve everyday tasks. Therefore, they are resistant to changes and traditional teaching. Haverlíková (2013) defines the misconceptions as follows: "The misconceptions are deformed thinking structures, which lead to incorrect predictions, interpretations, explanations or problem solving in the field of science. Although the individual may use scientific concepts but argues with preconceptual mental structures."

Wijaya et al. (2016) states an easier definition to describe the concept of misconception. According to this misconceptions are the concepts created by the students that differ from explanations given by professionals.

As we can see, different authors define the concept of preconception and misconception in different ways. Under the phrase preconception we understand the ideas which students could acquire based on their own experiences in everyday life even before starting the primary school. These ideas might be correct or incorrect. Students' ideas after starting compulsory education are developing into an either correct or incorrect scientifically accepted idea. This incorrect idea is called misconception in our terminology. We use the terms correct and incorrect idea in our work, mainly because of their clarity.

SURVEY ABOUT STUDENTS' IDEAS IN HYDROSTATICS

As we mentioned before, physics teachers should be familiar with students' ideas about physical concepts or phenomena. Incorrect students' ideas may also affect their individual creative work, which for example includes shooting a short movie with physics theme at the Festival of Movies about Physics. We saw couple of these movies and found out that students' movies are dealing with a lot of various discrepancies. Based on these deficiencies connected with explanation and students' argumentation we have decided to closer examine students' ideas regarding concepts and phenomena from Hydrostatics.

The list of incorrect students' ideas in physics could be found in multiple other sources. At webpage *http://amasci.com/miscon/opphys.html* is shown the list below of incorrect ideas from category Forces and Fluids:

- Objects float in water because they are lighter than water.
- Objects sink in water because they are heavier than water.

- Mass/volume/weight/heaviness/size/density may be perceived as equivalent.
- Wood floats and metal sinks.
- All objects containing air float.
- Liquids of high viscosity are also liquids with high density.
- Adhesion is the same as cohesion.
- Heating air only makes it hotter.
- Pressure and force are synonymous.
- Pressure arises from moving fluids.
- Moving fluids contain higher pressure.
- Liquids rise in a straw because of "suction".
- Fluid pressure only acts downward.

Speaking of foreign literature, Wijaya et al. (2016) was focusing in their research on diagnosis of incorrect ideas regarding hydrostatic pressure in the group of high school students. The most common incorrect students' ideas, which are derived from the results of research, are as follows:

- Students believe that hydrostatic pressure is directly proportional to the distance of a point on the surface of the water.
- Students believe that hydrostatic pressure has a greater value in a narrow place.
- Students believe that hydrostatic pressure is directly proportional to the height.
- Students believe that the fluid is more concentrated when it is placed in a container, which is denser / narrower and the hydrostatic pressure becomes bigger.
- Students believe that the depth is measured from the bottom of the container.
- Students believe that hydrostatic pressure is bigger when a hole is wider.
- Students believe that hydrostatic pressure is bigger when it is near an open hole.
- Students believe that hydrostatic pressure is bigger when it is near a closed hole.
- Students believe that hydrostatic pressure is bigger in a narrower hole.
- Students believe that hydrostatic pressure is inversely proportional to the density of the fluid.
- Students believe that hydrostatic pressure is proportional to the mass of the object.
- Students believe that hydrostatic pressure is inversely proportional to the mass of the object.

The task of the survey

There are many different tools and options for diagnosing students' ideas. In our study in order to find out students' ideas in primary schools about phenomena in Hydrostatics or about the concept of density we chose a test using the concept of open-ended questions. When compiling the test, we used information which was found in the movies sent by students to the Festival of Movies about Physics. The sources of information were also from various cases found in the literature. Additionally, we used our own gained experience in physics teaching. The main goal of our survey was to identify how primary school students interpret selected expressions and phenomena in the thematic unit Hydrostatics (more precisely density, Pascal's law, Archimedes' law, buoyant force).

We assume that students have incorrect conceptions about certain concepts and phenomena in the thematic unit Hydrostatics. Based on other surveys and researches, and also the analysis of movies sent by students to the Festival of Movies about Physics, we are expecting the following statements:

- The students mostly consider the mass of the certain objects crucial when deciding how they behave in liquid.
- The students confuse the term of density with the term of viscosity.
- When solving a task on Archimedes' law, the students do not consider applying the law.
- The students believe that when the external force is applied on the liquid in a closed container, there will be the same pressure at each point of the liquid.
- The students believe that the magnitude of the buoyant force depends on the immersion depth even when the entire object is submerged in the water.

The methods of the survey

The survey was made in March and April 2017 and also in March 2018 in the form of a written test which contained open questions. There were 6 questions in the test. The tasks were focused on the understanding the concepts and phenomena in Hydrostatics. Three of the six questions (first, second and sixth) were related to the understanding of the concept of density and the behavior of objects in liquid. The remaining three questions (third, fourth and fifth) included questions regarding the Pascal's law, Archimedes' law and also the buoyant force. The students filled in the test during a 45-minute-long lesson. The analyzed and processed data were evaluated using the programme Excel.

In this report we are focusing mainly on the analysis of solutions to the one task based on students' ideas regarding the term of density. The assignment was as follows:

"Miško found an old aluminium spoon. He put it into a container filled with water. The spoon sank down to the bottom of the container. Then he put old aluminium coins, which he found, in the container in the same manner, as the spoon before. The coins sank down to the bottom of the container as well. Then he found an aluminium foil, which is actually a thin piece of aluminium. He tore off a piece of aluminium foil with size of 5 by 5 centimetres, submerged it under the surface of the water in the container and released it. How did this piece of aluminium foil act in the water? How would the smaller piece of aluminium foil act in the water? Please do explain your answers!"

Characterization of the group

Primary school students from Slovakia and Hungary joined the survey. From Slovakia 89 students from the Private Primary School Česká in Bratislava and Comenius Primary School in Tvrdošovce joined the survey. From the Private Primary School Česká 52 students answered the questions in the test: 7 students from the 7th grade and 45 students from the 8th grade. From Comenius Primary School 37 students filled in the test: 18 students from the 7th grade and 19 students from the 8th grade. 35 students from János Vaszary Primary School in Tata, Hungary, took part in the survey: 22 students from the 7th grade and 13 from the 8th grade. As we can see, 124 students participated in the survey from the three primary schools. Number of respondents involved in the survey could be seen in table 1.

Table 1. Number of respondents involved in research

Primary School Name	Grade	6.	7.	8.	Total
Private Primary School Česká in Bratislava	**Number of Students**	39	7	45	**91**

Comenius Primary School in Tvrdošovce		12	18	19	**49**
	Total	**51**	**25**	**64**	**140**

Processing and interpreting the results of the survey

The respondents were divided into two groups. The first group includes students attending primary schools in Slovakia, and in the second group are the primary school students from Hungary. The answers of the two groups were evaluated separately. We evaluated every task in every group separately. First, we categorized the answers to a given question based on the students' conclusion. After that we were looking for common signs in every category – what kind of assumption, thought led the students to the given answer. We divided the categories of the answers further into smaller groups. After that we created a table which contains the division of the answers with the relative frequency of each response by grade. In the table 2 provided below we highlighted the correct answers with orange colour. As a correct answer we accepted that one in which the student provided also an explanation. If the student answered correctly, but did not explain his statement, we did not consider it as a correct answer because we strictly requested an explanation. In the table the answers with the wrong ideas (which met our expectations) are marked in green.

Table 2. The relative frequency of each response by grade in Task 1 for both groups

Task 1		Relative frequency by grade / %		
		7^{th} grade Sk / Hu	8^{th} grade Sk / Hu	Both Sk / Hu
The larger and smaller pieces of aluminium foil also sink to the bottom of the container	correct explanation - the density of aluminium is bigger than the density of water	12 / 4,5	3,1 / 7,7	5,6 / 5,7
	without explanation	4 / 0	3,1 / 15,4	3,4 / 5,7
Neither the larger nor the smaller pieces of aluminium foil sink to the bottom of the container	incorrect assumption - flotation is only related to the mass	36 / 36,4	34,4 / 23,1	34,8 / 31,4
	incorrect assumption - the density of objects depends on their size even if they are made of the same substance	0 / 0	15,6 / 7,7	11,2 / 2,9
	without explanation	16 / 4,5	23,4 / 7,7	21,3 / 5,7
Bigger and smaller pieces of aluminium foil will not behave the same	incorrect assumption - the density of objects depends on their size even if they are made of the same substance	24 / 9,1	6,3 / 0	11,2 / 5,7
	using incorrect terminology	0 / 4,5	0 / 0	0 / 2,9
Other wrong answers		4 / 31,8	10,9 / 30,8	9 / 31,4
Unsolved		4 / 9,1	3,1 / 7,7	3,4 / 8,6
Both		100 / 100	100 / 100	100 / 100

According to the results of the survey 5.6% / 5.7% (Sk / Hu) of all respondents answered the first question correctly, which means 5 / 2 (Sk / Hu) students. The table shows that 34.8% / 31.4% (Sk / Hu) of the respondents incorrectly assumed that flotation of the object is only related to the mass of the object. Another rather numerous groups consist of students who think that the density of objects depends on their size even if they are made of the same substance. 22.4% / 8.6% of respondents (Sk / Hu) belong to this group.

DISCUSSION

The first task in the test was related to the behaviour of objects submerged in liquids. Flotation of objects is related to their density. But students have incorrect idea about whether the object floats, floats right under the surface of the liquid or sinks, because they think that it is related only to the mass of the object. The results of the survey show that even students, who were considering density in case of flotation of the object, have incorrect idea that it is related to their mass - a smaller piece of foil has smaller density. From this we have concluded that students would associate flotation of an object with the mass of the object. According to our survey, 57.2% of the respondents from Slovakia consider the mass of the object when deciding on its behaviour. 40% of respondents from Hungary are thinking the same way, too. As a typical incorrect answer, we could consider the following answer: “The aluminium foil will be on the surface of the water. The smaller piece too, because the aluminium foil is not so heavy at all.”

Therefore, the results of our survey in this task show that while there are no differences between the two involved groups in the number of correct answers, the involved primary school students in Slovakia were more likely to have a wrong idea.

In a similar way as the task mentioned above, we evaluated also the next task from our test. Here the students were supposed to think about the buoyant force. The magnitude of the buoyant force does not depend on the depth if the whole object is submerged in the water. Even so the students have wrong idea because they think that if we submerge the whole object in the water just below the water level and then deeper, higher buoyant force will apply on the object there. In the group of the involved Slovak students 10.1% of the respondents, and in the group of the involved Hungarian students 5.7% of the respondents claimed that the buoyant force depends on the depth even if the whole object is submerged in the water.

As we can see from the answers given to this task, the involved students from Hungary have incorrect ideas in a less extent about the topic in the task. Regarding correct answers, two respondents from Slovakia gave correct answers, while in the group of Hungarian respondents there was no correct answer.

Analysing the survey results led us to the confirmation that the primary school students taking part in the survey have the incorrect ideas of various concepts and phenomena in thematic unit Hydrostatics. One of the incorrect ideas is related to how the objects behave in liquids: the students consider mostly the mass of the object crucial when deciding about how the objects behave in liquid. It also turned out, that the students have incorrect ideas regarding the buoyant force: they think, that the magnitude of the buoyant force depends on the depth even if the whole object is submerged in the water.

There are several reasons for the differences between given two groups, which we would like to examine in more details later. We would like to focus on the basic curriculum, lesson distribution and teaching methods in both countries. Furthermore, we would also like to assess the level of their argumentation based on students' responses - to propose criteria how to evaluate students' argumentation and to evaluate their arguments on this basis.

ACKNOWLEDGEMENT

This paper was elaborated with the support of the projects VEGA no. 1/0396/18.

REFERENCES

Alwan, A. A. (2011). Misconception of heat and temperature among physics students. *Procedia Social and Behavioral Sciences, 12, 600-604*. Retrieved from https://www.academia.edu/3585334/MISCONCEPTION_IN_PHYSICS_AMONG_HIGH_SCHOOL_STUDENTS

Haverlíková, V. (2013). *Alternatívne predstavy žiakov vo fyzikálnom poznávaní*. Bratislava: FMFI UK. Retrieved from https://zona.fmph.uniba.sk/fileadmin/fmfi/sluzby/elektronicke_studijne_materialy/ip_uk/Fyzikalne_poznavanie_alt_predstavy.pdf

Mandíková, D., & Trna, J. (2011). *Žákovské prekoncepce ve výuce fyziky*. Brno: Paido.

National Research Council. (1997). *Science Teaching Reconsidered: A Handbook*. Washington, DC: The National Academic Press. Retrieved from https://www.nap.edu/read/5287/chapter/5

Průcha, J. et al. (2013). *Pedagogický slovník.* Praha: Portál.

Read, J. R. (2004). *Children´s Misconceptions and Conceptual Change in Science Education.* Retrieved from http://www.asell.org/global/docs/conceptual_change_paper.pdf

Weber, S. (2004). *Präkonzepte und Misskonzepte im Physikunterricht.* Retrieved from http://web.archive.org/web/20050506210711/http://didaktik.phy.uni-bayreuth.de/skripten/fachdid4/node3.html

Wijaya, C. P. et al. (2016). The diagnosis of senior high school class X mia B students misconceptions about hydrostatic pressure concept using three-tier. *Jurnal Pendidikan IPA Indonesia, 5(1), 13-21*. Retrieved from: https://doaj.org/article/ef7fe6fd31554b58832fa64ba4c8a62f

Wilhelm, T. (2007). *Schülervorstellungen zur Elektrizitätslehre.* Retrieved from http://www.thomas-wilhelm.net/Vortraege/Elektrizitaetslehre.pdf

AN INVESTIGATION OF STUDENT'S CONCEPTUAL UNDERSTANDING ABOUT COSMOLOGY THROUGH CLUSTER ANALYSIS

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In this study, we analyse high school students' patterns of understanding about conceptual dimensions of Cosmology using cluster analysis of responses to an open-ended questionnaire. First, drawing from previous studies and accepted scientific models of the Universe, we identified seven different dimensions that we deemed as important for conceptual understanding of Cosmology. Then, we designed seventeen questions and categorized them according to the chosen dimensions. Content validity and categorization of the questions were checked with three professional astrophysicists. The questionnaire was administered to 432 high school students (17-19 years old) attending extra-curricular activities on modern physics. Students' responses to each question were first categorized using a grounded approach and then combined through cluster analysis to identify students' reasoning about the identified dimensions. Results confirm that students hold many misconceptions about Big Bang, as well as about the Universe expansion and its future evolution. Moreover, evidence suggests that a low level of knowledge of basic astrophysics definitions affects knowledge about fundamental concepts. Implications for designing teaching-learning sequences to address students' difficulties about the targeted concepts are briefly described.

Keywords: Conceptual understanding, Quantitative methods, Physics.

INTRODUCTION AND AIMS

Recent curriculum reforms in Italy have promoted the introduction at secondary school level of up-to-date physical topics, such as quantum mechanics, particles' standard model, and the origin of the Universe. However, the implementation of such reforms has proven to be difficult, since such advanced subjects require a deep understanding of the underlying physical mechanisms and theories. In this paper, we focus on Cosmology, which is a meaningful context not only to teach other contemporary physics topics, such as nuclear reactions, light spectra, redshift and dark matter, but also to explicitly address some aspects of the nature of science. Prior studies have addressed students' misconceptions about specific aspects related to the Universe, mainly at the undergraduate level (Prather, Slater & Offerdahl, 2002; Trouille et al., 2013; Wallace, Prather & Duncan, 2012). Their results suggest that students may begin university courses in astrophysics with pre-existing notions that may interfere with instructional efforts.

For instance, previous findings indicate that many students (about 70%) are unaware that the universe is expanding (Lightman et al., 1987; Lightman and Miller, 1989; Prather, Slater & Offerdahl, 2003) and think that matter, as we know it now, existed also before the Big Bang

(Lightman et al., 1987). The study by Trouille et al. (2013) also revealed some misconceptions such as the belief that the Big Bang theory, which describes the creation of planets and/or the solar system or the universe, always existed. Similarly, Prather et al. (2003) found that 42% of high school and 51% of college students regard the Big Bang theory as a theory describing the creation of the universe; 24% in both groups regard the Big Bang as a theory describing the creation of planetary systems and furthermore, 29% and 42%, respectively, believe that the Big Bang was an explosion of some kind. In some cases, students struggle to read and interpret the Hertzsprung-Russell and Hubble's plots or confuse the definitions of galaxy and solar system (Hayes et al., 2011; Wallace et al., 2012).

While providing valuable insights about students' difficulties when dealing with Cosmology, a more coherent picture of students' conceptual understanding in this content area is yet to be provided. By identifying common patterns amongst such beliefs and ideas, it would be possible to frame meaningful and more effective teaching activities to improve students' understanding of Cosmology. Therefore, the research question that guided the present study was: *to what extent can students' conceptions about relevant aspects of Cosmology be organized in coherent patterns of understanding?*

METHODS

Instrument

To answer our research question, we first identified, on the basis of previous studies and accepted scientific models of the Universe, seven conceptual dimensions that we deemed as important for a meaningful understanding of Cosmology (Prather et al., 2003; Bailey et al., 2012; Wallace, 2011; Trouille et al., 2013; Wallace, 2012). For the sake of clarity, these dimensions can be divided into two groups of concepts: "basic" and "advanced". Basic concepts concern fundamental astronomical entities as stars, galaxies, constellations, and nebulae and the physical relationships between them. For instance, in this group, we include the notion that stars are formed from a nebula due to gravitational collapse, while galaxies are approximately self-gravitating systems formed by stars and nebulae and so on. Moreover, drawing on results in astronomy education (Rajpaul et al., 2018, Cole et al., 2018) we also considered as basic concepts the time and distance scale of typical astronomical events and entities. For instance, we included in this group the notion that life appeared on Earth after the formation of solar systems and of our galaxy; similarly, we included the notion that the Sun is the closest star to Earth and that the centre of our galaxy is farther than the other galaxies. Advanced concepts include: the birth of the Universe; the universe age and how we can estimate it (expansion rate, background radiation, etc.); how temperature and chemical composition of the universe changed with time; the space-time expansion; hypothesis about the future evolution of the Universe. More advanced topics include also fundamental notions about black holes, dark matter and energy. For instance, we included in this group the notion that a black hole is an astronomical object characterized by its gravitational field.

Then, starting from previous work (Bailey et al., 2012; Coble et al. 2013a, b), we designed a written task with 17 open-ended questions that addressed two or more aspects of the identified dimensions, except for the first question that simply requested to define the term "Universe". In Table 1, we summarize the correspondence between the conceptual dimensions and the designed questions. The questions included three types of task (see Table 2): written, drawing, and ranking. The reason for including also a drawing task was to link students' representations with the reasoning emerging from the written answer (Tytler et al., 2020). Ranking tasks were designed only for the age and distance of astronomical objects. The content validity of the questions was checked with three professional astrophysicists. Examples of the three types of task are reported in Table 2.

Table 1. Question distribution across the conceptual dimensions of Cosmology.

	Conceptual dimensions related to Universe	Acronym	Questions [a]
Basic	Celestial objects and their relationships	CO	Q11, Q14a, Q14b, Q14c, Q14d
	Celestial objects age and distance	AD	Q12, Q13
Advanced	Universe age and its determination	AGE	Q2, Q3
	Birth of Universe	BB	Q5, Q6, Q7
	Universe temperature and composition	T&C	Q4, Q10
	Expansion and future evolution of Universe	EX	Q8, Q9
	More advanced topics (e.g., black holes, dark matter)	BHDM	Q16a, Q16b, Q17

[a.] Note that questions Q1 and Q15 were not analysed in this study.

Table 2. Type of questions.

Type	Questions [a]	Examples
Written text	Q2, Q3, Q4, Q5, Q6, Q7, Q8, Q9, Q10, Q11, Q14, Q16, Q17	(Q2) What is the age of the universe? (Trouille et al., 2013) (Q6) Describe what existed or occurred just before the Big Bang (Prather et al., 2003) (Q7) Describe what evidence you think supports the Big Bang theory (Q9) Explain, in as much detail as possible, what astronomers mean when they say ''the universe is expanding'' (Wallace, 2011)
Drawings	Q4, Q5, Q9, Q10, Q11, Q14	(Q4) Plot how the temperature of the Universe changes over time (Q5) How would you describe the Big Bang with a drawing? (Q9) Using a schema or drawing, explain what you mean when you say ''the universe is expanding" (Q10) Explain, using also a drawing, how the chemical composition of the Universe changes over time (Q11) Draw our galaxy and the sun's position
Ranking	Q12, Q13	(Q13) Rank the following celestial objects by their distance from the Earths surface: cluster of galaxies, galaxies, Jupiter, the international space station, nebulae, Proxima Centauri, Sun, the center of our galaxy, Moon.

[a.] Note that questions Q1 and Q15 were not analysed in this study.

To collect contextual information about student' self-efficacy in and attitudes towards science, we designed a six-item Likert scale (from 1 = not at all to 10 = completely), with three items for each variable.

Sample

We involved in this study a sample of 432 Italian secondary school students (43.8% female; average age 17.9±0.7 years old). Students attended three types of school: scientific (78.7%), humanities (14.4%), and vocational (6.9%). Scientific is a secondary school stream specially focused on science and mathematics. Humanities are more focused on literature and human sciences, while vocational schools are aimed at technical and job-oriented instruction. The involved students voluntarily attended extra-curricular activities about general physics topics at the authors' department from February to May 2019. Prior to these activities, they were taught about basic elements of Astronomy for a total of about 8 hours during their first year of secondary school as part of Earth Science curriculum. However, they were not involved in specific teaching-learning sequences or extra-curricular activities focused on Astrophysics. Students were on average self-confident (average score on the three items: 6.1±1.4) and motivated towards science and astronomy (average score: 7.6±1.5).

Data Analysis

First, we categorized the students' responses using a constant comparative method (Strauss & Corbin, 1998). Three researchers independently analysed the whole data set generating for each question a suitable number of categories to fit the students' responses. Then, we collapsed the initial categories into five hierarchical macro-categories, ranging from "not given or unclear response" to "scientifically correct or acceptable", depending on the content of the question. Two researchers reviewed again the students' responses to check the categorization. Inter-rater reliability was evaluated obtaining at the end of the process a satisfactory level of about 0.80. Categories for two questions concerning the AGE (Q3) and T&C (Q10) dimensions are reported in Table 3.

Table 3. Examples of categories regarding AGE and T&C dimensions.

Question	*Category*	*Description*
Q3.What is the age of the Universe and how do we know it?	1	No reference to how to estimate the age of Universe
	2	It is not possible to estimate the age of Universe or it has always been existing
	3	Student gives reference to archaeological, biological or geological evidences
	4	Some reference to astrophysical measurements but rather generic
	5	Correct reference to Hubble law or to recessional velocity of galaxies
Q10. Explain, using a also a drawing, how the chemical composition of Universe changes over time	1	No answer
	2	Generic or incorrect answer
	3	Basic elements with no evolution to more complex ones
	4	Basic elements gave rise to the more complex ones
	5	Basic elements gave rise to the more complex ones via nuclear fusion

Finally, we combined the students' responses to the questions related to the same dimension using cluster analysis (Fazio & Battaglia, 2018). In such a way, we could identify reasoning patterns corresponding to different levels of conceptual understanding about the targeted dimensions. We used cluster analysis: (i) because our sample was large and heterogeneous; (ii) in order to identify which dimension best distinguishes students' understanding (Aldenderfer and Blashfield, 1984; Ammon et al., 2008). We performed a separated clustering of each basic and fundamental conceptual dimension using the SPSS K-means routine. The choice of the number of clusters to be retained was iteratively carried out (using 2 to 10 clusters) double checking the variance of distance from the centres for each number of cluster, the iteration history of the K-means algorithm and the between-subjects ANOVA values for each of the questions related to the chosen dimension. The final interpretation of each cluster was validated by the same professional astrophysicists, who had already checked the question validity. For each dimension, we found five clusters, which reflect increasingly complex reasoning about the concepts related to that dimension. The clusters are schematically described in Tables 4 and 5. Finally, we investigated the correlation between the knowledge of basic and advanced concepts. To this aim, we recoded the clusters for all dimensions into two categories: clusters characterized by scarce or incorrect knowledge (Clusters 1 and 2) were coded with 0, whereas clusters characterized by a partial/correct knowledge with some inconsistencies (cluster 3 to 5) were coded with 1. Finally, using crosstabs, we performed a chi-square analysis to look whether the knowledge about basic concepts may affect the knowledge about more advanced concepts about the Universe.

Table 4. Clustering of students' answers related to basic conceptual dimensions.

Concepts	*Cluster*	*Description*	*%*
AD	1	Scarce or no knowledge about the topics	46.5
	2	Correct knowledge of recent and middle timeline, but they know only a near distance scale	16.0
	3	Correct knowledge only of recent timeline and of near and middle distance	15.7
	4	Correct knowledge only of recent timeline. Partially correct knowledge of celestial objects distances	12.1
	5	Correct knowledge of timeline and partially correct knowledge of celestial objects distances	9.7
CO	1	No knowledge about the topics	34.7
	2	No or incorrect definition of star and nebulae. They define the constellation generically as a group of stars, the nebulae as cluster of gas and the galaxies as set of celestial objects	27.1
	3	No or incorrect definition of constellation and nebulae. They define the star as an emitting light object and the galaxies as set of celestial objects	13.9
	4	No or incorrect definition of star. They define the constellation generically as a group of stars, the nebulae as cluster of gas and the galaxies as set of stars held together by gravitational force	10.2
	5	They define the constellation generically as a group of star near each other, the star as an emitting light object with a reference to chemical composition or chemical reaction, the galaxies as set of celestial objects and nebulae as cluster of gas and dust	14.1

Table 5. Clustering of students' answers related to advanced conceptual dimensions.

	Cluster	Description	%
AGE	1	Scarce or no knowledge about the topics and no reference to how to estimate it.	10.4
	2	Scarce or no knowledge about the topics, generic reference to how to estimate its age.	5.6
	3	Student knows the order of magnitude of the age of universe, but doesn't give any reference to how to estimate it.	34.3
	4	Student knows the order of magnitude of the age of universe and partial reference to how to estimate it.	31.2
	5	Correct estimate of age and partial reference to how to estimate it.	18.5
BB	1	Belief that the Big Bang is a terrestrial catastrophe and the Universe existed in some way before. Evidence cannot be obtained.	19.5
	2	Big Bang as an explosion of energy and matter, which existed in some way before. Some evidence is given but in an incorrect way.	20.8
	3	Big Bang as an explosion of energy and matter, there was nothing before. No reference to evidence.	27.3
	4	Big Bang as an explosion of energy and matter, there was nothing before. Incorrect or generic references to evidence are provided.	19.9
	5	Big Bang as an explosion generating the Universe, when before there was very dense matter and/or energy. Correct evidences are provided.	12.5
T&C	1	Scarce or no knowledge about the topics.	34.9
	2	Temperature increased, but no idea about composition.	42.6
	3	No idea about the temperature. Basic elements gave rise to the more complex ones.	3.5
	4	Changing temperature and basic elements with no evolution to more complex ones.	3.3
	5	Temperature decreases. Basic elements gave rise to the more complex ones.	15.7
EX	1	No idea about theories describing the future of the Universe and its expansion.	15.5
	2	Alternative/Non-scientific theories about the future of the Universe. No idea about expansion.	30.6
	3	No idea about theories describing the future of the Universe. Expansion as an increase of distance between celestial objects.	9.5
	4	There exists theories describing the future of the Universe with no details. Expansion as an increase of distance between celestial objects.	15.7
	5	Correct evidences about the future of the Universe are provided. Expansion as an increase of distance between celestial objects.	28.7
BHDME	1	No answer.	54.6
	2	No knowledge about dark matter and dark energy. Generic definition of black hole.	14.6
	3	No knowledge about dark matter and dark energy. The black hole is an object with a strong gravitational force.	15.7
	4	The student knows that dark matter and dark energy exist, but without any details. The black hole is an object with a strong gravitational force.	10.4
	5	Students give an correct definition of dark matter and dark energy. The black hole is an object with a strong gravitational force.	4.7

RESULTS

Figures 1 and 2 report the students' distribution in the emerging clusters for basic and advanced topics about the Universe.

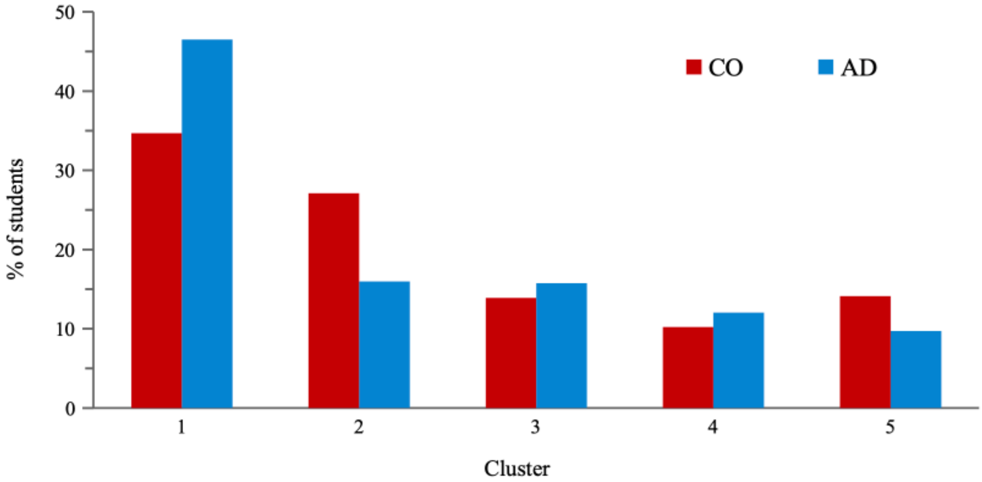

Figure 1. Students' distribution in the basics concepts clusters.

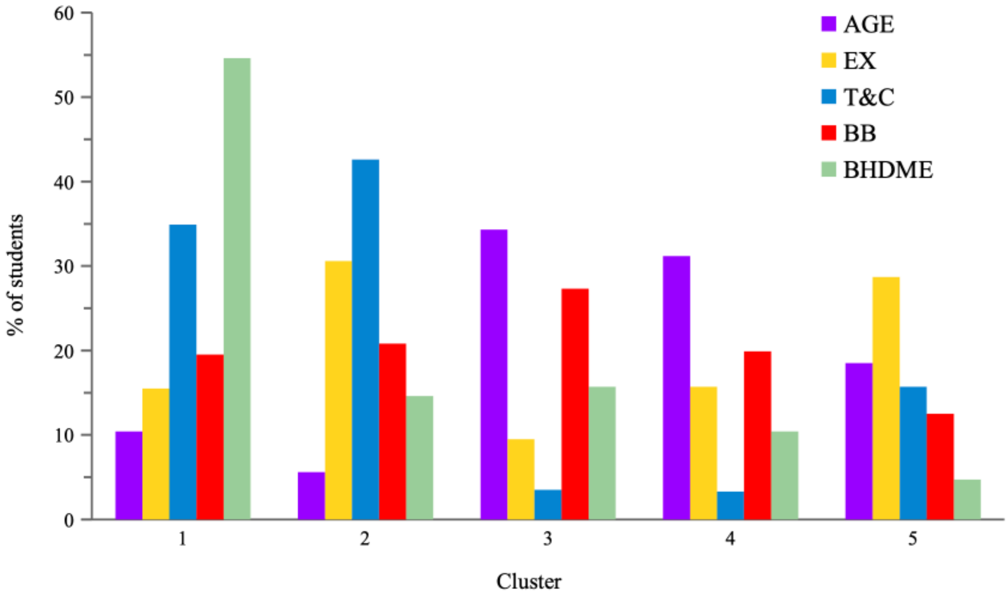

Figure 2. Students' distribution in the advanced concepts clusters.

Overall, students in our sample have a scarce knowledge of both basic and advanced concepts. Concerning basic concepts, on average 40% of the students belong to the scarce or no knowledge cluster, while only 10% show a more correct knowledge. Specific difficulties concern: the definition of star and the role of gravity; how to correctly estimate the relative distance between Earth, Sun, planets and the centre of the galaxy. Concerning advanced topics, data show a more complex pattern, according to the chosen dimensions. While expansion and age of the Universe seem slightly more understood by students (about 40% belong to clusters characterized by a partial or correct knowledge), on the other hand, for the T&C dimension, two-thirds students show a very scarce knowledge. In particular, they have no idea about the variations of temperature and of composition of the Universe. Also in the BB dimension, which is focused on topics that are taught since primary school, students show some difficulties. In particular, they consider the Big Bang as an explosion and are often unable to relate it with the birth of the Universe. Moreover, about half of the students think that the Universe has always existed, thus the Big Bang is viewed as a kind of catastrophe. This evidence also suggests a confusion between deep and geological time. To the same concern, the great majority of the students (about 90%) think that the Big Bang involved an explosion of energy and matter. Furthermore, few students were able to refer to experimental evidence to support the Big Bang or the estimate of Universe age.

In figure 3, we report the correlation between the knowledge of basic and advanced dimensions. Correlation is significant ($c^2 = 9.162$; df = 1; p = 0.002; Cramer' phi = 0.146), thus a scarce or generic (partial or correct) knowledge about basic concepts lead more likely to a scarce or generic (partial) knowledge about advanced concepts.

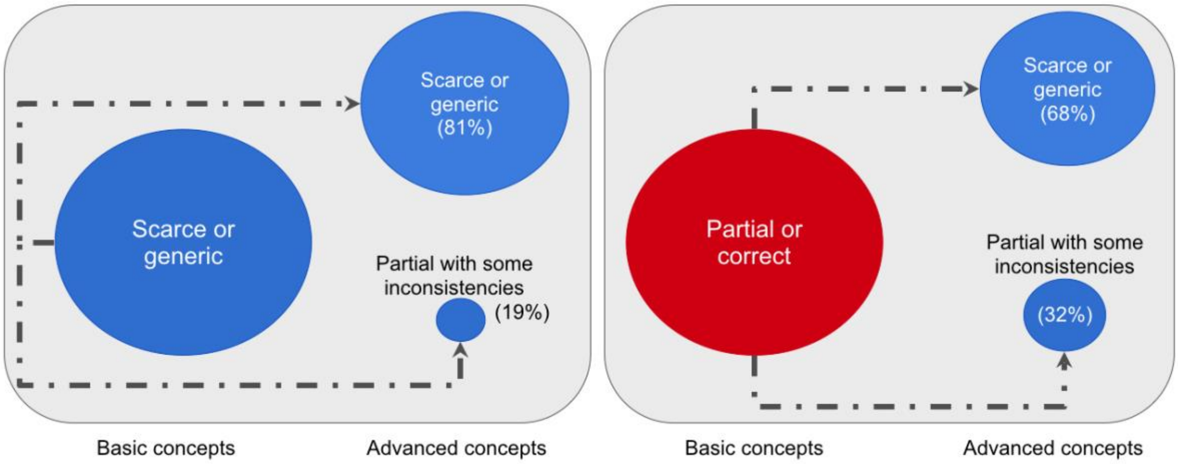

Figure 3. Correlation between basic and advanced topics knowledge.

DISCUSSION AND CONCLUSIONS

Our analysis reveals that the students' knowledge about the Universe is rather limited. While the collected students' responses suggest that Cosmology is addressed somehow during curricular teaching and dissemination activities in informal setting, results of the cluster analysis point out that some relevant aspects are neglected, for instance how scientists support claims about theories of the Universe.

Furthermore, curricular teaching seems to have a limited impact on students' ideas also about basic aspects such as: definition of stars, nebulae and galaxies, order of magnitude of distances between celestial objects, timeline of relevant events as the appearance of life on Earth and the formation of planets and stars, the role of gravity and other physical mechanisms (spectra, nuclear reactions).

Cluster analysis reveals also a fragmented knowledge about basic aspects in Cosmology. In particular, students found it difficult to relate the distance between celestial objects and timeline of events. Regarding advanced dimensions, as expected, knowledge is on average scarce (about 30% in clusters 1 and 2, on average). On the other hand, a better understanding of Universe birth, age, and expansion leads to a better understanding of concepts as a black hole.

As next step of our research, we are identifying transversal patterns of reasoning strategies about the targeted topics. In conclusion, our data suggest that typical high school teaching does not allow a deep conceptual understanding about Cosmology. To address this issue, we are also developing a teaching-learning sequence, which includes paper-and-pencil as well as laboratory activities.

REFERENCES

Aldenderfer, M.S., & Blashfield, R.K. (1984). Cluster analysis. *Beverly Hills: Sage.*

Ammon, B.V. & Bowman, J. & Mourad, Roger. (2008). Who are our students? Cluster analysis as a tool for understanding community college student populations. *Journal of Applied Research in the Community College*. 16. 32-44.

Bailey,J.M., Coble, K., Cochran,G., Larrieu, D., Sanchez,R., Cominsky, L.R. (2012). A multi-institutional investigation of students: preinstructional ideas about cosmology**,** *Astron. Educ. Rev*., 11 (1), 10.3847/AER2012029

Coble K., Camarillo C. T., Trouille, L. E., Bailey, J. M., Cochran, G. L., Nickerson, M. D., Cominsky, L. R. (2013). Investigating Student Ideas about Cosmology I: distances and structure, *Astron. Educ. Rev.*, 12(1), 010102

Coble K., Nickerson, M. D., Bailey, J. M., Trouille, L. E., Cochran, G. L., Camarillo C. T., Cominsky, L. R. (2013). Investigating Student Ideas about Cosmology II: Composition of the Universe, *Astron. Educ. Rev.*, 12(1), 010111

Cole, M., Cohen, C., Wilhelm, J., Lindell, R. (2018), Spatial thinking in astronomy education research, *Phys. Rev. Phys. Educ. Res., 14, 10.1103/PhysRevPhysEducRes.14.010139*

Fazio, Cl., & Battaglia, O. R. (2018). Conceptual Understanding of Newtonian Mechanics Through Cluster Analysis of FCI Student Answers, *International Journal of Science and Mathematics Education,* https://doi.org/10.1007/s10763-018-09944-1

Hayes, V., Coble, K., Nickerson, M., Cochran, G., Camarillo, C. T., Bailey, J. M., McLin, K. M., and Cominsky, L. R. (2011). Investigating Student Understanding of the Universe: Structure, *Bulletin of the American Astronomical Society*, 43, 333.04.

Lightman, A. P., and Miller, J. D. (1989). Contemporary Cosmological Beliefs, *Social Studies of Science*, 19, 127.

Lightman, A. P., Miller, J. D., and Leadbeater, B. J. (1987). Contemporary Cosmological Beliefs, *in Misconceptions and Educational Strategies in Science and Mathematics, Vol. III*, ed. J. D. Novak, Ithaca, NY, Cornell University Press, 309.

Prather, E. E., Slater, T. F., & Offerdahl, E. G. (2003). Hints of a Fundamental Misconception in Cosmology, *Astronomy Education Review, 1*, 2, 28-34.

Rajpaul,V. M., Lindstrøm, C., Engel, M.C., Brendehaug, M., Allie, S. (2018). Cross-sectional study of students' knowledge of sizes and distances of astronomical objects, *Phys. Rev. Phys. Educ. Res.,* 14, 020108

Strauss, A., Corbin, J. (1998). Basics of Qualitative Research Techniques and Procedures for Developing Ground Theory, *SAGE: London*

Trouille, L., Coble, K. L., Cochran, G., Bailey, J., Camarillo, T. C., Nickerson, M., & Cominsky, L., (2013). Investigating Student Ideas About Cosmology III: Big Bang Theory, Expansion, Age, and History of the Universe. *Astronomy Education Review, 12*. 10.3847/AER2013016

Tytler, R., Prain, V., Aranda, G., Ferguson, J., Gorur, R., (2020). Drawing to reason and learn in science. *J Res Sci Teach*; 57: 209– 231.

Wallace, C.S. (2011) An Investigation into Introductory Astronomy Students' Difficulties with Cosmology and the Development, Validation, and Efficacy of a New Suite of Cosmology Lecture-Tutorials, *Ph.D. Thesis University of Colorado at Boulder*

Wallace, C.S., Prather, E., Duncan, K. (2012). A Study of General Education Astronomy Students' Understandings of Cosmology. Part IV. Common Difficulties Students Experience with Cosmology, *Astronomy Education Review, 11*, 0104.

DO MISLEADING THERMAL SENSATIONS UNDERLIE SOME HEAT AND COLD MISCONCEPTIONS?

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Alternative conceptions are ideas found universally in people, regardless of their age, education, sex, race and religion. This suggests that there exists an underlying reason common to all human beings. Recently, it has been proposed that misconceptions might arise from the ambiguity in the perception of external stimuli (physical variables). The aim of this study was to explore whether misconceptions on heat and "cold" are based on thermal sensations. We prepared three objects with different thermal conductivity and we kept them at constant temperatures. Then, 160 students (12-15 years old) were presented with the objects along with a set of questions. Although the objects were at the same temperature, students reported different sensations and estimated temperatures. When students were asked to explain why they felt those sensations, we identified common misconceptions. The ambiguity of thermosensation and the identified common misconceptions suggest that misleading sensations contribute to the development of well-known misconceptions on heat and temperature. Finally, revealing the real temperature of the objects to students resulted in a tendency to reject their first explanation and to seek for an alternative one. Understanding how concepts are grounded on our perception will help developing teaching strategies that tackle these misconceptions.

Keywords: Misconceptions, Learning and Neuroscience, Conceptual Understanding

INTRODUCTION AND THEORETICAL FRAMEWORK

Feeling temperature is a matter of life or death. Humans show a broad range of highly elaborate responses to temperature changes such as wearing clothes, developing air conditioning systems or switching the heating on. These complex responses seem to be based on our mental representations –or concepts- of heat, "cold", temperature, etc.

It has been observed that concepts are developed in an ordered and universal sequence. This process was called conceptual trajectory by Driver (1989). The ideas found at each step of the conceptual trajectory are usually called alternative conceptions or misconceptions (Driver and Easley, 1978; Abimbola, 1988). These alternative conceptions are very common, and they transcend age, education, sex, and culture (Abrahams et al., 2015). They are also very persistent and resistant to change and to extinction (Chiappetta & Koballa, 2006). The universality and persistency of alternative conceptions suggest that there exists an underlying reason common to all human beings. Some researchers have suggested that the way our senses work influence the development of spontaneous ideas (Wenning, 2008). Recently, it has been proposed that misconceptions might arise from perceptual ambiguity in the perception of external stimuli (physical variables) (Ezquerra-Romano & Ezquerra, 2017; Kubricht, Holyoak & Lu, 2017; Ezquerra & Ezquerra-Romano, 2018).

The aims of this study were:

- To explore how we describe the thermal state of objects based on our thermal perception
- To analyse statements about the reasons for the given descriptions based on perceptual ambiguity
- To discuss the statements in the context of thermosensation

Firstly, we asked students to rate the sensations and the temperature of different objects. Then, students had to interpret their sensations. After this, we revealed the real temperature of the objects to students and asked students to interpret their sensations again.

RESEARCH METHOD AND DESIGN

We prepared three objects with different thermal conductivities (TC): polyethylene foam, K = 0.03-0.04 W/m·K (low TC); brick, K = 1.31 W/m·K (medium TC) and aluminium, K = 205 W/m·K (high TC). There were four conditions: 10.9 ºC, 23.0 ºC, 33.6 ºC, and 38.1 ºC. In each condition, all objects were kept at the same temperature. The experiment was conducted in 4 different high schools in Madrid (Spain). In total 160 students (12-15 years old) were presented with the objects alongside the following questions (36 students at 10.8 ºC; 39 students at 23.0 ºC, 42 students at 33.6 ºC, 43 students at 38.1 ºC):

- Question 1: What did you feel when you touched each object?
- Question 2: At what temperature do you think each object is?
- Question 3: Explain with your own words why you felt this sensation when you touched the object.
- Question 4: Once the temperature of the objects is known, explain why you think this is so.

Question 1 and 2 measured the perceptual quality and quantity of the thermal percepts. Question 3 aimed to trigger interpretation of the thermal sensations. After Question 3 was answered, students were asked to check the temperature of each object with an Infrared thermometer (model: Fisherbrand™ Traceable™ Infrared Dual Lasers Thermometer w/Type-K Probe). Then, the students replied Question 4, which goal was to again prompt interpretation of the sensations.

In our analysis, we did not control for group, age or school. We pooled all the values by conditions. We are interested in studying universal tendencies about how misleading sensations contribute to the development of well-known misconceptions on heat and temperature.

RESULTS

To analyse the answers to Question 1, we identified the units of information (words, expressions or sentences) used by students to describe what they felt. Based on Green, Roman, Schoen & Collins (2008), we grouped them in seven categories (icy, cold, cool, in-between, warm, hot, burning, and nothing). Table 1 shows students' responses when the objects were at 10.8 ºC and 38.1 ºC.

Table 1. Frequency and percentage of the units of information found in answers to question 1 to describe what students felt. The units of information were grouped in 7 categories (icy, cold, cool, in-between, warm, hot, burning, and nothing). Data is from conditions in which objects were at 10.8 ºC and 38.1 ºC.

	10.8 ºC						38.1 ºC					
	Foam Low TC		Brick Medium TC		Aluminium High TC		Foam Low TC		Brick Medium TC		Aluminium High TC	
Icy	0	0.0 %	6	16.7 %	27	75.0 %	0	0.0 %	0	0.0 %	0	0.0 %
Cold	2	5.6 %	13	36.1 %	7	19.4 %	2	4.7 %	5	11.6 %	0	0.0 %
Cool	4	11.1 %	12	33.3 %	2	5.6 %	2	4.7 %	2	4.7 %	0	0.0 %
In-between	11	30.6 %	3	8.3 %	0	0.0 %	9	20.9 %	8	18.6 %	1	2.3 %
Warm	17	47.2 %	2	5.6 %	0	0.0 %	20	46.5 %	14	32.6 %	0	0.0 %
Hot	2	5.6 %	0	0.0 %	0	0.0 %	10	23.3 %	12	27.9 %	15	34.9 %
Burning	0	0.0 %	0	0.0 %	0	0.0 %	0	0.0 %	1	2.3 %	27	62.8 %
NR	0	0.0 %	0	0.0 %	0	0.0 %	0	0.0 %	1	2.3 %	0	0.0 %
Total	36	100	36	100	36	100	43	100	43	100	43	100

We found that the distribution of responses was different for each object at all temperatures (Table 1). Specifically, most units of information found when describing the sensation elicited by touching foam fell in 'In-between' and 'Warm'. In the case of brick, the frequency of units of information varied across conditions. In the conditions at 10.8ºC and 23.0ºC, most units of information fell in the categories 'Cold' and 'Cool'. In the conditions at 33.6ºC and 38.1ºC, most units of information fell in the categories 'In-between', 'Warm' and 'Hot'. In the case of aluminum, we found a stronger deviation of the units of information from central categories. In the conditions at 10.8ºC and 23.0ºC, most units of information fell in the categories 'Icy' and 'Cold'. In the conditions at 33.6ºC and 38.1ºC, most units of information fell in the categories 'Hot' and 'Burning'.

Importantly, responses in all conditions (object and temperature) are distributed across categories (Table 1). Namely, sensations did not consistently fall within one category.

Overall, these results indicate that student's thermal perception depends on the temperature of the objects, and, given a constant temperature, perception depends on the TC of the materials. They also show a disagreement in the categorisation of sensations. Individuals categorise sensations elicited by objects differently. This could result in miscommunications, which could be problematic in educational settings.

Although objects were at the same temperature for each condition, the answers to Question 2 showed that students assigned different temperatures to each object. Figure 1 shows the distribution for the frequencies of temperatures reported by students when the objects were at 23.0 ºC. Table 2 shows the data for all temperatures.

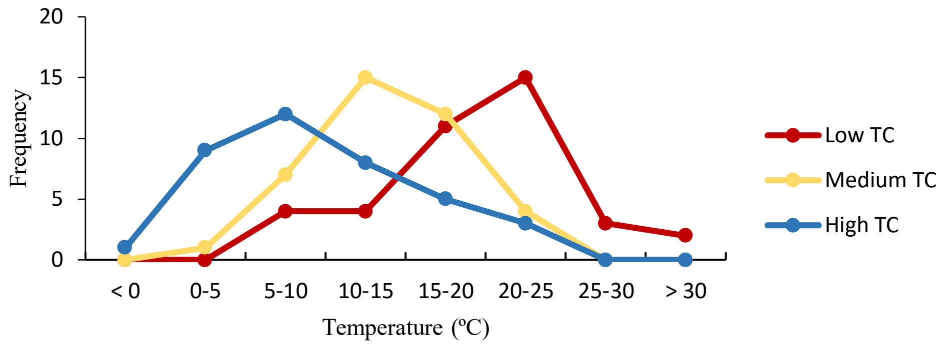

Figure 1. Frequency of temperatures reported by students when objects were at 23.0 ºC. Mean average: low TC, 18.3 ºC: medium TC, 12.4 ºC; high TC, 8.2 ºC.

As shown in Table 2, the means of the object temperature estimation within each condition differed. At each condition, pair-wise paired t-tests revealed significant differences ($p < 0.05$) within conditions except for foam vs brick at 33.6ºC and foam vs brick at 38.1ºC.

Table 2. Mean, standard deviation (S.D.) and kurtosis from temperature estimations in Question 2.

Condition	Statistical parameters	Foam Low TC	Brick Medium TC	Aluminium High TC
10.8 ºC	Mean	13.9	7.5	1.7
	S.D.	9.1707	10.3865	9.8556
	Kurtosis	0.2913	4.5644	1.3306
23.0 ºC	Mean	18.3	12.4	8.2
	S.D.	6.6598	4.9460	6.7310
	Kurtosis	-0.2529	-0.1279	-0.3125
33.6 ºC	Mean	19.9	22.8	41.6
	S.D.	11.1052	11.5876	18.3204
	Kurtosis	1.1404	-0.0617	0.7115
38.1 ºC	Mean	19.8	19.6	40.9
	S.D.	22.4555	17.0863	31.4946
	Kurtosis	28.7328	11.2502	16.2788

These results indicate that students were not able to make a correct estimate of the temperature of the objects with their thermal sensation. Consistent with the previous quesiton, these results suggest that object temperature estimation depends on the temperature of the object and its thermal conductivity. On the one hand, the estimated temperature is related to the temperature of the object. On the other hand, the estimated temperature varies as a function of the thermal conductivity for a constant temperature. The estimated temperature varies more when touching a material with high thermal conductivity as opposed to when a material with low thermal conductivity is touched. This suggests that the effect of thermal conductivity on the estimated temperature is lower for materials with low thermal conductivity.

Moreover, the standard deviation and kurtosis differs within and across conditions. At 38.1ºC, the kurtosis is positive and high, which indicates a sharp peak compared to a normal distribution. At this temperature, the responses gravitate closer to the mean (positive kurtosis). At 33.6ºC, the kurtosis was very close to cero with negative and positive values for different objects. At 23.0ºC, the responses were more spread (negative kurtosis and very close to cero). Therefore, at 33.6ºC and 23ºC, the responses are more spread than at 38.1ºC. At 10.8ºC, we observed positive values of the kurtosis, but not as high as those for 38.1ºC. Importantly, the mean temperature of the skin is 32-33ºC (Rajek et al., 2000). These results suggest that object temperature estimations are less spread at extreme temperatures than at less extreme temperatures.

To analyse the answers to Question 3 and 4, we identified, collated and classified the units of information (words, expressions or sentences) used by students to explain what and why they felt. Question 4 was formulated after students revealed the real temperature of the objects.

Consistent with the literature, students based their explanations on well-known alternative conceptions. Some examples were: “the heat (do not) travels to the fingers”, “Polyethylene is warmer because it keeps internal heat” or “metals are cold materials”. These statements reveal two kind of misconceptions. Firstly, these explanations assume that heat is a fluid that moves from object to object (caloric theory). Secondly, they also show the misconception that materials are naturally hot or cold (Brook et al., 1985), or attractors of hotness/coldness (Kesidou and Duit, 1993). Therefore, based on the literature, we grouped the units of information in 4 categories: material has heat/cold (mhhc); the materials are different (md); we perceive differently (pd); caloric theory (ct).

Figure 3 shows the frequency for each category. The analysis revealed that many students’ explanations contained units of information belonging to more than one category. We noticed that in many explanations the units of information identified were contradictory. Therefore, the total sum is greater than the number of students and it differs between Question 3 and 4. In our design, we did not expect this. Therefore, we could not conduct a properly designed statistical analysis.

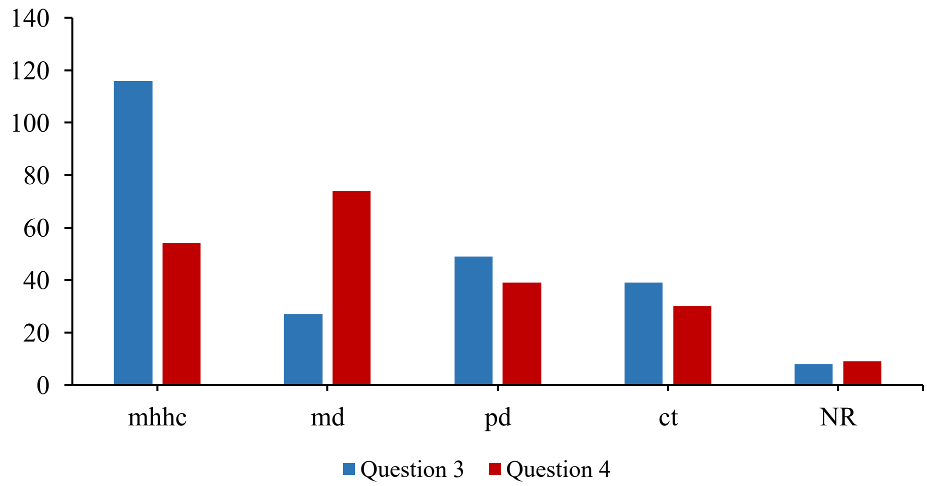

Figure 2. Frequency of the units of information found in the explanations given to Question 3 and 4.

However, we observed a trend in the frequency of units of information in Question 3 and 4 (Figure 2). It seems that knowing the real value of the temperature made students to change their explanations. In Question 3, most units of information fell in the category 'Material has heat/cold', whereas in Question 4 most units of information were classified in the group 'Materials are different'.

DISCUSSION AND CONCLUSIONS

In this study, we presented three objects with different thermal conductivity at constant temperatures to students in high school (12-15 years old). Although objects were at the same temperature in each condition (10.9 ºC, 23.0 ºC, 33.6 ºC, and 38.1 ºC), we found differences in the categorisation of sensations (Question 1; Table 1) as well as in the estimation of objects' temperatures (Question 2; Table 2 & Figure 1). Furthermore, we found common misconceptions when students were asked to explain the reasons why they perceived those sensations (Question 3; Figure 2). Finally, when the real temperature of the objects was revealed to students, we observed a tendency to reject their first explanation and to seek for an alternative one (Question 4).

The results obtained in Question 1 and 2 are coherent (Table 1 & 2 and Figure 1). They indicate that there is not common agreement when labelling the sensation. This is supported by the distribution of the frequencies in Table 1 and by the pattern of the responses in Table 2 and Figure 2. Additionally, these results also show that thermal perception depends on material's thermal conductivity and their temperature. This is consistent with previous literature that showed how subjects can discriminate between materials based on thermal cues (Ho & Jones, 2006). Our results show that thermal perception is ambiguous (Ezquerra-Romano & Ezquerra, 2017; Kubricht, Holyoak & Lu, 2017). They support the theory that perceptual ambiguity of physical variables influences the development of alternative conceptions (Wenning, 2008; Ezquerra & Ezquerra-Romano, 2018).

In the context of teaching, this observation has important consequences. It is challenging to find an agreement when labelling sensations, given that each individual will categorise the sensation differently. Consequently, miscommunications are likely to occur. When explaining concepts related to heat and temperature, pupils might get lost in the reasoning when, for instance, the teacher uses real-life examples. Each individual will picture a different sensation, which might lead to inaccurate understandings.

Furthermore, our results in Question 2 show that many students are very far from the real temperature of objects when they were asked to estimate their temperature. This observation reveals a problem in the context of education. Students find it difficult to estimate object's temperature, which seems to have an internal origin (perception). Moreover, their learning through daily-life experiences (external) has not provided them with the right tools to estimate objects' temperature. We suggest two solutions to tackle this problem. Firstly, students should be aware of the limitation of their thermosensation. To accomplish this, content about the workings of our thermosensory system should be included in lessons of thermodynamics (Ezquerra and Ezquerra-Romano, 2019). Secondly, students in early stages of the school curriculum should carry out activities in which they estimate and measure the temperature of objects in their familiar environments (e.g. At what temperature are the following items? Soup, shower, soft drink with ice).

Moreover, the explanations given in Question 3 and 4 were consistent with the sensations and temperatures reported in Question 1 and 2. Overall, analysis of the identified misconceptions showed that students based their explanations on their reported sensations. Interestingly, even when their perception was challenged with the real temperature (Question 4), their explanations kept relying on the perceived sensations. However, we found a trend to find alternative explanations after the real temperature of the object was revealed. This change does not result from a conceptual change. Nevertheless, this activity (to experience the thermal sensation of different objects and measure its temperature) triggered an immediate intention to change their explanation. There are two stages in this process. Firstly, they rejected their first explanation. Secondly, they sought for an alternative explanation. This activity catalysed a rupture of the cognitive equilibirum (Pritchard & Woollard, 2010).

Our results are coherent with the way that our thermosensory system works (Ezquerra-Romano & Ezquerra, 2017). We do not have a unique temperature detection mechanism (a thermometer), but a family of thermoTRPs that work at different ranges (Schepers & Ringkamp, 2010). Furthermore, thermal information is transmitted separately through two main channels in the nervous system, which contributes to the conceptual creation of two ranges: hot and “cold” (Craig, 2003; Ezquerra & Ezquerra-Romano, 2018).

It seems that the structure and arrangement of our thermosensory system shapes and constrains the creation of the concepts of heat and “cold”. Understanding how concepts are shaped by our perception will help developing teaching strategies that directly tackle ingrained misconceptions.

ACKNOWLEDGEMENT

This work has been funded by Project RTI2018-094303-A-I00 of the Ministry of Economy and Competitiveness, Spain, the State R & D & I Program Oriented to the Challenges of the Society, State Plan for Scientific Research and Technical and Innovation 2018.

REFERENCES

Abimbola, I. O. (1988). The problem of terminology in the study of student conceptions in science. Science Education, 72(2), 175-184.

Abrahams, I., Homer, M., Sharpe, R., & Zhou, M. (2015). A comparative cross-cultural study of the prevalence and nature of misconceptions in physics amongst English and Chinese undergraduate students. Research in Science & Technological Education, 33(1), 111-130.

Brook, A., Briggs, H., Bell, B. and Driver, R. (1985). Secondary students’ ideas about heat: Workshop pack, children’s learning in science project. Leeds, UK, University of Leeds, Centre for Studies in Science and Mathematics Education.

Chiappetta, E. L., & Koballa, Jr., T. R. (2006). Science Instruction in the Middle and Secondary Schools. Upper Saddle River, NJ: Pearson/Merrill Prentice Hall.

Craig, A. (2003). A new view of pain as a homeostatic emotion. Trends in Neurosciences, 26(6), 303-307.

Driver, R. (1989). Students' conceptions and the learning of science. International journal of science education, 11(5), 481-490.

Driver, R., & Easley, J. (1978). Pupils and paradigms: A review of literature related to concept development in adolescent science students. Studies in Science Education, 5, 61–84.

Ezquerra, A. and Ezquerra-Romano, I. (2018). From Thermosensation to the Concepts of Heat and Temperature: A Possible Neuroscientific Component. Eurasia Journal of Mathematics, Science and Technology Education, 14(12).

Ezquerra, A. and Ezquerra-Romano, I. (2019). Using neuroscience evidence to train pre-service physics teachers on the concepts of heat and cold. Journal of Physics: Conference Series, Volume 1287 (1).

Ezquerra-Romano, I., & Ezquerra, A. (2017). Highway to thermosensation: a traced review, from the proteins to the brain. Reviews in the Neurosciences, 28(1), 45–57.

Green, B. G., Roman, C., Schoen, K., & Collins, H. (2008). Nociceptive sensations evoked from 'spots' in the skin by mild cooling and heating. PAIN®, 135(1-2), 196-208.

Ho, H. N., & Jones, L. A. (2006). Contribution of thermal cues to material discrimination and localization. Perception & Psychophysics, 68(1), 118-128.

Kesidou, S. y Duit, R. (1993). Students' conceptions of the second law of thermodynamics - An interpretive study. Journal of Research in Science Teaching, 30, 85-106.

Pritchard, A. & Woollard, J. (2010). Psychology for the classroom: Constructivism and social learning. New York: Routledge.

Rajek, A., Grief, R., Sessler, D. I., Baumgardner, J., Laciny, S., & Bastanmehr, H. (2000). Core cooling by central venous infusion of icecold (4 degrees Celcius or 20 degrees Celcius) fluid: isolation of core and peripheral thermal compartments. Anaesthesiology, 93(3), 629-637.

Schepers, R. J., & Ringkamp, M. (2010). Thermoreceptors and thermosensitive afferents. Neuroscience & Biobehavioral Reviews, 34(2), 177-184.

STUDENTS INTERPRETATION OF GRAPH SLOPE IN KINEMATICS INVESTIGATED BY THE EYE-TRACKING METHOD

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We employed the eye-tracking method in order to observe students' strategies of choosing an option when they solved multiple-choice tasks focused on graph slope in kinematics. 32 high school students participated in the study. We provide comparison of attention allocation between two students group: those, who solved a test task correctly and those who did not. Correctly answering students paid more attention to all correct options than incorrectly answering students. And vice versa. Incorrectly answering students mostly paid the most attention to options which show typical identified misconceptions in graph (slope) interpretation.

Keywords: Physics, Graphical Representations, Eye-tracking

INTRODUCTION

Graph reading and interpretation is necessary skill for students focused not only on science in these days. Students' graph interpretation has been investigated in many studies not only in physics education field but in mathematics education and psychology field as well. See Susac et al. (2018) for the review. In physics field, we are mostly interested in scatterplots, which have several important features. In the research, we focused on the graph slope interpretation, which is intuitively not easily accessible concept for students. In several previous studies, typical students' misinterpretations of the concept have been identified. For example, *Slope/height confusion*, *Variable confusion* or *Nonorigin Slope Errors* (Beichner, 1994, McDermott et al., 1987). Moreover, typically students show misunderstanding where "graph is considered to be like a photograph of the real situation" as well.

Previous researches used interview or multiple-choice testing as a research method. Nowadays, we also employ the eye-tracking method, which allows us to get deeper insight into students' thinking processes (Susac et al., 2018, Klein et al., 2019). By the method, we can track students' eye-movements and so to follow their attention. A typical methodological approach is embedded in novice-expert paradigm, where we compare problem solving strategies of experts and novices, and experts' strategies are considered to be the better one. In the educational field, typically we compare students who solved a task correctly and those who did not.

Our research questions are as follows:

1. How does students' gaze allocation on options in a multiple-choice test differ according to correctly or incorrectly answering a test task?

2. And what students' (mis)interpretation of the graph slope concept can we conclude based on this eye-movements observation?

METHOD

Students were observed by the eye-tracking method, when they solved multiple-choice tasks focused on the graph slope in kinematics. Moreover, after the eye-tracking session, students fulfilled a questionnaire about their gender, age school, grades, and attitudes to science and “graph as a sketch of the real situation” typical students’ conception about graphs was examined by additional tasks.

Apparatus

Eye-tracker by Tobii was used, particularly TX300 with frequency 300 Hz, which has accuracy less than 0.5 °of visual angle. The infrared camera was placed under the 23-inch screen of the stimulus PC. The resolution of the screen was set to 1900 x 1280 pixels. A five point calibration and validation procedure was used before start of the experiment. Eye movements were recorded by Tobii Studio 3.2 and for identification of fixations inbuilt IVT filter was used. Eye movement was classified as a saccade when eye’s velocity exceeded 30°/s. Minimum fixation duration was set on 60 ms.

Test’s tasks

Each student solved 6 multiple-choice tasks (#3 upto #8) focused on graphs in kinematics. Five tasks were adopted from Beichner’s TUG-K test (Beichner, 1994) and one task was adopted from Czech research by Fenclova (1980). All tasks were focused on position-time graphs and determining velocity from the graphs as it is stated in the Objective 1 of the Beichner’s original test. Moreover, the first task (#1) was adopted from McDermott et al. research (McDermott, et al. 1987) and students should determine which object (A or B) was moving faster at the time = 2s. Position-time graph with two lines of different slopes was given. The task #2 was due to technical problems from further analysis omitted.

Sample of students

There were 32 participants in the study (53 % women, 47 % men) mostly focused on science, aged 18-20y.

Data analysis

In order to get answer on our research questions, we analyzed data obtained by the eye-tracker as it follows: For each task we created so called AOIs, Areas Of Interest, as it is shown in Figure 1. Because we always compared two groups we did not need to take into account areas size of these AOIs. Each stem-text, stem-graph and each option was marked as a separate AOI. Then we divided students into two groups whether they answered a task correctly or not, and compared the mean of total fixations duration which each student group spent on AOIs.

RESULTS AND DISCUSSION

Relative number of students (in %), who answered a task correctly, is shown in Table 1.

Table 1. Percentage of students, who answered particular task correctly.

Task no.	1	3	4	5	6	7	8
% of students	50.00 %	40.63%	22.58%	31.25%	25.81%	15.63%	65.63%

Almost 2/3 of students solved correctly task #8, whilst task #7 was the most difficult one. Students typically showed misunderstanding that *a graph is a sketch of a real situation*. Task #4 and #6 were focused on quantitative determination of slope at a particular time. In task #4 students worked with positive slope, in task #6 with the negative one. Surprisingly, slightly more students solved correctly task #6 than task #4.

Given position – time graph (right). Students should choose from five velocity – time graphs which describe the same motion.

(From Beichner 1994, task No. 11.)

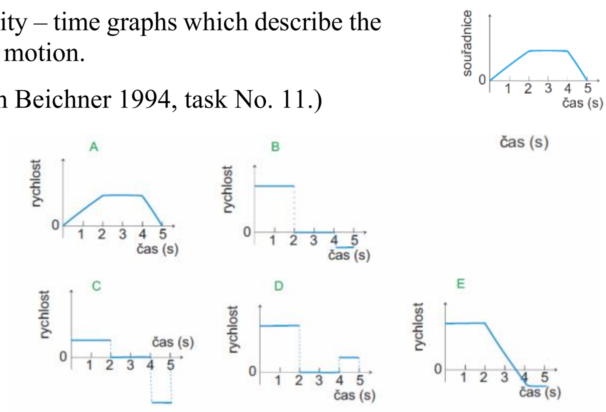

Figure 1. A task #3 and an example of created AOIs (right).

Total fixations duration of each participant related to their score is shown in Figure 2. Most participants solved the test in range 2 upto 7 minutes. Participants no. 20, 23 and 37 spent on tasks much more time than the others, particularly more than 9 min. We considered them as outliers and provided further analysis with and without them.

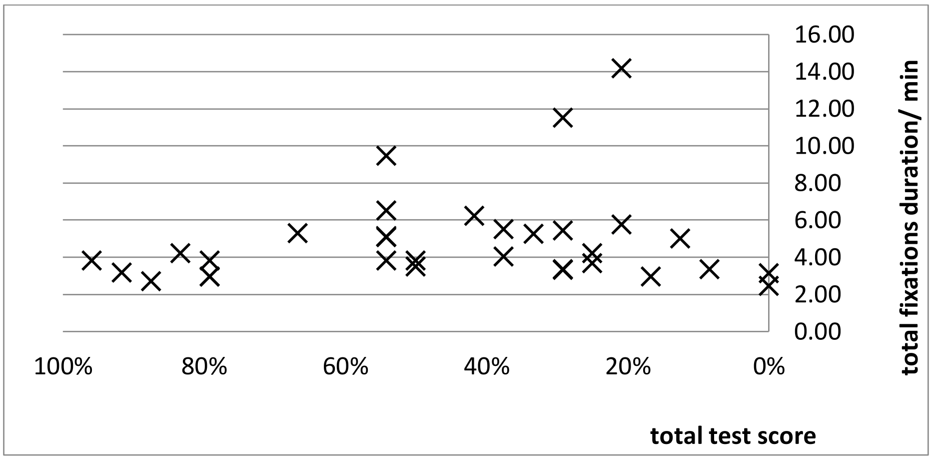

Figure 2. Total fixations duration of each participant related to their total test score.

Total fixations duration spent on each task by each participant is shown in Figure 3. Participants are ordered according to their total test score. Participant no. 11, left, gained the highest total test score (96%). In order to complete a task, roughly the best (left) and worst (right) performers needed shorter time than the other ones.

Most participants solved a task in less than 1 minute. Average total fixations durations of task #1, #3, #4, #5, #6, #7 and #8 are as follows: 24.5 s, 61.1 s, 46.9 s, 33.8 s, 43.4 s, 40.1 s and 42.1 s. (without “outliers” 23.8 s, 49.4 s, 43.2 s, 28.3 s, 37.3 s, 33.1 s and 34.4 s). The longest average total fixations duration was made on task #3, #4 and #6.

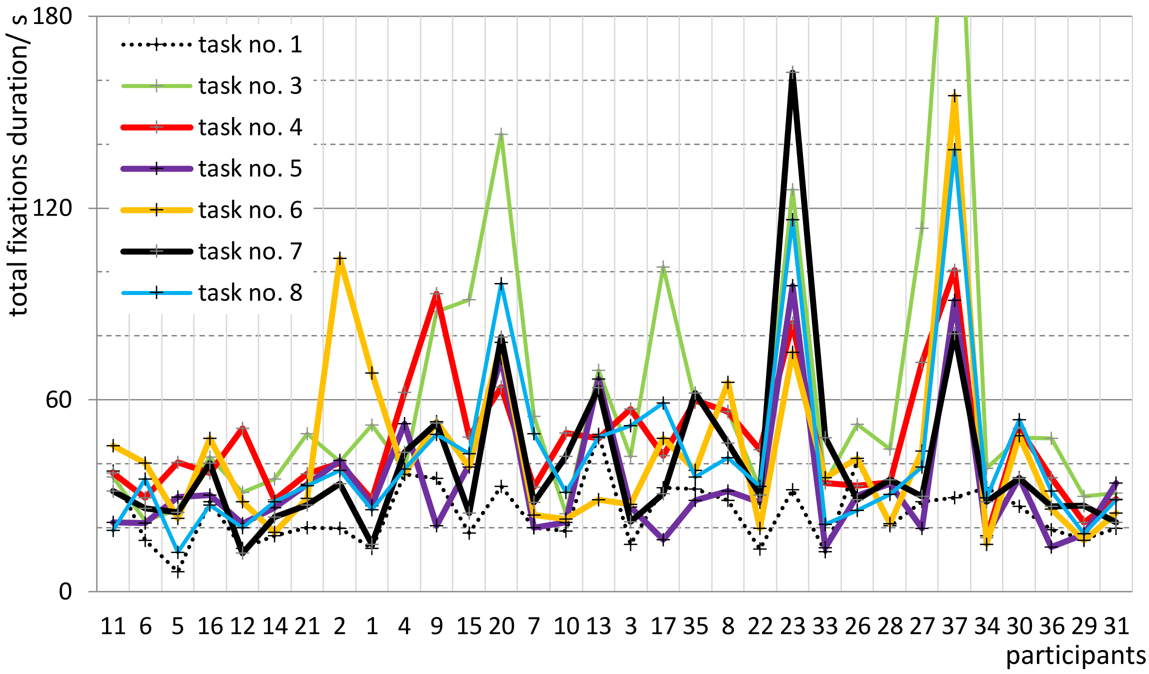

Figure 3. Total fixations duration of each participant for each task. Ordered according to the total test score (the best performer is in the left).

Correctly and incorrectly answering students showed different total fixations duration on options' AOIs. See Figure 4. In line with gaze bias hypothesis (Lindner et al., 2014), correctly answering students spent more time on correct options (3_c, 4_b, 5_e, 6_c, 7_b&c, 8_e), whilst incorrectly answering students were more focused on the other options. The correct options were the only options which correctly answering students spent more time on than incorrectly answering students. The finding suggests that total fixations duration mean could serve as good predictor between correctly and incorrectly answering students.

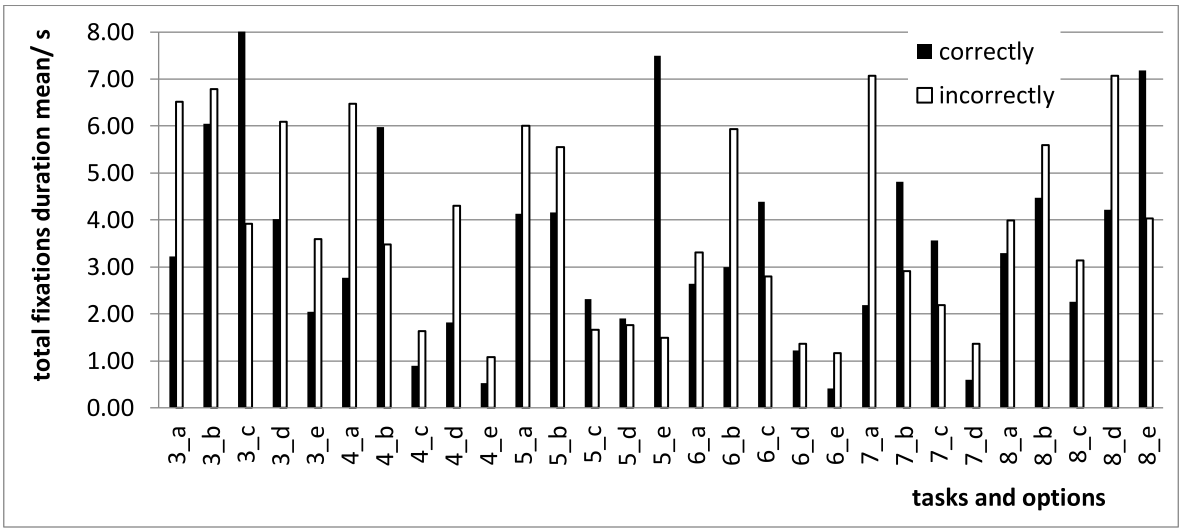

Figure 4. Total fixations duration mean on each task option. Group of students who answered correctly (black) and incorrectly (white).

Statistically significant differences are shown in Table 2. We used nonparametric Kolmogorov-Smirnov test by Statistica Software from Statsoft Inc. Company. We did not find any statistically significant differences in group means of task #8 options. However, the groups differ in their total fixations duration mean of options 8_d and 8_e the most. Option 8_e was much more fixated by the correctly answering students and option 8_d by the incorrectly answering students. The task was solved the most successfully. In contrast to the other options, option 8_e and _d offered graphs with very similar curves. In contrast, the groups statistically significantly differ in two options of task #7, which is shown in Figure 5. Incorrectly answering students who chose either option 7_a or 7_d showed typical “graph as a picture or sketch of a real situation” error.

Table 2. Statistical significant differences in total fixations duration mean of students who answered correctly (group 1) and incorrectly (group 2). Kolgomorov-Smirnov test by Statistica software. If we omitted “outliers” (see Figure 2), there is statistical significant difference in option 3_a as well.

Task	Option	Max Neg	Max Pos	**p-value**	Mean 1	Mean 2	Std.Dev. 1	Std.Dev. 2
5	e	0,000	0,955	**p < 0.001**	7,50	1,49	5,843	2,078
4	a	-0,690	0,042	**p < 0.025**	2,77	6,48	1,234	3,940
6	c	-0,043	0,715	**p < 0.005**	4,39	2,80	1,937	5,576
7	a	-1,000	0,000	**p < 0.01**	2,19	7,07	0,530	3,273
7	d	-0,857	0,000	**p < 0.05**	0,60	1,37	0,225	0,453

Task #4 and task #6 were focused on determining of slope (positive in task #4, negative in task #6) at a particular time. Students show typical *Nonorigin Slope Error* (Beichner, 1994), where they simply divide position (at the given time) by the given time. Even in the case, when slope does not intersect the origin. The incorrectly answering students chose such option as their answer and they also paid much more time to the option. The difference in total fixations duration mean for the two groups was statistically significant (see Table 2). Surprisingly, they were also interested a lot in option „time divided by position“ (see task #4, option 4_d). Both students’ groups showed the least total fixations duration mean on options which offered only *height of a graph*. So they do not show *Slope-height confusion error* (Beichner, 1994) when solving the type of a task.

In task #5 based on the given description of a motion (An object starts from rest and undergoes a positive, constant acceleration for ten seconds. It then continues on with constant velocity.), students should choose from five position – time graphs which describe the motion. (From Beichner 1994, task no. 9). Both correctly and incorrectly answering students paid the least attention to the two improbable options (5_c, 5_d). They differ (statistically significantly) in attention paid to the correct option 5_e. Incorrectly answering students paid similar amount attention to it like to the previously mentioned ones. They were interested much more in options, where the graph curve is at the end parallel with the time axis. Obviously, these students interpreted motion with constant velocity as horizontal line in the position-time graph. Task #3 is shown in Figure 1. The correctly answering students paid the most attention to option 3_b and to the correct one (3_c). Probably, in the given position-time graph they firstly identified positive and negative constant slope and they focused on their magnitudes later. Whilst incorrectly answering students spent the most time on options 3_a, 3_b and 3_d. Probably, in contrast to the correctly answering students, they (incorrectly) identified magnitudes of the slopes and then they focused on solving the problem whether they are negative or positive. This shows differently perceived importance of magnitude and negativity or positivity of a slope by the two groups. Focus on option 3_a is in line with typical error called *Variable confusion* (Beichner, 1994), where students tend to perceive graph curve describing the same motion event as the same or at least similar regardless graph variables.

Given position – time graph (see picture). Students should choose from five options which describe the motion.

a) A car is moving along inclined plane down.

b) A car is moving with a constant velocity.

c) A car is going back to the zero point.

d) A car is almost falling down.

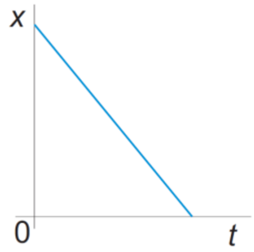

Figure 5. Task#7.

CONCLUSION

We showed differences in attention allocation (operationalized by total fixations duration) among correctly and incorrectly answering students which they paid to options in multiple-choice test focused on graph slope interpretation in kinematics. Correctly answering students paid more attention to all correct options than incorrectly answering students and vice versa. Incorrectly answering students mostly paid the most attention to options which show typical identified misconceptions in graph (slope) interpretation. They prefer interpretation which misleads abstract nature of a graph and sketch of a real situation. Obviously, correctly and incorrectly answering students differ in their perceived importance of magnitude and orientation of a graph slope. In the end, again we showed value of the eye-tracking method, which makes students' thinking and decision making processes visible.

REFERENCES

Beichner, R. J. (1994). Testing student interpretation of kinematics graphs. *American Journal of Physics*, 62, 750–762.

Fenclova, J. (1980). Fyzikalni vedomosti nasich studentu, *CSAV study,* no.5, Academia, Prague.

Klein, P., Küchemann, S., Brückner, S., Zlatkin-Troitschanskaia, O. and Kuhn, J. (2019). Student understanding of graph slope and area under a curve: A replication study comparing first-year physics and economics students. *Physical Review Physics Education Research*, 15, 020116.

Lindner, M. A., Eitel, A., Thoma, G.-B., Dalehefte, I. M., Ihme, J. M., & Köller, O. (2014). Tracking the decision making process in multiple-choice assessment: Evidence from eye movements, *Applied Cognitive Psychology*, *28*, 738-752

McDermott, L.C., Rosenquist, M.L., van Zee, E.H. (1987). Student difficulties in connecting graphs and physics: Examples from kinematics, *American Journal of Physics*, 55 (6), 503-513.

Susac, A. et al. (2018). Student understanding of a graph slope and area under a graph: A comparison of physics and nonphysics students. *Physical Review Physics Education Research*, 14, 020109.

EDUCATIONAL RECONSTRUCTION OF CURRENTS AND STRUCTURE FORMATIONS

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In a preliminary study, it is found that numerous out-of-school learning venues near the coast need help in addressing aspects of coastal physics in their educational offerings. Therefore, an Educational Reconstruction (Duit, Gropengießer, Kattmann, Komorek & Parchmann, 2012) of coastal physics is carried out in the present research and development project. The aim is to outline principles and formulate educational guidelines for the operators of out-of-school learning venues to support them in their effort to integrate aspects of coastal physics into their existing educational offerings. As part of the Educational Reconstruction, a document analysis of scientific literature is undertaken to clarify the subject matter structure. This is followed by an empirical study in which the learners' conceptions of coastal phenomena (currents and structure formations) are investigated. The creation of educational guidelines is ultimately based on both the learners' conceptions and the results of the subject matter clarification.

Keywords: Coastal Physics, Model of Educational Reconstruction, Out-of-school learning

INTRODUCTION AND PRELIMINARY STUDY

As the effects of climate change on the Trilateral World Heritage Wadden Sea are particularly severe, more than 30 out-of-school learning venues have been founded in Germany alone to emphasise the dynamics and sensitivity of the Wadden Sea attracting millions of visitors each year. To learn more about the educational offerings, expert interviews (Bogner, Littich & Menz, 2009) are conducted with the operators of the out-of-school learning venues. These expert interviews serve as a preliminary study because the interviews helped to concretise the research and development tasks in the present project. It is investigated to what extent coastal physics already appears in educational offerings of out-of-school learning venues and whether the operators want more coastal physics in their offerings. It is found that almost no physics is addressed yet: ocean currents, structure formations in the sand, and the formation of islands are missing along with physical explanations and models. Most of the educational offerings are firmly focussed on biological content. The operators of the out-of-school learning venues are aware of that imbalance. Still, they are not able to fix it on their own, as the operators typically come from the fields of biology or environmental science and do not have much experience with coastal physics. Therefore, they need help integrating coastal physics into their offerings. This help is provided in the present research and development project.

MODEL OF EDUCATIONAL RECONSTRUCTION

The Model of Educational Reconstruction (Duit et al., 2012) serves as a theoretical framework for all research and development tasks carried out in the present project. The model was created by science education researchers and calls for the same attention to be paid to the clarification and analysis of science content and the examination of relevant learners' conceptions. The outline of principles and the formulation of educational guidelines that help the operators to design new teaching and learning environments is therefore based equally on both the clarification and analysis of science content and the research on teaching and learning. The following figure shows the three components of the model. Each element represents a task that must be accomplished for an educational reconstruction of the topic of interest.

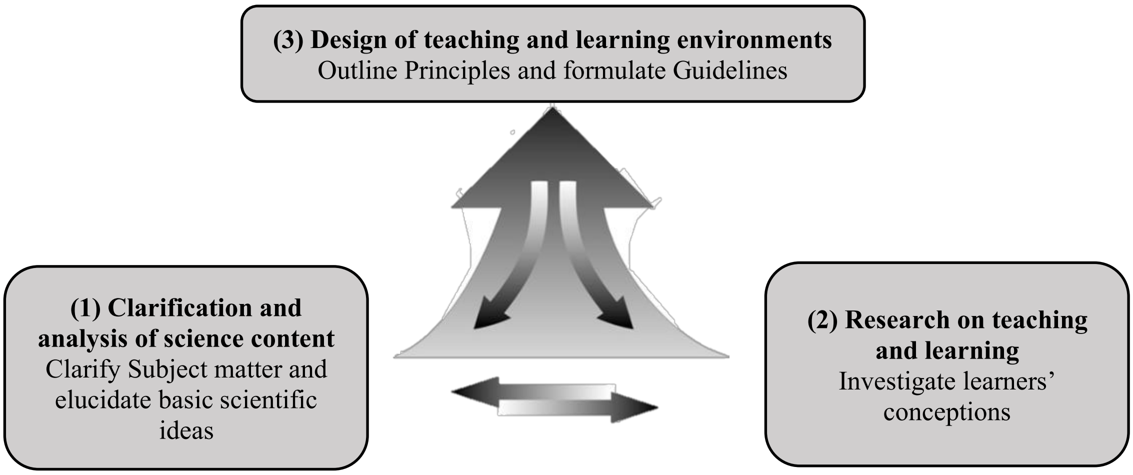

Figure 1. The three elements of the Model of Educational Reconstruction (based on Duit et al., 2012)

Since the Model of Educational Reconstruction is a theoretical framework, in each of the three elements, it must be determined how the respective task should be mastered based on further science education research concepts. Therefore, the elements of the model represent the following three chapters, in which it is specifically shown with which concepts the respective task is processed.

(1) CLARIFICATION AND ANALYSIS OF SCIENCE CONTENT

In coastal regions, learners are mainly confronted with phenomena that can be assigned to (a) currents and (b) structure formations of granular matter (sand). For this reason, these two areas of phenomena will play a significant role in future educational offerings and are therefore subject to clarification. The concept of Elementarisation (Duit, Schecker, Höttecke & Niedderer, 2014) is used in this project to provide the necessary clarification of the subject matter structure. The concept of Elementarisation aims to elucidate the basic scientific ideas, principles, and general laws of the topic to be educationally reconstructed. Hence, a document analysis of scientific literature is carried out that is dedicated to the subject of interest. Because of the focus on currents and structure formations, scientific literature from the fields of continuum mechanics (Haupt, 2002), thermodynamics (Blundell & Blundell, 2010), non-equilibrium thermodynamics (Demirel, 2014) and the theory of complex systems (Bar-Yam, 2003; Nicolis & Prigogine, 1977) is analysed to elucidate basic scientific ideas, principles and general laws used to explain currents and structure formations in the context of coastal regions.

a) Currents: Basic Idea of Equalisation

There are two types of currents described in the scientific literature, each triggered by different causes. On the one hand, there is natural convection and, on the other hand, forced convection. Natural convection occurs as a result of temperature or concentration gradients in a fluid. When sufficient temperature or concentration gradients occur, density differences result, causing the fluid to begin to flow. Molecular transport processes of heat and mass, which are associated with conduction and diffusion, are then superimposed by convective transport processes. Forced convection is driven by external forces on a fluid. Related to a surface area, the external force can be described as a pressure that acts on the fluids' surface. If there is a pressure gradient in the fluid, it changes its shape and starts to flow. The shear stresses that the fluid experiences depend on its viscosity. That emerging gradients are associated with transport processes can be seen particularly well in the equations for each molecular transport process. They always have the same shape: Gradients are proportional to molecular transport processes via a proportionality factor, which is either the thermal conductivity coefficient, the diffusion coefficient, or the viscosity. But it is remarkable that in all cases, the emerging currents reduce the causative gradients: Due to natural convection, conduction, and diffusion temperature gradients and concentration gradients decrease. Due to forced convection and the associated change in the shape of the fluid, the pressure gradients are also reduced. Occurring gradients cause processes (called natural convection, forced convection, conduction, or diffusion) that lessen the gradients again. So, all molecular and convective transport processes have a particular direction. They always lead to an equalisation of prevailing gradients. Gradients decrease over time because the equalised state has higher entropy than an unequalised state (Demirel, 2014). Therefore, the equalised state is the most likely to occur in the long term and becomes a stable attractor. For this reason, currents are interpreted as a phenomenological expression of an equalisation principle.

b) Structure formations: Basic Idea of self-organisation due to positive and negative feedback

On the coast, currents and granular matter interact far from the thermodynamic equilibrium. Thus, there are no stable attractors so that random fluctuations can initially increase undamped. The excess entropy (Nicolis & Prigogine, 1977; Demirel, 2014) acts as a stability criterion for systems outside the thermodynamic equilibrium and describes whether random fluctuations lead to positive or negative feedback. If positive feedback occurs, influences are not damped, the system is unstable, and it may change into a new state. In the case of negative feedback, influences are damped so that the system always falls back into its original state. Structure formation through self-organisation is based on an interplay of positive and negative feedback: A system leaves its original state through positive feedback. At some point, it will be finally stabilised into a new state by negative feedback occurring. Structures in the sand, for example, depending on the initial distribution of sand grains and obstacles (Anderson, 1990). In places where there is more sand, there are more impacts between the grains and, thus, a higher dissipation rate. Accumulations arise. The emerging gatherings lead to even more impacts between the grains and thus to an even higher dissipation rate so that the accumulations are self-amplifying. This is a positive feedback mechanism. However, the accumulation eventually reaches a critical slope and cannot continue to grow due to any more grains of sand roll off the pile, which is a negative feedback mechanism. The interplay between positive and negative feedback leads to a new dissipative structure formation through self-organisation: metastable states are reached. In the course of the document analysis, many other phenomena are identified, which are also described based on an interplay between positive and negative feedback mechanisms. These include cyclones (Ooyama, 1982), tidal deltas (Fagherazzi, 2008), ripple marks (Anderson, 1990), meandering rivers (Stølum, 1996), ocean waves (Smyth und Moum, 2012), and vortex streets (Ikeda & Apel, 1981; Banerjee, 2005). In the present project, structure formations are interpreted as a phenomenological expression of the interplay between self-amplification (positive feedback) and self-inhibition (negative feedback).

(2) RESEARCH ON TEACHING AND LEARNING

In the course of the second component of the Model of Educational Reconstruction, the learners' perspectives and conceptions in the relevant subject area are empirically investigated. The investigation is divided into two phases: first of all, the focus is only on the notions (the terms) "current" and "structure formation". The aim is to find out what the learners associate with both notions and what properties must be fulfilled from their perspective in order to call something "current" or "structure formation". This is of interest because both notions are used in many everyday life contexts and have a different meaning there than in science. In the second phase, it is probed how learners explain currents and structural formation phenomena. These two investigation phases lead to the following research questions:

(i) What characteristics do the notions "current" and "structure formation" have from the learners' perspective?
(ii) Which scientific ideas, laws, and principles do learners use to explain currents and structure formations?

Methods

In total, 22 structured guideline interviews are conducted with visitors to out-of-school learning venues. Since the learning venues are open not only to schoolchildren but to anyone interested, people between the ages of 15 and 70 are interviewed. People under the age of 18 are interviewed in pairs, as experience has shown that couple interviews lead to an increased willingness to talk and discuss, which is vital since younger subjects often do not dare to give detailed answers in a one-on-one interview. Interviews are divided into two series, each dedicated to answering one research question. The same people take part in both interviews of the series, which are conducted approximately one week apart.

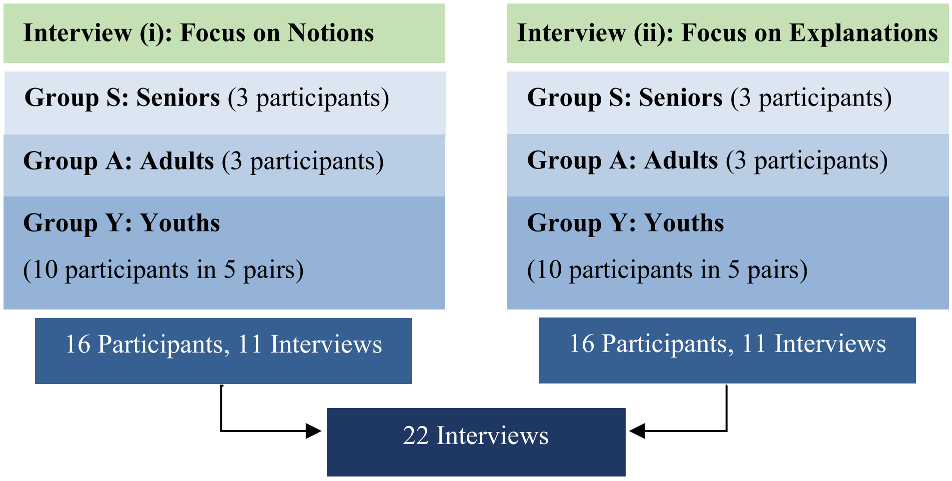

Figure 2. Distribution of test subjects across the various interviews conducted.

(i) In the first series of interviews, pictures, and videos are used to determine the characteristics of currents and structure formations from the learners' perspective. They are given 30 images showing many different everyday phenomena, including currents and structure formations. The interviewees are then asked to select the images that they viewed as currents. After the pictures are chosen and a stack is formed, there is an intense discussion about what must be fulfilled from the learners' point of view to include a picture in the group of currents. Besides, they are asked to name counterparts, synonyms, and definitions of currents and had to justify them. Subsequently, the same procedure is repeated for structure formations.

(ii) In the second series of interviews, two experiments are used: in one, learners observed a convection cell, and in the other, a structure formation in the sand is created.

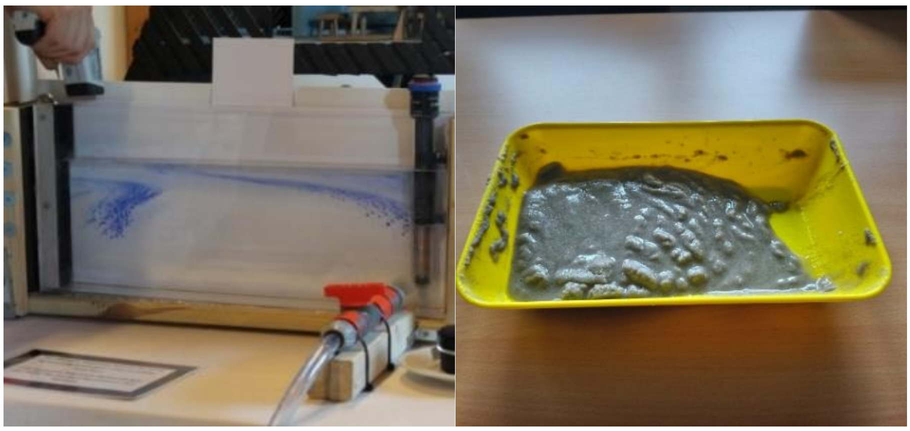

Figure 3. Experiments are carried out to create a convection cell (left) and a structure formation (right)

To create a convection cell, a water basin is used, which is heated by an aquarium heater on one side and cooled by Peltier elements on the other side. The current can be observed after the addition of ink. To form a structure in the sand, a tray is filled with sand and a little water. If the tray is moved back and forth, a pattern is formed in the sand. To investigate the concepts used to explain the phenomena, the interview is structured according to the POE method (White & Gunstone, 1992). The letters stand for **p**redicting, **o**bserving, and **e**xplaining. Therefore, the second interview is divided into these three sections, each for currents and structure formations.

Both interviews are evaluated using qualitative content analysis (Mayring, 2014): Categories are formed which are statements about the characteristics of the notions "current" and "structure formation" (interview (i)) and statements about explanatory concepts on the emergence of currents and structure formations (interview (ii)).

Results

(i) Currents are considered to be a particular form of movement characterised by three features: currents are joint movements (collectivity) of a large number of individual objects that are distributed quasi-continuously (continuity) and move with a minimum of speed and extension (intensity). For this reason, the interviewees consider not only the directional movement of water and air as currents but also the collective motion of a large number of animals, people or cars. However, the interviewees decide subjectively whether a phenomenon seen in the picture has the three characteristics mentioned or not. That is why the learners come to a different grouping of the images despite arguing with the same characteristics since some already see an almost collective movement as a current. In contrast, others insist on an utterly joint movement. When confronted with structure formations, the learners distinguish between two types of structures: temporal sequences of events (e.g., a daily routine) and spatial arrangements (e.g., a dune). The characterisation of these two types of structures causes them significant problems. Many learners use the term "regularity" to describe structures in the context of the coastal regions. Others, on the other hand, use the exact opposite and explain that structures are characterised by "irregularity". Still, others see a mixture of both characteristics, which is particularly clear from the statement of a learner who says that structure formations are characterised by an "irregular regularity". The difficulty in assigning a consistent feature to structure formation is because it depends on what the respective structure is mentally compared with: Structures in nature are never entirely regular. If compared with a structure created by humans (e.g., a very regular tile pattern), it is concluded that natural structures are somewhat irregular. However, if natural structures are compared with an extremely unstructured state (e.g., a very smooth, uniform surface), it is concluded that structures are characterised by regularity.

(ii) To explain the convection cell in the experiment, learners refer to the density of the water. They state that the density of the water depends on its' temperature. Since they know that ice floats on water, they falsely conclude that the density of cold water is lower than the density of heated water. However, this contradicts their observations in the experiment and leads to cognitive conflict. Hence, they fail to explain the convection cell consistently. In general, it is found that learners prefer forced convection over natural convection. Although the interview focusses on natural convection, they keep talking about forced convection and offer explanations in this regard. As an explanatory strategy, they use the principle that other already existing movements are transferred to still water or still air (e.g., with a fan or a pump). As a result, the still water or the still air begins to flow. To explain structure formations, learners mostly use two explanation strategies. In the first explanation strategy, they interpret structure formations as an imprint. To illustrate this, they speak of a shoe print that is created because the structure of the sole is transferred to the sand. Analogously, the interviewees falsely explain that the ripple marks are an imprint of the water waves. And in their opinion water waves get their structure from the fact that the structure of the wind is transferred to the water. Accordingly, the learners are only able to explain structures if structures already exist. The learners thereby create a *chicken and egg problem* and are unable to explain structures from a state of total unstructuredness. In the second explanation strategy, the learners try to explain occurring structure formations with the help of irregularities. They describe that the grains of sand are of different sizes, or the tray in which the sand is located cannot be moved back and forth perfectly regular. These are irregularities that ultimately result in irregularities in the sand, which are recognised as structure formations. This frequently happens in the interview: the learners mention irregularities in the environmental conditions and thus see the structure formation as clarified. However, the learners cannot explain which exact mechanisms work so that initial irregularities ultimately lead to the formation of structures.

(3) DESIGN OF TEACHING AND LEARNING ENVIRONMENTS

In the final step of the Model of Educational Reconstruction, educational guidelines are formulated to help design teaching and learning environments. For this purpose, the analysed scientific content and the empirically examined learners' perspective on currents and structure formations are being compared with each other (Duit et al., 2012). It is ascertained to what extent the learner's perspective differs from the scientific view on currents and structure formations. Based on the results, suggestions are made for the teaching-learning environment on how to make a connection between the learner's perspective and the scientific perspective if the two are close to each other (continuous teaching-learning pathways). If the two perspectives differ greatly, a discontinuous teaching-learning pathway is indicated so that it is shown how the learners' conceptions can be confronted (Scott, Asoko & Driver, 1992; Amin, Smith & Wiser, 2014). The formulated educational guidelines are presented in the following subsections. They are intended to help the operators of the out-of-school learning venues to integrate coastal physics into their educational programs.

I) The teaching-learning environment is phenomenon-based

The out-of-school learning venues are visited by many different people who vary in their abilities. For this reason, the educational offerings should start with an observation of phenomena (here: currents and structure formations phenomena) to ensure everyone being able to take part in the educational offerings (differentiated learning).

In the interviews, learners prefer forced convection to discuss the characteristics of currents. For this reason, the phenomenon of forced convection will be thematised first before addressing natural convection. Since the learners see water as a prototypical medium for currents, phenomena such as the tides, rip currents, or flowing rivers must be addressed. Finally, structure formations are introduced. Here the learners often refer to structures in the sand and the clouds. For this reason, ripples, dunes, and cloud streets must be discussed in a teaching-learning environment.

II) The characteristics of currents and structure formations are being addressed.

The discussion about the characteristics of currents and structure formations proved to be very fruitful in the interview because this way, the learners are intensively occupied with both phenomena. This potential should also be exploited at out-of-school-learning venues. Hence, after observing currents and structure formations phenomena, their characteristics are discussed.

In the case of currents, a connection can be made between the scientific perspective and the learners' conceptions: the named characteristics "collectivity" and "continuity" can be clearly illustrated using the example of water currents. In the interview, the learners also mention the characteristic "intensity". This differs from the scientific view because it does not require a certain intensity to classify movements as currents. Here their ideas must be confronted. Since the interviewees describe currents as dangerous in the interview, they presumably name the characteristic "intensity" to underline that currents can be life-threatening. A connection to this can be made in a teaching-learning situation by also dealing with the possible dangers that arise from currents.

Regarding structure formations, the learners fluctuate between the two characteristics "regularity" and "irregularity", so that they fail in characterizing structure formations consistently. The problem with the two characteristics is that they represent two extremes on a mental scale. Therefore, the characteristic of similarity is offered. On the mental scale mentioned, the term similarity is located between regularity and irregularity. Maximum similarity (e.g. a tile pattern) would mean an absolute regularity, while minimal (e.g. a chaotic state) similarity could be described as a total irregularity. In a teaching-learning environment, structures are defined by the characteristic of similarity, and it will be made clear that specific spatial arrangements or temporal sequences are repeated with a certain similarity.

III) For an explanation, the principles of equalisation and feedback are introduced.

Explaining the emergence of currents and structure formations means the highest cognitive demands for the learners. Thus, the explanations are given only after observing the phenomena and after discussing their characteristics. In this way, all visitors can take part in the educational offerings and decide for themselves whether they only want to observe the phenomena or whether they also require explanations.

Since, as described in the first guideline (I), the teaching-learning environment starts with forced convection, pressure differences are used for an explanation. A fan or a pump can be discussed as an example from everyday life to create forced convection. The currents resulting there are interpreted as equalization processes: the pressure differences are reduced by the emerging currents. Thinking about equalisation serves as an excellent transition to finally discuss free convection too. Temperature differences and concentration differences are introduced as causes of free convection. To establish a connection to the learners' conceptions, both temperature differences and concentration differences are related to differences in density. As indicated in the interview, the density anomaly of the water must be pointed out in this regard to prevent cognitive conflicts that have arisen in the interview. Explanations in the teaching-learning environment go beyond the statements of the learners in the interview since free convection is also described via equalisation: The emergence of currents reduces differences in temperature and concentration so that differences in density also decrease. Free convection can, therefore, also be interpreted as an equalisation process.

Because the interviewees often explain structure formation based on existing structures, which transfer their structure like an imprint, they must be confronted with the resulting *chicken and egg problem*. It must be made clear that structures in the sand or the clouds form differently than structures that are created by a shoe print. The term self-organization can be applied very well here. Because the term makes it clear that the structures are not imprinted from the outside but that they are self-organized without external control. This way, a connection can be made to the perspective of the learners because, in the interview, they also underline that structures arise from irregularities in the initial conditions (e.g., different grain sizes of the sand). The connection is made by explaining that initial irregularities can self-amplify. If there is an irregularity (e.g., a little more sand in a certain place in the beginning), more and more moving sand gets stuck there, and the accumulation of sand continues to grow, which is positive feedback. However, the gathering does not grow forever because the accumulation becomes steeper and steeper, and the currents (wind or water currents) that move the sand eventually become turbulent. At some point, the maximum size is reached, and more sand that hits the accumulation rolls down again, which is negative feedback. Overall, the interplay of positive and negative feedback explains the structure formation in the sand. Positive and negative feedback are then also used to describe other structure formation phenomena, which are named in the analysis and clarification of science content (e.g., cyclones, tidal deltas, etc.)

OUTLOOK

The research and development work carried out so far leads to two new tasks that need to be mastered in the present project as well.

1) Interviews with the operators of the out-of-school learning venues must be conducted. The interview aims to discuss the developed educational guidelines. This is necessary because the operators have to accept the educational guidelines and support their usage. The results of the interviews are used to revise the guidelines and adjust them to the needs of the operators.

2) Based on the educational guidelines, specific educational offerings (e.g., learning stations, exhibits, etc.) must be developed, which are then empirically examined in the field of the out-of-school-learning venues. With the results of the empirical study, the specific educational offerings are adapted, and the guidelines are further developed.

ACKNOWLEDGEMENT

The present project is funded by the German Environmental Foundation (DBU) and is part of a graduation program of the Ministry for Science and Culture of Lower Saxony. We thank both for their support.

REFERENCES

Amin, T. G., Smith, C. L. & Wiser, M. (2014). Student Conceptions and Conceptual Change: Three Overlapping Phases of Research. In N. G. Lederman & S. K. Abell (Eds.), *Handbook of Research on Science Education. Volume II* (p. 57-81). New York, London: Routledge.

Anderson, R. S. (1990). Eolian ripples as examples of self-organization in geomorphological systems. *Earth-Science Reviews, 29 (1-4)*, 77-96.

Banerjee, P. K. (2005). *Oceanography for Beginners*. New Delhi u. a.: Allied Publishers.

Bar-Yam, Y. (2003). *Dynamics of Complex Systems*. Boulder, CO: Westwing Press.

Blundell, S. J. & Blundell, K. M. (2010). *Concepts in Thermal Physics*. Oxford: Oxford University Press.

Bogner, A. Littich, B. & Menz, W. (2009). *Interviewing Experts.* New York, NY: Palgrave McMillan.

Demirel, Y. (2014). *Nonequilibrium Thermodynamics: Transport and Rate Processes in Physical, Chemical and Biological Systems*. Amsterdam: Elsevier.

Duit, R., Gropengießer, H., Kattmann, U., Komorek, M. & Parchmann, I. (2012). The Model of Educational Reconstruction – a framework for improving teaching and learning science. In D. Jorde & J. Dillon (Eds.), *Science Education Research and Practice in Europe* (p. 13-37). Rotterdam: Sense Publishers.

Duit, R., Schecker, H., Höttecke, D. & Niedderer, H. (2014). Teaching Physics. In N. G. Lederman & S. K. Abell (Eds.), *Handbook of Research on Science Education. Volume II* (p. 434-456). New York, London: Routledge.

Fagherazzi, S. (2008). Self-organization of tidal deltas. *Proceedings of the National Academy of Sciences of the United States of America, 105 (48),* 18692-18695.

Haupt, P. (2002). *Continuum Mechanics and Theory of Materials*. Berlin, Heidelberg: Springer.

Ikeda, M. & Apel, J. R. (1981). Mesoscale Eddies Detached from Spatially Growing Meanders in an Eastward-Flowing Oceanic jet Using a Two-Layer Quasi-Geostrophic Model. *Journal of Physical Oceanography, 11 (12)*, 1638–1661.

Mayring, P. (2014). Qualitative Content Analysis: Theoretical Background and Procedures. In A. Bikner-Ahsbahs, C. Knipping & N. Presmeg (Eds.), *Approaches to Qualitative Research in Mathematics Education* (p. 365-380). Berlin, Heidelberg: Springer.

Nicolis, G. & Prigogine, I. (1977). *Self-Organization in Nonequilibrium Systems: From Dissipative Structures to Order through Fluctuations*. New York: Wiley.

Ooyama, K. V. (1982). Conceptual Evolution of the Theory and Modeling of the Tropical Cyclone. *Journal of the Meteorological Society of Japan, 60 (1),* 369-380.

Scott, P. H., Asoko, H. M. and Driver, R. H. (1992) Teaching for conceptual change: A review of strategies. In R. Duit, F. Goldberg & H. Niedderer (Hrsg.), *Research in Physics Learning: Theoretical Issues and Empirical Studies Proceedings of an International Workshop held at the University of Bremen, March 4-8, 1991* (S. 310-329). Kiel: Institut für die Pädagogik der Naturwissenschaften.

Smyth, W. D. & Moum, J. N. (2012). Ocean Mixing by Kelvin-Helmholtz Instability. *Oceanography, 25 (2)*, 140-149.

Stølum, H. H. (1996). River Meandering as a Self-Organization Process. *Science, 271 (5256)*, 1710-1713.

White, R. & Gunstone, R. (1992). *Probing Understanding*. London: Routledge.

GENETIC CONCEPTS, REPRESENTATIONS AND MODELS IN STUDENTS' AND EDUCATORS' CONCEPTIONS

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Scientific literacy is considered, internationally, one of the fundamental goals of education, with genetic literacy being a crucial part of it. In this framework, an extensive literature review of students' and teachers' conceptions on the gene was conducted, followed by a meta-analysis of 45 papers in order to trace in these conceptions the five historical models for the gene and its function; Mendelian, classical, biochemical-classical, neoclassical and modern model. The findings of the meta-analysis outline systematic difficulties and misconceptions in students' and educators' conceptions in genetics, as well as outdated perceptions of the gene model that lacks modern aspects.

Keywords: Educators, Students, Gene historical models

INTRODUCTION

In a society infused with scientific and technological achievements, which are a great part of modern everyday life, citizens are involved in democratic procedures that require a deep understanding of science. Therefore, the inclusion of basic concepts and possibilities of those scientific accomplishments in the education of students is deemed crucial for their future in society (Gericke & Hagberg, 2010a). More specifically, citizens are increasingly facing matters that require critical thinking and understanding of genetic concepts, methods and processes namely gene therapy, genetic testing, reproduction, hereditary and behavioural issues, as well as social controversies concerning origins and race (Ahmed et al., 2018; Aldahmash et al., 2012; Stern & Kampourakis, 2017). Such extended range of genetics applications renders genetics literacy, an important pillar of scientific literacy, a pivotal aspect of the modern citizen. Genetics, apart from an integral part of modern biology, constitutes a solid branch of secondary and upper education biology curricula (Agorram et al., 2010; Dorji, Tshering, & Dorji, 2017; Gericke & Hagberg, 2007). Despite its central role in science education, it is one of the most problematic areas of the curriculum of biology, mostly due to the conceptual, linguistic difficulties students face; these difficulties may emerge either from students' inability to connect the different organizational levels of genetic phenomena and processes (Duncan & Reiser, 2007; Marbach-Ad & Stavy, 2000), or the incongruency between the level of conceptual difficulty and students' cognitive level (Lewis & Kattmann, 2004; Lewis & Wood-Robinson, 2000), or inaccurate or even lack of previous knowledge (Donovan & Venville, 2014; Venville et al., 2005). Students' difficulties are subsequently reinforced by low-quality textbooks lacking cohesion, poor didactic transformation of scientific to scholar knowledge from the educators, and lastly, by the preconceptions both parts hold before instruction which are also formed by the mass media (Stern & Kampourakis, 2017).

In addition to the afore-mentioned issues, the intrinsic complexity of genetics resulting from the conceptual variation of core terms, such as that of the "gene" is aggravating the perplexity of genetics instruction and understanding. As the "gene" term and its function has undergone a conceptual change since its first appearance in the beginning of the twentieth century, there have been multiple scientific gene models describing its structure and function in different historical contexts (Gericke & Hagberg, 2010b). It has been proven (Blonder & Mamlok-Naaman, 2019) that didactic approaches integrating historical aspects into the science curricula enhance the understanding of the nature of science (NOS) and, therefore, aide in coping with alternative conceptions both educators and students may hold, causing implications in instruction.

The gene concept and function has undergone a lot of discussion and analysis in the scientific world (El-Hani et al., 2014; Kampourakis, 2017) and of course at the implications it conceptual change in education and the learning process. Multiple studies have focused on how the gene concept is portrayed in biology textbooks (Aivelo & Uitto, 2015; Christidou & Papadopoulou, 2018; Gericke et al., 2014; Gericke & Hagberg, 2010a, 2010b; Santos et al., 2012), but also researched students' and educators' conceptions in genetics (Table 3). The need for a review of the curricula worldwide is prominent (Aivelo & Uitto, 2015), and it is suggested that it should be based on systematic research conducted on the conceptions of both students and educators (Osman et al., 2017).

The latter has been the scope of our literature review where we researched the international literature for the conceptions of students and educators about the gene and its function. Moreover, we conducted a meta-analysis of the results in order to trace in those conceptions the epistemological features from the five historical models of the gene and its function (Mendelian, classical, biochemical-classical, neoclassical, modern) as described by Gericke and Hagberg (2007). The models share the idea of a hidden hereditary factor (gene) influencing a characteristic or function of an organism, while each of them represents a significant change in the way the function of the gene has been perceived through history (Gericke & Hagberg, 2010b).

METHOD

We conducted a literature review on students' and educators' conceptions, focusing on secondary education, in regards to genetics, and more specifically, to the concept of gene and its function. Our research extended in 105 scientific journals on education with the following keywords: students'/ teachers' conceptions, genetics, alternative ideas, gene concept.

The meta-analysis was based on the five historical models of the gene and its function as described by Gericke και Hagberg (2007). Using the secondary attributes of the historical models which are described by the epistemological features-variants as presented in Table 1, students' and teachers conceptions were analysed and classified under the respective models (

For instance, middle school students' conceptions researched by Donovan and Venville (2012) were driven by the deterministic belief that genes are determined by the corresponding traits they code for, or that there is no separation between the gene and the trait as concepts. This type of gene view is matched with the epistemological feature which explains the relationship of genotype with phenotype (symbolized as 4a, Table 1) as described in the Mendelian model (**Error! Not a valid bookmark self-reference.**). Furthermore, the two researchers found that students' perception for genes' structure was mainly references to heritable particles of abstract material structure (1a – Mendelian model) or of DNA segments (1c – neoclassical model). Therefore, this study's students' conceptions were categorized as hybrid, as there was prominent coexistence of epistemological features of different historical models.

Table 2). From the papers studied, a total of 45 were included in the meta-analysis (Table 3); the majority of research studies analysed used written questionnaires and/or interviews for the extraction of conceptions; their results' section was analysed in order to find words or phrases correlated with the models. The main epistemological features' categories discovered concerned the materialistic (or not) view of the gene, its definition from a (phenotypical) characteristic, the description of the relationships among the entities in the model, and the gene's function.

Table 1. Description of the epistemological feature-variants used in the classification of the textbook models (Gericke & Hagberg, 2010a).

Epistemological features	Legend for feature-variant
1	**The relationship between the structure and function of the gene**
1a	The gene is an abstract entity and has no structure.
1b	The gene is a particle on the chromosome.
1c	The gene is a DNA segment.
1d	The gene consists of one or several DNA segments with various purposes.
2I	**The relationship between organizational level and definition of gene function**
2Ia	The model has entities at the macro- and symbolic levels.
2Ib	The model has entities at the macro- and cell levels.
2Ibx*	The model has entities at the macro-, cell- and molecular levels.
2Ic	The model has entities at the molecular level.
2Icx*	The model has entities at the cell- and molecular levels.
2II	**The relationship between organizational level and definition of gene function**
2IIa	The correspondence between the gene and its function is one-to-one.
2IIb	The correspondence between the gene and its function is many-to-many.
3	**The "real" approach to defining the function of the gene**
3a	The function of the gene is defined top–down.
3b	The function of the gene is defined bottom–up.
3c	The function of the gene is defined by a process.
4	**The relationship between genotype and phenotype**
4a	There is no separation between genotype and phenotype.
4b	There is a separation, without explanation, between genotype and phenotype.
4c	There is a separation between genotype and phenotype, with an enzyme as the intermediary.

4d	There is a separation between genotype and phenotype with a biochemical process explanation.
5I	**The idealistic versus naturalistic relationships in the models**
5Ia	The relationships in the model are idealistic.
5Ib	The relationships in the model are naturalistic.
5II	**The idealistic versus naturalistic relationships in the models**
5IIa	The relationships in the model are causal and mechanistic.
5IIb	The relationships in the model are process oriented and holistic.
6	**The explanatory reduction problem**
6a	There is explanatory reduction from the macro level to the symbolic level.
6b	There is explanatory reduction from the macro level to the cell level.
6bx*	There is explanatory reduction from the macro to the molecular level.
6c	There is no explanatory reduction.
7	**The relationship between genetic and environmental factors**
7a	Environmental entities are not considered.
7ax*	Environmental- and genetic entities result in a trait/product/function.
7b	Environmental entities are implied by the developmental system.
7c	Environmental entities are shown as part of a process.

**The non-historical features were found in the textbooks by Gericke & Hagberg (2010a), but are not present in any of the historical models*

For instance, middle school students' conceptions researched by Donovan and Venville (2012) were driven by the deterministic belief that genes are determined by the corresponding traits they code for, or that there is no separation between the gene and the trait as concepts. This type of gene view is matched with the epistemological feature which explains the relationship of genotype with phenotype (symbolized as 4a, Table 1) as described in the Mendelian model (**Error! Not a valid bookmark self-reference.**). Furthermore, the two researchers found that students' perception for genes' structure was mainly references to heritable particles of abstract material structure (1a – Mendelian model) or of DNA segments (1c – neoclassical model). Therefore, this study's students' conceptions were categorized as hybrid, as there was prominent coexistence of epistemological features of different historical models.

Table 2. The historical model-categories of gene function as defined by the different epistemological feature-variants (Gericke & Hagberg, 2010a).

Historical model-category	Epistemological feature-variants								
	1	2I	2II	3	4	5I	5II	6	7
Mendelian model	1a	2Ia	2IIa	3a	4a	5Ia	5IIa	6a	7a
Classical model	1b	2Ib	2IIb	3a	4b	5Ia	5IIa	6b	7a
Biochemical-classical model	1b	2Ib	2IIa & 2IIb	3a &3b	4c	5Ia	5IIa	6b	7a
Neoclassical model	1c	2Ic	2IIa	3b	4d	5Ib	5IIa	6c	7b
Modern model	1d	2Ic	2IIb	3c	4d	5Ib	5IIb	6c	7c
Non-historical		2Ibx, 2Icx						6bx	7ax

The main categories of epistemological features identified in the studies analysed referred to, the relationship between the structure and function of the gene (1a, 1b, 1c), the relationship between organizational level and definition of gene (2Ia-2Ic & 2IIa), the "real" approach to defining the function of the gene (3a, 3b), the relationship between genotype and phenotype (4a, 4b, 4c) and a few references to the idealistic versus naturalistic relationships in the models (5IIa) and the relationship between genetic and environmental factors (7ax). Lastly, all conceptions were categorised based on the epistemological features found in the papers studied.

Table 3. Total scientific papers analysed in meta-analysis on students' and educators' conceptions.

Papers on students' conceptions	Papers on educators' conceptions
Agorram et al., 2010; Ahmed et al., 2018; Aivelo & Uitto, 2015; Banet & Ayuso, 2000; Chin & Teou, 2010; Clough & Wood-Robinson, 1985; Jenny Donovan & Venville, 2012; Dorji, Tshering, Chettri, et al., 2017, 2017; Duncan et al., 2011; Duncan & Reiser, 2007, 2007; Duncan & Tseng, 2011; El-Hani et al., 2014; Gericke & Hagberg, 2007; Gericke & Wahlberg, 2013; Giasemis, 2011; Halldén, 1988; Haskel-Ittah et al., 2018; Haskel-Ittah & Yarden, 2017; Kementsietzidou, 2009; Koers, 2016; Koumparou et al., 2011; LeVaughn, 2016; Lewis, 2014; Lewis et al., 2000a, 2000b; Lewis & Kattmann, 2004; Marbach-Ad, 2001; Marbach-Ad & Stavy, 2000; Osman et al., 2017; Saka et al., 2006; Tsui & Treagust, 2010; G. Venville et al., 2005; G. Venville & Treagust, 1998; Wood-Robinson et al., 2000	Antonelli-Ponti et al., 2018; Dikmenli et al., 2011; Forissier & Clément, 2003; N. M. Gericke & Hagberg, 2007; Kampourakis et al., 2016; Marbach-Ad, 2001; Martins & Ogborn, 1997; G. J. Venville & Treagust, 1998; Walker & Plomin, 2005

RESULTS

Students' conceptions

From the totality of research papers reviewed, we found 36 studies in 17 countries (Figure 1), where it was feasible to categorise students' conceptions according to the five historical models of the gene and its function (Gericke & Hagberg, 2007). The most prevalent models were found to be the Mendelian and the classical, individually or in combination (hybrid), while elements from the biochemical-classical and the neoclassical emerged in a few results, but for the most part in hybridisation with other models, as shown in Figure 2. Furthermore, genetic determinism appeared in students' conceptions on genetics, reflecting predominantly the causal relationship of gene-trait, which constitutes a difficult core concept in teaching genetics (Wahlberg et al., 2018), leading to alternative conceptions/ misconceptions. The modern model was hardly detected in any study, as no epistemological feature-variant belonging to solely this model was found in the papers reviewed.

Educators' conceptions

In relation to the literature on students' conceptions on genetics, the research studies on educators' or pre-service teachers' conceptions were almost half (9 studies in 10 countries). The trend, however, is similar to that of the students' conceptions (Figure 2), as the predominant models were the Mendelian, the classical and the biochemical-classical, while there was a complete lack of the modern model. Hybridization of different models through instruction is a common finding, as educators rarely shifts from one view of a gene (abstract entity) to another (physical entity) without former explanation, therefore implicating students' understanding or conceptions (Thörne et al., 2013).

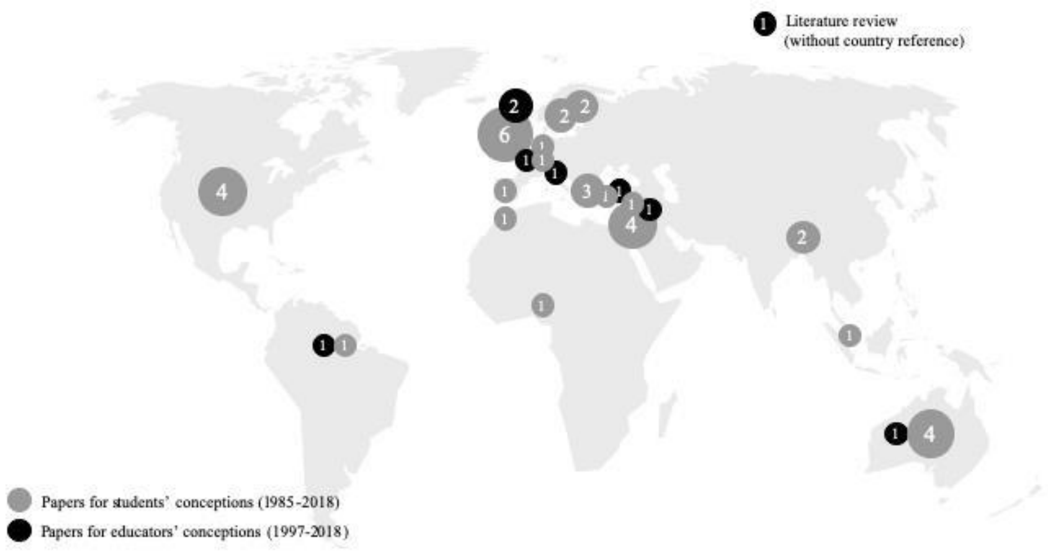

Figure 1. Map of literature results analysed in the meta-analysis. All studies for students' (with grey colour) as well as educators' (with black colour) conceptions are depicted according to the country they took place.

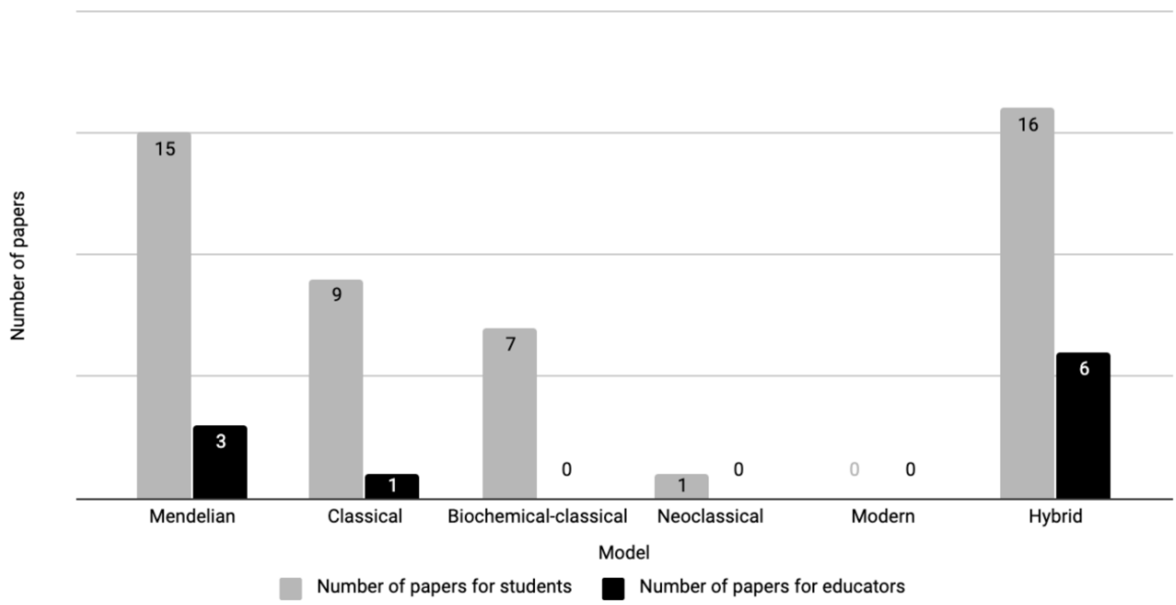

Figure 2. Models of gene function as identified in the papers for students' and educators' conceptions, in regards to the epistemological features-variants as described by Gericke and Hagberg (2007). (The identification of multiple models in one study is shown by the increased number of models in the Figure 2 (48) in contrast to the total number of papers analysed (36)).

DISCUSSION AND CONCLUSIONS

In conclusion, it is evident from our literature review that from the total of research papers studied and from the 45 which were analysed, 36 referred to studies investigating secondary school students' conceptions on genetics, whereas only 9 detected conceptions of educators, both pre-service teachers, as well as primary school teachers. All studies pinpoint misconceptions that students hold and are of importance in the planning of instruction by the educators. Additionally, the prevalence of confusion about the various models for the concept and function of gene, indicates the difficulties in conceptual understanding and consequently in their use by both students and educators. The conceptual variation, which is a consequence of the use of multiple historical models, is not intrinsically problematic, as it is highly useful to scientists (Aivelo & Uitto, 2015); however, in the school environment, it appears that the plurality in the depiction of gene function impedes its deeper understanding, resulting in hybridisation of the models used (El-Hani et al., 2014).

To sum up, literature worldwide presents systematic difficulties students and educators face in regards to genetics, as well as misconceptions formed when the former are not tackled. Hence, there is a need for further research so as to update the curricula and the outdated teaching methods which lack modern concepts in genetics.

ACKNOWLEDGEMENT

This research is co-financed by Greece and the European Union (European Social Fund- ESF) through the Operational Programme "Human Resources Development, Education and Lifelong Learning" in the context of the project "Strengthening Human Resources Research Potential via Doctorate Research" (MIS-5000432), implemented by the State Scholarships Foundation (IKY).

REFERENCES

Agorram, B., Clement, P., Selmaoui, S., Khzami, S. E., Chafik, J., & Chiadli, A. (2010). University students' conceptions about the concept of gene: Interest of historical approach. *US-China Education Review*, ISSN 1548-6613, USA, *7*, 9–15.

Ahmed, M. A., Opatola, Y. M., Yahaya, L., & Sulaiman, M. M. (2018). Identification of Alternative Conceptions of Genetics held by Senior School Students in Ilorin, Nigeria, Using a Three-Tier Diagnostic Test. *KIU Journal of Social Sciences*, *4*, 97–104.

Aivelo, T., & Uitto, A. (2015). Genetic determinism in the Finnish upper secondary school biology textbooks. *Nordic Studies in Science Education*, 11, 139–152.

Aldahmash, A. H., Alshaya, F. S., & Asiri, A. A. (2012). Secondary school students' Alternative conceptions about genetics. *Electronic Journal of Science Education*, *16*. http://ejse.southwestern.edu/article/view/7401

Antonelli-Ponti, M., Versuti, F. M., Da Silva, J. A., Antonelli-Ponti, M., Versuti, F. M., & Da Silva, J. A. (2018). Teachers' perception about genes and behavior. *Estudos de Psicologia (Campinas)*, *35*, 421–431. https://doi.org/10.1590/1982-02752018000400009

Banet, E., & Ayuso, E. (2000). Teaching genetics at secondary school: A strategy for teaching about the location of inheritance information. *Science Education*, *84*, 313–351. https://doi.org/10.1002/(SICI)1098-237X(200005)84:3<313::AID-SCE2>3.0.CO;2-N

Blonder, R., & Mamlok-Naaman, R. (2019). Teaching chemistry through contemporary research versus using a historical approach. *Chemistry Teacher International*. https://doi.org/10.1515/cti-2018-0011

Chin, C., & Teou, L.-Y. (2010). Formative Assessment: Using Concept Cartoon, Pupils' Drawings, and Group Discussions to Tackle Children's Ideas about Biological Inheritance. *Journal of Biological Education*, *44*, 108–115.

Christidou, A., & Papadopoulou, P. (2018). Representations of gene models in Greek secondary school biology textbooks. *XII Conference of European Researchers in Didactics of Biology (ERIDOB)*, *65*. https://eventos.unizar.es/_files/_event/_8746/_editorFiles/file/eridob2018/Abstracts%20Book%20Eridob%202018.pdf

Clough, E. E., & Wood-Robinson, C. (1985). Children's understanding of inheritance. *Journal of Biological Education*, *19*, 304–310. https://doi.org/10.1080/00219266.1985.9654757

Dikmenli, M., Cardak, O., & Kiray, S. A. (2011). Science Student Teachers' Ideas about the 'Gene' Concept. *Procedia - Social and Behavioral Sciences*, *15*(Supplement C), 2609–2613. https://doi.org/10.1016/j.sbspro.2011.04.155

Donovan, Jenny, & Venville, G. (2012). Exploring the influence of the mass media on primary students' conceptual understanding of genetics. *Education 3-13*, *40*, 75–95. https://doi.org/10.1080/03004279.2012.635058

Donovan, Jenny, & Venville, G. (2014). Blood and Bones: The Influence of the Mass Media on Australian Primary School Children's Understandings of Genes and DNA. *Science and Education*, *23*, 325–360. Scopus. https://doi.org/10.1007/s11191-012-9491-3

Dorji, K., Tshering, P., Chettri, R. K., & Dorji, L. (2017). *Conceptual Understanding of Genetic Phenomena by Higher Secondary School Students: A Case of Samtse Dzongkhag*. 21.

Dorji, K., Tshering, P., & Dorji, U. (2017). *Understanding of Genetic Entities: Exploration of Bhutanese Students' Conceptual Status*.

Duncan, R. G., Freidenreich, H. B., Chinn, C. A., & Bausch, A. (2011). Promoting Middle School Students' Understandings of Molecular Genetics. *Research in Science Education, 41*, 147–167. https://doi.org/10.1007/s11165-009-9150-0

Duncan, R. G., & Reiser, B. J. (2007). Reasoning across ontologically distinct levels: Students' understandings of molecular genetics. *Journal of Research in Science Teaching, 44*, 938–959. https://doi.org/10.1002/tea.20186

Duncan, R. G., & Tseng, K. A. (2011). Designing project-based instruction to foster generative and mechanistic understandings in genetics. *Science Education*, *95*, 21–56. https://doi.org/10.1002/sce.20407

El-Hani, C. N., Almeida, A. M. R. de, Bomfim, G. C., Joaquim, L. M., Magalhães, J. C. M., Meyer, L. M. N., Pitombo, M. A., & Santos, V. C. dos. (2014). The Contribution of History and Philosophy to the Problem of Hybrid Views About Genes in Genetics Teaching. In *International Handbook of Research in History, Philosophy and Science Teaching* (pp. 469–520). Springer, Dordrecht. https://doi.org/10.1007/978-94-007-7654-8_16

Forissier, T., & Clément, P. (2003). Teaching 'biological identity' as genome/environment interactions. *Journal of Biological Education*, *37*, 85–90. https://doi.org/10.1080/00219266.2003.9655857

Gericke, N., & Hagberg, M. (2007). Definition of historical models of gene function and their relation to students' understanding of genetics. *Science & Education*, *16*, 849–881. https://doi.org/10.1007/s11191-006-9064-4

Gericke, N., & Hagberg, M. (2010a). Conceptual Incoherence as a Result of the use of Multiple Historical Models in School Textbooks. Research in Science Education, 40, 605–623. https://doi.org/10.1007/s11165-009-9136-y

Gericke, N., & Hagberg, M. (2010b). Conceptual Variation in the Depiction of Gene Function in Upper Secondary School Textbooks. *Science & Education*, *19*, 963–994. https://doi.org/10.1007/s11191-010-9262-y

Gericke, N., Hagberg, M., Santos, V. C. dos, Joaquim, L. M., & El-Hani, C. N. (2014). Conceptual Variation or Incoherence? Textbook Discourse on Genes in Six Countries. *Science & Education*, *23*, 381–416. https://doi.org/10.1007/s11191-012-9499-8

Gericke, N., & Wahlberg, S. (2013). Clusters of concepts in molecular genetics: A study of Swedish upper secondary science students understanding. *Journal of Biological Education*, *47*, 73–83. https://doi.org/10.1080/00219266.2012.716785

Giasemis, I. (2011). *Highschool students' study of knowledge and attitudes in biotechnology and genetics topics* [Doctoral dissertation, University of Patras, Department of Educational Sciences and Early Childhood Education]. http://hdl.handle.net/10442/hedi/31967

Halldén, O. (1988). The evolution of the species: Pupil perspectives and school perspectives. *International Journal of Science Education*, *10*, 541–552. https://doi.org/10.1080/0950069880100507

Haskel-Ittah, M., & Yarden, A. (2017). Toward Bridging the Mechanistic Gap Between Genes and Traits by Emphasizing the Role of Proteins in a Computational Environment. *Science & Education*, *26*, 1143–1160. https://doi.org/10.1007/s11191-017-9927-x

Haskel-Ittah, M., Yarden, A., & Spell, R. (2018). Students' Conception of Genetic Phenomena and Its Effect on Their Ability to Understand the Underlying Mechanism. CBE—Life Sciences Education, 17, ar36. https://doi.org/10.1187/cbe.18-01-0014

Kampourakis, K. (2017). *Making Sense of Genes*. Cambridge, UK: Cambridge University Press.

Kampourakis, K., Silveira, P., & Strasser, B. J. (2016). How Do Preservice Biology Teachers Explain the Origin of Biological Traits?: A Philosophical Analysis. *Science Education*, *100*, 1124–1149. https://doi.org/10.1002/sce.21245

Kementsietzidou, S. (2009). *Knowledge, opinions and attitudes of Middle School students of Western Thessaloniki area, in Genetics and Biotechnology* [Doctoral dissertation, Aristotle University of Thessaloniki]. http://ikee.lib.auth.gr/record/114305

Koers, A. L. (2016, March 1). *Which meaning do students, with knowledge of genetics on upper secondary school biology level, attribute to the concept 'hereditary trait'?* [Master thesis]. http://dspace.library.uu.nl/handle/1874/327903

Koumparou, E., Kyriakoudi, M., & Athanasiou, K. (2011). *Evolution of Greek students' ideas on Genetics and Inheritance. Interactions of Educational Research and Action in Natural Sciences*, 414–421.

LeVaughn, J. (2016). What's in a gene: Undergraduates' ideas and misconceptions about gene function. *Theses and Dissertations--Science, Technology, Engineering, and Mathematics (STEM) Education*. http://dx.doi.org/10.13023/ETD.2016.097

Lewis, J. (2014). From Flavr Savr Tomatoes to Stem Cell Therapy: Young People's Understandings of Gene Technology, 15 Years on. *Science & Education*, *23*, 361–379. https://doi.org/10.1007/s11191-012-9523-z

Lewis, J., & Kattmann, U. (2004). Traits, genes, particles and information: Re-visiting students' understandings of genetics. *International Journal of Science Education*, *26*, 195–206. https://doi.org/10.1080/0950069032000072782

Lewis, J., Leach, J., & Wood-Robinson, C. (2000a). All in the genes? — Young people's understanding of the nature of genes. *Journal of Biological Education*, *34*, 74–79. https://doi.org/10.1080/00219266.2000.9655689

Lewis, J., Leach, J., & Wood-Robinson, C. (2000b). What's in a cell? — Young people's understanding of the genetic relationship between cells, within an individual. *Journal of Biological Education*, *34*, 129–132. https://doi.org/10.1080/00219266.2000.9655702

Lewis, J., & Wood-Robinson, C. (2000). Genes, chromosomes, cell division and inheritance—Do students see any relationship? *International Journal of Science Education*, *22*, 177–195. https://doi.org/10.1080/095006900289949

Marbach-Ad, G. (2001). Attempting to break the code in student comprehension of genetic concepts. *Journal of Biological Education*, *35*, 183–189. https://doi.org/10.1080/00219266.2001.9655775

Marbach-Ad, G., & Stavy, R. (2000). Students' cellular and molecular explanations of genetic phenomena. *Journal of Biological Education*, *34*, 200–205. https://doi.org/10.1080/00219266.2000.9655718

Martins, I., & Ogborn, J. (1997). Metaphorical reasoning about genetics. *International Journal of Science Education*, *19*, 47–63. https://doi.org/10.1080/0950069970190104

Osman, E., BouJaoude, S., & Hamdan, H. (2017). An Investigation of Lebanese G7-12 Students' Misconceptions and Difficulties in Genetics and Their Genetics Literacy. *International Journal of Science and Mathematics Education*, *15*, 1257–1280. https://doi.org/10.1007/s10763-016-9743-9

Saka, A., Cerrah, L., Akdeniz, A. R., & Ayas, A. (2006). A Cross-Age Study of the Understanding of Three Genetic Concepts: How Do They Image the Gene, DNA and Chromosome? *Journal of Science Education and Technology*, *15*, 192–202. https://doi.org/10.1007/s10956-006-9006-6

Santos, V. C. dos, Joaquim, L. M., & El-Hani, C. N. (2012). Hybrid Deterministic Views About Genes in Biology Textbooks: A Key Problem in Genetics Teaching. *Science & Education*, *21*, 543–578. https://doi.org/10.1007/s11191-011-9348-1

Stern, F., & Kampourakis, K. (2017). Teaching for genetics literacy in the post-genomic era. *Studies in Science Education*, *53*, 193–225. https://doi.org/10.1080/03057267.2017.1392731

Thörne, K., Gericke, N., & Hagberg, M. (2013). Linguistic Challenges in Mendelian Genetics: Teachers' Talk in Action. *Science Education*, *97*, 695–722. https://doi.org/10.1002/sce.21075

Tsui, C.-Y., & Treagust, D. (2010). Evaluating secondary students' scientific reasoning in genetics using a two-tier diagnostic instrument. *International Journal of Science Education*, *32*, 1073–1098. Scopus. https://doi.org/10.1080/09500690902951429

Venville, G., Gribble, S., & Donovan, J. (2005). An exploration of young children's understandings of genetics concepts from ontological and epistemological perspectives. *Science Education*, *89*, 614–633. https://doi.org/10.1002/sce.20061

Venville, G., & Treagust, D. (1998). Exploring conceptual change in genetics using a multidimensional interpretive framework. *Journal of Research in Science Teaching*, *35*, 1031–1055. https://doi.org/10.1002/(SICI)1098-2736(199811)35:9<1031::AID-TEA5>3.0.CO;2-E

Wahlberg, S. J., Gericke, N. M., & Wolfson, A. (2018). Conceptual Demography in Upper Secondary Chemistry and Biology Textbooks' Descriptions of Protein Synthesis: A Matter of Context? *CBE—Life Sciences Education*, *17*, ar51. https://doi.org/10.1187/cbe.17-12-0274

Walker, S. O., & Plomin, R. (2005). The Nature–Nurture Question: Teachers' perceptions of how genes and the environment influence educationally relevant behaviour. *Educational Psychology*, *25*, 509–516. https://doi.org/10.1080/01443410500046697

Wood-Robinson, C., Lewis, J., & Leach, J. (2000). Young people's understanding of the nature of genetic information in the cells of an organism. *Journal of Biological Education*, *35*, 29–36. https://doi.org/10.1080/00219266.2000.9655732

THOUGHTS ABOUT QUANTUM PHYSICS EDUCATION – QFT FOR SECONDARY SCHOOL: THE MILAN-ROME APPROACH

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We describe the conceptual frame and the general guidelines of the Milan-Rome approach to develop a consistent learning path about quantum physics involving Quantum Field Theory. Most current educational presentations of quantum physics still propose most of the same difficulties emerged during the early '900 years and construct Quantum Physics "against" classical physics. The latter is often compared to modern physics as a radically different theory (or, maybe, set of theories) and quantum physics is introduced as a "revolution", insisting on its apparently paradoxical aspects. We will discuss this problem, both from the epistemological and the educational point of view and give indications to provide an increasingly solid foundation for the educational reconstructions of quantum physics starting from classical physics, which must be reconsidered in view of the final objective, rather than opposing it to modern physics.

Keywords: Quantum Physics Education, Classical Physics Education, Quantum Field Theory

INTRODUCTION

The importance of quantum physics for the education of the future citizens has been – and still is being - put forward by several educators and associations (Mishina, 2019 and references therein; Am. J. Phys., 2002, March). On the other side, despite the large presence in textbooks of modern physics topics, the didactical quality of most presentations is clearly unsatisfactory (Cavallini & Giliberti, 2008). The results coming from Physics Education Research are sufficiently unambiguous and known for at least twenty years: many students (even graduate and master degree students in physics) show great difficulty in understanding the relevant aspects of quantum physics (Michelini, Santi, Ragazzon & Stefanel, 2008; Giliberti, 2007, Tarsitani, 2008). In fact, often, even secondary school teachers do not have a coherent picture of quantum physics.

The traditional approach to quantum physics is probable responsible of profound misunderstandings and, therefore, it is not sufficient a careful and somewhat coherent teaching to solve the problem, if one remains within the "standard" approach. Many educational difficulties emerge from the lack of awareness of the nature of the theories, which, we propose, are to be identified with their mathematical formalism together with a coherent physical interpretation that sets the rules of correspondence with possible experiments and their interpretation (Cavallini & Giliberti, 2008; Ludwig & Thurler, 2007).

On the contrary, physical concepts are often proposed making reference to a mixture of ideas that are uncritically taken from other areas and from other theories, with the addition of pre-scientific or common sense schemes.

To avoid misleading interpretations, we propose, instead, to conceptually start from the mathematical formalism of the theory and develop the educational path within this disciplinary framework (Giliberti, 2014).

This assumption, does in no way mean that the proposed secondary school path should be axiomatic and top-down; on the contrary, starting from some crucial experimental results, one have to induce the basic principle of the theory, that are to be understood in their mathematical and physical meaning and used to describe important real-world properties.

THE CHOICE OF QUANTUM FIELD THEORY

The expression "quantum physics" hides very different ideas and comprises various theories and visions. The old Quantum Mechanics (QM), developed between 1900 and 1925, has to do with experimental facts and their interpretation like the black body radiation, photoelectric effect and atomic spectra. It can be regarded as a set of phenomenological models sharing the same idea of the existence of quanta.

One can start talking of real quantum theories with the advent of the formalism by Heisenberg, Jordan, Bohr, Schrodinger and Dirac. The resulting theory is non relativistic and describes the behavior of a finite (usually small) number of interacting particles. Most of its results have no direct physical meaning, in the sense that the physical systems for which one can find a solution are often very crude approximations of real ones.

Quantum Field Theory (QFT), instead, is a relativistic theory that works sufficiently well at both low and high energy and, in fact, is able to derive exact predictions for the observable in real systems. As a matter of fact, QFT is the most precise and validated theory in physics, being tested over many orders of magnitude in energy regimes and to precision degrees that are indeed unconceivable for classical physics. The idea that classical physics is more "understandable" might then be contradicted by the facts (Organtini, 2017).

The most successful theories nowadays are QFT. Quantum Electrodynamics is a QFT in which matter and fields are very well defined. The Standard model of electroweak interactions and Quantum Chromodynamics are QFT, as well.

Most of the physics around us is governed by the interaction between charged particles. Quantum electrodynamics thus becomes the reference theory, indispensable for treating the electromagnetic field; furthermore it is even the conceptual basis of the Standard Model.

Its "ontology" is indeed simpler than that of the old QM, hence it is the best candidate for an introduction to QM.

THE MILAN-ROME APPROACH

The Milan-Rome approach is then twofold: it consists of a research to introduce, in a consistent and rigorous, though simplified, way a theory of quantum fields, as well as a review of the classical physics concepts needed to allows the introduction of quantum physics as a "natural" evolution of classical physics.

It is worth noting that this is not the first occasion in which an apparently more complex theory replaces an apparently more intuitive one. It happened with Newtonian physics, for example. The current way of teaching it has nothing to do with its original formulation. The latter was mostly based on geometrical entities, while the current approach adopts the vision of Euler who was the first to introduce the concept of vectors to describe motion as well as in introducing the physics laws in terms of equations.

Also, the current way of introducing electromagnetism has almost nothing to do with what was this theory in the Maxwell's Treatise. The current formulation must be ascribed to Heaviside that made electromagnetism much simpler to learn, even if nowadays we are looking for a revival of the physical aspects of the potentials, somewhat hidden in Heaviside formulation.

There is no reason, then, to continue to insist in introducing a vision of QM that has been surpassed. Using old concepts like the wave function, as a matter of fact, is just a way to simplify certain calculations in selected systems, for which a QFT approach would be harder. We propose not to start from those old concepts to develop a theory whose objects are the fields, the states and the operators that must be consistently introduced. We believe that QM have to be seen, described and used as the limit of QFT when the number of particles is fixed and relativity can be neglected.

Of course that does not mean to completely forget the historical aspects of the development of the theory that, however, must be treated as such (as it often happens in classical physics).

Using those concepts we can talk of scattering processes, evolution of a state and probability of obtaining a result in a measurement. Most importantly, we can introduce Feynman Diagrams as a well known and effective way of understating the interactions between particles and fields. In many textbooks Feynman diagrams are already introduced, but just as a pictorial description of a process that does not imply any physical interpretation. In our approach, Feynman diagrams can be introduced as what they really are: a computational tool. In fact, though we cannot pretend to teach how to calculate the amplitude of a process using this technique, it is very possible to compute ratios of probability of processes illustrating just few very basic properties of the diagrams (Organtini, 2011).

The choice of QFT helps in avoiding misunderstandings and words that are used by the theories, but come from preceding conceptions (pre-theories, or even common sense) rooted in the biased idea that, as we have already noticed, physics reality can be identified even out of a formal theory (Giliberti, 2014). In QFT locality is easier, particles are seen as excitations and superposition of states is very natural.

As said, in order to successfully introduce QFT we have to rethink key concepts of Classical Physics. To that purpose, we need to start and redesign some paths in order to explicitly include some fundamental concepts.

We have to clearly introduce the concept of state (for a point like particle, a gas, a thermodynamic system, a circuit, etc.). Interference must be anticipated and the idea of evolution from an initial state to a final state must be stressed. Physics laws must be seen as something that allows to predict the final state of a system given the external conditions, represented by the action of operators. In classical physics evolution operators are often represented as algebraic equations, however one can have alternative representations (e.g., the state of a gas can be represented as a point in the Clapeyron plane, and transformations can be represented as a curve). The concept of force must be reviewed and rapidly turned into the general concept of interaction. Just as the interaction of a heat source with a gas can change the state of the gas (and of the source), similarly the interaction of a mass with a gravitational field can vary the state of the mass (and of the field). It is useful to stress the importance of the concept of measurement and the relational status of properties attributed to objects to define their state. Of course the concept of field is of capital importance (starting form mechanics: pressure fields, potential fields, temperature fields, velocity fields…).

Particular attention should be given also to oscillations, harmonic motions and normal modes (that are at the basis of the quantization process in QFT) already in classical physics.

Some "ancillary" physics must be promoted to fundamental: in particular, we must review optics as a process in which the scattering is the fundamental process occurring. Last, but not least, probability and statistical physics are be introduced (even by including some numerical computations). Moreover, some important classical concepts, like those of the magnetic vector potential (Barbieri & Giliberti, 2015; Barbieri, Giliberti & Cavinato, 2014; Barbieri, Giliberti & Fazio, 2014; Barbieri, Cavinato & Giliberti, 2013), often neglected as "non physical", have to be discussed and introduced in order to better understand electromagnetism (especially the phenomenon of induction) (M. Giliberti, E. Giliberti & Cavinato, 2019), to allow a clear introduction of the electromagnetic quanta and to be able to explain some important "applications" of the quantum theory, such as superconductivity (Barbieri & Giliberti, 2012; Giliberti, Perotti & Rossi, 2018; Barbieri, Giliberti & Fazio, 2012).

CONCLUSIONS

In order to avoid misleading interpretations of quantum concepts coming when they are mixed to classical concepts in common sense patterns, in quantum physics teaching, we propose to strictly adhere to its mathematical formalism and develop the educational path within this disciplinary framework.

To that purpose, the didactic reconstruction of the contents has to make precise references to the theory and has to be able to address the most common, already known concepts of Newtonian Mechanics such that it can be recovered ad a limit case of the new theory. We believe that a rethinking of this kind is particularly useful for the teaching of quantum physics, both for its intrinsic potentiality, and because it can help also clarify many aspects related to key concepts of classical physics, highlighting non trivial connections and interpretations.

Our current comprehension of the physical world is given though QFT; in fact, QFT makes it relatively easy to introduce fundamental interactions, in a way that is by far much more quantitative and rich than is typically done (e.g. Feynman diagrams are often presented as a picture of what really happens at microscopic level, though in a completely qualitative form) (Organtini, 2011). QFT can also shed new light on concepts, like the concept of energy that, as we all know, are very difficult to understand. One of us, in fact, exploited this feature in providing a non metaphoric explanation of the Higgs mechanism that is suitable to be presented to high school students (Organtini, 2016).

In summary, we propose to face the difficult task of teaching quantum physics starting from the ideas and concepts rooted in QFT and to construct an educational reconstruction of some key aspects of classical physics precisely starting from them. A first basic list of concepts involved in QFT teaching are: field, state, creation and destruction operators, waves, scattering, evolution and probability. These are, therefore, in the proposed Milan-Rome approach, the concepts that should give us the guide-lines to lead to a simultaneous reconstruction of classical and quantum physics for educational purposes.

REFERENCES

Am. J. Phys. 2002 70 3, March

Barbieri, S. R. & Giliberti, M. A. L. (2012). Laboratorio aperto: superconduttività. ISBN:97888-8132-660-0.

Barbieri, S., Giliberti, M. & Fazio, C. (2012). Conduction as a prerequisite for superconductivity. In *Physics alive proceedings: GIREP-EPEC Conference 2011*, 161-166, Jyväskylä, Finland - ISBN:978-951-39-4801-6.

Barbieri, S., Cavinato, M. & Giliberti, M. (2013). An educational path for the magnetic vector potential and its physical implications, *Eur. J. Phys. 34 (5),* 1209-1219. doi:10.1088/0143-0807/34/5/1209 - ISSN:0143-0807.

Barbieri S., Giliberti, M. & Cavinato, M. (2014). Magnetic vector potential in secondary school: a teachers' path. In *ICPE-EPEC 2013 The International Conference on Physics Education Active learning – in a changing world of new technologies.* 2013 Prague, Czech Republic Conference Proceedings, 417-423. - ISBN:978-80-7378-266-5.

Barbieri S., Giliberti, M. & Fazio, C. (2014). The explicative power of the vector potential for superconductivity: a path for high school. In *ICPE-EPEC 2013 The International Conference on Physics Education Active learning – in a changing world of new technologies.* 2013 Prague, Czech Republic Conference Proceedings, 279-286. - ISBN:978-80-7378-266-5.

Barbieri, S. R. & Giliberti, M. (2015). High School Students Face the Magnetic Vector Potential: some Relapses in their Learning and Tips for Teachers Dealing with Electromagnetism. In *Teaching/Learning Physics: Integrating Research into Practice*, 165-174. ISBN:978-88-907460-7-9.

Cavallini, G. & Giliberti, M. (2008). La lezione della fisica quantistica. *Epistemologia, 31 (2)*, 219-239 - ISSN:0392-9760.

Giliberti, M. (2007). Elementi per una didattica della Fisica Quantistica. CUSL Milano.

Giliberti, M. (2008). Campi e particelle: introduzione all'insegnamento della fisica quantistica. In *Approcci e proposte per l'insegnamento-apprendimento della fisica a livello preuniversitario*, edited by P. Guidoni and O. Levrini, FORUM, Udine.

Giliberti M. (2014), Theories as crucial aspects in quantum physics education, in: B. Sidharth, M. Michelini, L. Santi (Eds), *Frontiers of fundamental physics and physics education research*, Springer Proceedings in Physics 145, 497-503. doi:10.1007/978-3-319-00297-2_51 - ISBN:9783319002965, 9783319002972 - ISSN:0930-8989.

Giliberti, M., Perotti, L. & Rossi, L. (2018). Motion of a superconducting loop in an inhomogeneous magnetic field: A didactic experiment. *Eur. J. Phys. 39 (5)* 055503 (11pp). doi:10.1088/1361-6404/aad168 - ISSN:0143-0807.

Giliberti, M., Giliberti, E. & Cavinato, M. (2019) A case study about the comprehension of electromagnetic induction in Northern Italy. *J. Phys.: Conf. Ser. 1287 0126*.

Ludwig, G. & Thurler, G. (2007). *A new foundation of physical theories*. Springer-Verlag, Heidelberg.

Michelini, M., Santi, L., Ragazzon, R. & Stefanel, A. (2008). La meccanica quantistica nella scuola superiore per costruire il pensiero teorico. In *Approcci e proposte per l'insegnamento-apprendimento della fisica a livello preuniversitario*, edited by P. Guidoni and O. Levrini, FORUM, Udine.

Mishina, O., Sherson, J., Losert-Valiente Kroon, C. M., Brand, C., Müller, R., van Joolingen ,W., Peeters, W., Macchiavello, C. & Wilhelm-Mauch, F. (2019). Strategic Agenda Summary: Education for QT. https://qt.eu/app/uploads/2019/03/Strategic-Agenda-Summary-Education-for-QT_19.03.19.pdf

Organtini, G. (2011). Matter and Interactions: a particle physics perspective. *Phys. Educ. 46* 544.

Organtini, G. (2016). The Higgs mechanism for undergraduate students. *Nuclear and Particle Physics Proceedings* 273–275 (2016) 2572–2574.

Organtini, G. (2017). Towards a demystification of quantum mechanics, PoS EPS-HEP2017, 830. doi: 10.22323/1.314.0830.

Tarsitani, C. (2008). Le linee essenziali di un approccio alla fisica quantistica: problemi didattici e concettuali. In *Approcci e proposte per l'insegnamento-apprendimento della fisica a livello preuniversitario*, edited by P. Guidoni and O. Levrini, FORUM, Udine.

CROSSING DISCIPLINARY KNOWLEDGE BOUNDARIES AND BRIDGING THE GAP BETWEEN SCIENCE EDUCATION RESEARCH, EDUCATIONAL PRACTICES, SOCIETY AND CITIZENS: INQUIRY BASED LEARNING AND RESPONSIBLE RESEARCH AND INNOVATION

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It is widely acknowledged today that an Inquiry-Based approach to Research and Innovation processes can improve the interest of students in studying scientific topics. Such approaches can enable students to have the opportunity to interact with cutting edge topics, research results and work with researchers and other societal actors to better align research processes and their outcomes with the values, needs and expectations of today's society. However, there is still no clear consensus between researchers about the impact that inquiry-based approaches have on the student scientific knowledge and conceptual understanding at different ages and cultural levels. This paper discusses these aspects from a vertical and interdisciplinary curriculum perspective. Firstly, the impact of a series of inquiry-based learning activities on the acquisition of scientific knowledge and in the development of pupils' positive attitudes toward science in pupils aged 10–13 is discussed. Secondly, a discussion on important pre-conditions needed for an introduction of cutting-edge topics to the classroom, and the role of the inquiry that has to be offered to students to effectively construct knowledge is considered at the pre-university level. Following this, an approach adopted by three large scale European projects (ESTABLISH, SAILS and OSOS) that focus on enhancing science education curricula, pedagogy and assessment practices and supporting science educators in embedding Inquiry-Based Education or Responsible Research and Innovation principles in science education is presented. Finally, an innovative Doctoral Degree in Sustainability Science, which seeks transformative education that challenges the attitudes of both professors and students is presented and some of its most relevant aspects are discussed.

Keywords: inquiry-based learning; responsible research and innovation; responsible citizenship.

INTRODUCTION

Inquiry-Based Science Education (IBSE) strategies have received considerable attention over the last several years and are often presented in the scientific literature (Hake, 1998; Sharma et al., 2010) as a credible solution to the reported lack of efficacy of more 'traditional' educative approaches. Inquiry-based learning strategies are credited to improve student understanding in many conceptual fields, due to their strongly contextualized nature, that focuses on the interdependence of situation and cognition. Many research project reports (e.g. IRRESISTIBLE, 2013; Ark of Inquiry, 2013) have also shown that an Inquiry-Based approach to Research and Innovation (RRI) processes (Sutcliffe, 2006) can improve the quality of student interest in scientific subjects, as students can be actively involved in studying cutting edge topics and research results and possibly in working together with researchers and other societal actors to better align both the research processes and their outcomes with the values, needs and expectations of today's society. Moreover, the EU Framework for Science Education for Responsible Citizenship calls on science educators to embed social, economic and ethical principles along with inquiry approaches into their science teaching and learning, at all levels, in order to prepare students for active citizenship.

However, some still remain skeptical about IBSE and RRI real efficacy. Although intensive research on effectiveness of inquiry-based teaching and learning has been carried out since 1980, there is still no wide consensus between researchers about the specific impact that using inquiry approaches on the increase of scientific knowledge and conceptual understanding. Also, more evidence is needed about how best to support in-service and pre-service teachers in embedding IBSE or RRI principles in science classroom, and to enhance science education curricula, pedagogy and assessment practices.

In this paper, we discuss these aspects from a vertical and interdisciplinary perspective in science education, discussing four different research studies. First, the impact of a series of inquiry-based learning activities on the acquisition of scientific knowledge and in the development of pupils' positive attitudes toward science in pupils aged 10–13 is discussed. Special attention is paid in this first study to medium-term retention of learning outcomes through inquiry. Three basic skills typical of IBSE are specifically targeted in this study: putting forward hypothesis, planning investigation and drawing conclusions. Then, a discussion on important pre-conditions and necessary steps needed for an introduction of cutting edge topics and new research findings to the classroom, and the role of the inquiry that has to be offered to students to effectively construct knowledge is done, together with some considerations on opportunities and challenges new findings in science bring to the science education at the pre-university level. Following this, an approach adopted by three large scale European projects (ESTABLISH, SAILS and OSOS) that focus on enhancing science education curricula, pedagogy and assessment practices and supporting science educators in embedding IBSE or Responsible Research and Innovation (RRI) principles in science education is presented. Particularly, the opportunities and challenges for integrating IBSE and RRI principles in science education are discussed using examples of classroom practices designed and implemented in these three projects. Finally, an innovative Doctoral Degree in Sustainability Science, which seeks transformative education that challenges the attitudes of both professors and students is presented. Main drivers include building a new body of interdisciplinary knowledge leading to the application of science to address real problems, and the integration of knowledge and innovation with the participation of society and citizens. Issues related to the involvement of students in a project work based on an inquiry perspective, and dealing with different dimensions are discussed, also in the aim to understand if this methodological approach is perceived by students as important to their learning as professionals and citizens.

RETENTION OF LEARNING THROUGH INQUIRY IN PUPILS AGED 10–13

Inquiry-based learning (IBL) occurs in repeated cycles of scientific investigation, and may be developed at different levels, related to different degrees of learner's dependence on teacher instruction, (e.g. Colburn 2000).Teaching through inquiry has been disseminated in science education for decades, yet the implementation of the method is not common in schools. Among many obstacles, teachers point out their concern about students' learning outcomes as measured by standard tests (Tan and Caleon 2016). Thus, ensuring the acquirement of basic knowledge through IBL seems to be one of the most important aspects determining the success of IBL implementation in a schooling system (Miner et al. 2009).
Although intensive research on effectiveness of teaching and learning through inquiry has been carried out since 1980s, there is still no consensus between researchers about the impact of teaching through inquiry on the increase of scientific knowledge, i.e. scientific investigation skills and content knowledge. Nevertheless, studies seem to confirm repeatedly that the effectiveness of learning through inquiry decreases with age (Hattie 2008). Also, quite common across different studies is the inference that IBL can be more effective than other instructional approaches provided that learners are supported and guided adequately (Lazonder and Harmsen 2016).
It is quite astonishing that rich spectrum of papers about research on impact of the inquiry-based approach on learning outcomes encompasses only a few studies in a medium and long term (e.g. Metz 2008), interesting and significant to teachers considering inclusion of IBL method in their teaching practice. Thus, to address this issue we proposed a 10-hour IBL implementation in ten classes of learners aged 10-13 during their science lessons and designed a research on retention of learning outcomes in a medium term (Sokolowska 2018).

Research method

The aim of the intervention was to implement a series of guided-inquiry activities and to investigate the effects of implementation on students' learning outcomes. Two rural and two urban schools were selected in a convenient neighborhood on the basis of they rank in official school ranking. Implementation of inquiry took place in all classes at the same time over 5-7 weeks. The IBL intervention involved altogether 170 students from ten classes. It was the first contact of learners with the method of teaching through inquiry. Each class was provided with ten lessons of guided inquiry, in which the teacher posed a problem to investigate and provided resources, and students planned investigation, conducted experiments, collected the data and drew research-based conclusions at the end.

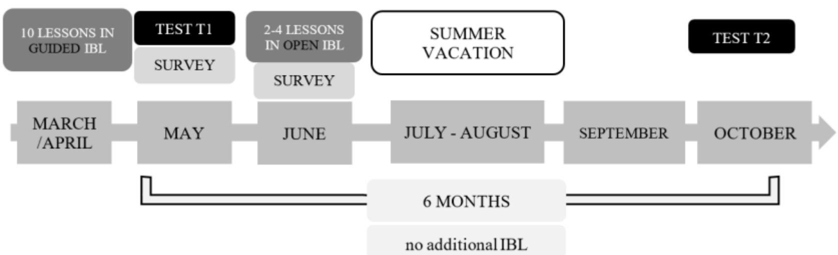

Figure 1. Research design schema for an investigation of the medium-term retention of learning outcomes acquired through guided IBL

The core instrument implemented in order to enable the measurement of learners' acquisition and retention of knowledge through guided-inquiry was the test T1 administered in April 2015, just after completing the series of the guided-inquiry lessons, and repeated as test T2 six months later (for research design schema, see Fig. 1). Three different tests were designed with respect to students' grade, all of them encompassed: multiple choice and open-ended questions, tasks involving reasoning and scientific inference, tasks requiring explanation of phenomena or observation, as well as one task of designing the experiment (consisting of putting forward the hypothesis, choosing adequate materials and tools, planning the investigation and drawing conclusions).

Results

In order to describe the change of an individual's learning gain in a medium term (6 months) we calculated the normalized change factor, c (Marx and Cummings, 2007). Mann-Whitney test (double-tailed) indicated no statistical significant difference in normalized change between boys ($c_{Mdn} = -0.079$) and girls ($c_{Mdn} = -0.086$) at the level of $p < 0.05$ (Sokolowska 2018). ANNOVA Kruskal-Wallis one-way analysis of variance by ranks, revealed no statistically significant difference of a normalized change across three ability groups, defined as: Level 1 (L1) – students with average scores below 70%, Level 2 (L2) – students with average scores of 70–80% and Level 3 (L3) – students achieving average scores above 80% in their regular science classes (Sokolowska 2018).
While studying solely the retention of three basic research skills: putting forward hypothesis, planning investigation and drawing conclusions, we found the two latter similarly difficult for learners, and the drop of planning skills as the only statistically significant change among these three research skills over the period of 6 months. Poor development of planning skills was confirmed by class observations and examination of students' worksheets, as well as answers given by students in Survey 1 and Survey 2.

INTRODUCTION OF NEW FINDINGS IN SCIENCE TO PRE-UNIVERSITY EDUCATION USING INQUIRY BASED LEARNING

Pre-university science is often considered as old and boring (Osborne, 2003), however scientists, pursuing new findings in laboratories and behind computers, have a diametrically opposite opinion. Physics, for example, is a vivid science with interesting challenges, full of surprises and beauty. Why such a difference in opinion? Several reasons were discussed, from a general public opinion that physics is very difficult and only very smart, but usually strange people, can understand it, to the modes of teaching focused on abstract calculations irrelevant for everyday life, and the rigid curricula that consider only topics more than hundred years old, an eternity from the standpoint of students.
Introduction of contemporary science to the pre-university classroom is very rare as we only found two examples beside ours (Garcia-Carmona, 2009; Pavlin 2013; Mandrikas, 2019). Nevertheless, we believe that front-end science can be, and has to be, introduced to students at the pre-university level, and its relevance for technology we meet every day has to be demonstrated. As new findings in science often consider phenomena not included to regular curriculum, the experimental inquiry type support providing preliminary experience through inquiry-based learning, is crucial.

New scientific Findings in pre-university education

Students nevertheless acquire some information on new findings through informal channels. But how extensive is this information? Around 400 students enroll to pre-service teacher studies at the Faculty of Education, University of Ljubljana, which include the pre- and primary school teachers' programs, art and STEM subjects trainings, and social and special education programs. Students come from groups with very different social status, abilities, personal motivations and interests and form a good representative sample for the population of students absolved the high school in general. To investigate the existing information on new findings, we chose five science topics: liquid crystals, hydrogels, biodiesel, gels and osmosis, and microwaves in anisotropic materials. The first-year students filled-in questionnaires which included a set of short questions on those topics allowing identification of the level of familiarity and knowledge related to them. Here we present more detailed analysis on two issues: familiarity with the name of the topic, and a self-assessed level of knowledge about it. The familiarity with the name was investigated by the yes/no question: Have you already heard about liquid crystals/hydrogels/...? Self-assessed knowledge offered more options for answering the question: How much do you know about liquid crystals/hydrogels/...? nothing/ very little/little/some. Results are given in Table 1 where we collected answers little and some to one category. Not surprising, the results evidently show that familiarity with the topics ends with the recognition of names, however the familiarity with the name provides the context.

Table 1. Self-assessed knowledge about contemporary topics. The questionnaire was filled in by N=257 first year students, age between 19 and 20. *The data for liquid crystals comes from a preliminary study with different participants (Pavlin, 2010).

Topic	I am familiar with the name [%]	I know little/some about the topic [%]
Liquid crystals*	33.0	5.2
Hydrogels	18.7	2.3
Microwaves	75.1	6.6
Polarization of light	55.6	6.6
Biofuels	88.4	11.6
Osmosis	90.9	24.9
Diffusion	90.9	23.2

Experiments in teaching units

To effectively introduce new findings in science to the pre-university education, a strong collaboration of active researchers, educators and teachers is needed. The researcher is the source of knowledge about a new topic, the educator finds appropriate places in the curriculum, analyses the role of the topic, together with the researcher adapts the topic to the cognitive level of students. Both also develop experiments to provide experience to students. The in-service teacher acts as a critical friend, who introduces the reality of the classroom to the team, and provides the "in-vivo" testing of newly developed units.

The experimental support for introduction of new findings is crucial. Very often, scientists that are invited to events aiming to popularization of science, prepare lectures, with a lot of nice photos and stories about discoveries, but the load of new information and the pace of the lecture does not allow a non-expert to develop an understanding. To avoid this, students have to experiment in person, in an inquiry way, which allows them to construct the new knowledge during the process. As an introduction of a new phenomenon usually meets an absence of preliminary knowledge, the inquiry provides the experience related to the unfamiliar topic. Although it is widely believed that laboratory equipment to teach new findings is not accessible to school, simplified qualitative experiments can be developed. Fig. 2 presents a few such experiments students meet during introduction of two topics: hydrogels and liquid crystals.

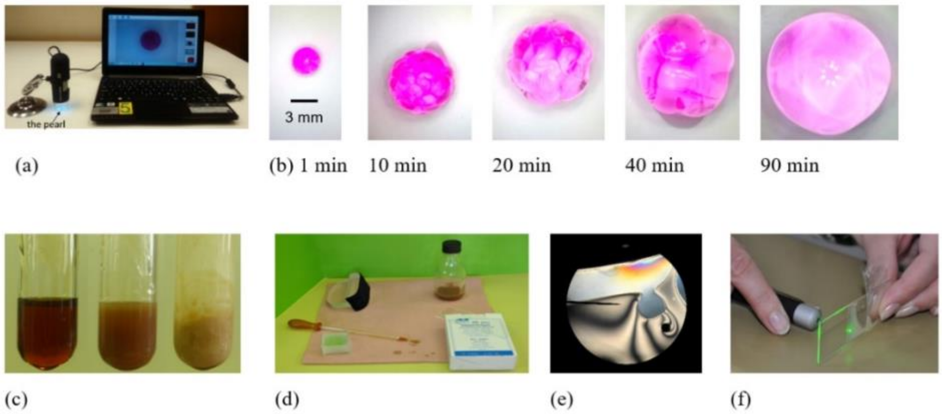

Figure 2. The growth of a hydrogel pearl observed under USB microscope. (a) The simple setup which allows for observation of hydrogel growth. (b) The shape of the surface changes drastically in time stimulating discussion and testing on possible reasons for the behaviour. (c) Three phases of a liquid crystal. (d) Equipment for making a cell for observation of liquid crystals (e) and propagation of light through them (f).

CHALLENGES AND OPPORTUNITIES FOR RETHINKING INQUIRY BASED SCIENCE EDUCATION

UNESCO's recent report "Rethinking Education: Towards a common global goal?" (UNESCO, 2018) reminds us that the changes that we face in the world today are characterized by new levels of complexity and contradiction. Today's citizens need a deeper understanding of global societal challenges and their implications for themselves, their families and their communities. This requires a broader vision of an active, engaged and responsible citizenship for the 21st century (Hazelkorn et al., 2015) and recommends that *"Science educators, at all levels, have a responsibility to embed social, economic and ethical principles into their teaching and learning in order to prepare students for active citizenship"* (Hazelkorn et al., 2015 p.35). In particular, this report advocates that "*education policies and systems should support schools, teachers, teacher educators and students of all ages to adopt an inquiry approach to science education as part of the core framework of science education for all*" (Hazelkorn et al., 2015 p.29). These objectives are further highlighted in the OECD Education 2030 framework which aims to build a common understanding of the knowledge, skills, attitudes and values necessary to shape the future towards 2030 (OECD, 2018). These reports highlight that in order to equip today's learners with agency and a sense of purpose, and the competencies they need, to shape their own lives and contribute to the lives of others requires changes to be made in science education curricula, pedagogy and assessment practices in the classroom. Over the past decade, several large-scale projects have focused on addressing these challenges and have supported teachers in adopting the principles of Inquiry-Based Science Education (IBSE) (Bevins and Price, 2016) and Responsible Research and Innovation (RRI) (Sutcliffe, 2006) in their classroom practices.

Methods

This research examines how IBSE and RRI are conceptualized and implemented across a diverse range of educational and cultural contexts under three large-scale European projects namely, ESTABLISH (2010), SAILS (2014) and OSOS (2017). The ESTABLISH (2010) and SAILS (2014) projects adopted an understanding of inquiry as the intentional process of

"diagnosing problems, critiquing experiments, and distinguishing alternatives, planning investigations, researching conjectures, searching for information, constructing models, debating with peers, and forming coherent arguments" (Linn, Davis & Bell, 2004). ESTABLISH (2010) designed a pedagogical framework for the development of IBSE units that were used to support teacher's use of inquiry based approaches in the second level science classroom. Each IBSE unit was presented over six parts: (1) Science topic; (2) IBSE character; (3) Pedagogical Content Knowledge; (4) Industrial Content Knowledge; (5) Learning Path(s) and (6) Student Learning Activities. A total of 18 IBSE units (with 281 learning activities) were developed across Physics, Chemistry, Biology and Integrated Science topics. SAILS (2014) presented a Framework for Inquiry and Assessment that addressed two key questions in science education: what to assess and how to assess? SAILS (2014) developed 19 Inquiry and Assessment Units that exemplified a range of strategies and tools to assess science inquiry skills. The SAILS units also included 93 case studies of service science teacher experiences of assessing inquiry learning in the science classroom. OSOS (2017) designed a framework that supported schools in embedding RRI principles and adopting an Open School Model to embed strategies that link education content to wider societal goals and engage learners to become responsible citizens. The Open School model supported student development of innovative and creative projects through a Feel, Imagine, Create and Share methodology (OSOS, 2017).
The research questions were: (1) How are IBSE and RRI (social, economic and ethical) principles conceptualized in science education and (2) What is the impact on teachers of using IBSE and RRI principles in the classroom? Data was collected from participating teachers in all three projects using questionnaires that had a combination of Likert scale and open response questions that were using at the start and end of the professional development programmes for science teachers.

Results

Analysis of science teacher's responses to questionnaires prior to participation in professional development programmes, revealed that teachers use of inquiry practices was low and some of the obstacles to their use of inquiry was "uncertainty of how to ask higher order questions that promotes thinking", "managing a classroom where each student group is doing different activities is difficult" and "feeling uncomfortable with teaching areas of science that I have limited knowledge of and of asking questions that I do not know the answer to" (N=458) (ESTABLISH, 2010). In general, the teachers that participated in the teacher education programmes of the ESTABLISH (N=2090) and SAILS (N=2500) projects, indicated increased understanding, attitudes and confidence of utilizing inquiry approaches. In addition, the SAILS approach strengthened teacher's assessment practices through developing their understanding of the role of assessment (SAILS, 2014). The SAILS approach exemplified how assessment practices can be embedded into inquiry lessons and illustrated a wide variety of assessment opportunities and /or assessment processes that are available to science teachers. Data from teachers that participated in OSOS project demonstrated how adopting RRI principles in science education promoted the development of strategies that link student learning (including knowledge, skills, attitudes and values) to wider societal goals and engaged learners in becoming responsible citizens (OSOS, 2017).

INQUIRY IN HIGHER EDUCATION: AN EXAMPLE OF CROSSING DISCIPLINARY KNOWLEDGE BOUNDARIES

The challenges which society faces are complex and multidimensional, leading to new paradigms associated with sustainability. To be promoters of change, the 21st century professionals must be endowed with solid scientific knowledge and, most importantly, must

hold the capacity to incorporate it in order to understand the interactions between global, natural, social and human systems, and how such interactions affect the sustainability contexts (UNESCO, 2015).
Societal challenges are complex and usually correspond to open questions that do not have neither a single answer nor unique explanations. In the search for a solution to socio-scientific problems, individuals are led to mobilize dialogical discourses, of a deliberative nature, in which they have to reason, criticize and justify, that is, they have to argue with the use of evidence. Hence, addressing sustainability clearly demands scientific literacy (understood in a comprehensive view of culture) to enable citizens to take and act in the defense of certain positions, in an informed and well-founded way (Bencze & Alsop, 2014; European Commission, 2015).
Building a new scientific area of Sustainability Science requires assimilation of knowledge and mastery of tools that are seldom addressed by individual disciplines and scientific areas with an integrated approach. Today, disciplinary science deeply contributes to understand the function of the various pieces that make up our world but has gaps in understanding how these parts relate to each other (Pellegrino & Hilton, 2012).
The required change to reach sustainability needs a responsive pedagogical model that is also attentive to the transition to new forms of skill acquisition and knowledge-building. The Doctoral Degree in Sustainability Science addresses this challenge by offering an innovative program which seeks transformative education that challenges the attitudes of both professors and students, combining a multidisciplinary composition of its Faculty members, gathering a wide range of disciplinary knowledge committed with a shared responsibility between natural sciences and social sciences in the coordination, organization and teaching of each curricular unit and in thesis supervision. This is a collaborative experience that relies on sharing all the class materials and establishing a bidirectional permanent work channel between students and professors through an ITC e-learning platform. Taking as an example the organization of four multidisciplinary thematic curricular units, we created an inquiry scenario, using a local multidimensional context, and the students, working in groups, should contribute to solve real and contemporary problems. Curricular units were paired according to common underlying themes to cope with a same starting point, so the results here presented relate to two project work problems. Contributing to take urgent action to mitigate climate change and its impacts framed the question addressed under the scope of the first pair of curricular units. Organizations should be aware of the implications of reducing their greenhouse gas emissions and in a scenario of need to reduce emissions by 2/3 of today's levels, students were challenged to work on a multilevel explanation model for the problem and to present a critical proposal for an adaptation program for the primary sector in the specific ecosystem of the Tagus "Lezírias". The problem addressed collectively while working the second pair of curricular units was to devise a city-wide planning model for the scenario of an inter-municipality agreement in the Lisbon metropolitan region that determines supplying public organism cafeterias with at least 60% of products with proximity origin.

Methods

This research intends to understand if the PhD students involved in a project work, based on an inquiry perspective, dealing with different dimensions, offers contribution to solve a problem on sustainability; and also to understand if this methodological approach is perceived as important to their learning as professionals and citizens. We worked with 14 doctoral students with different academic backgrounds that are simultaneously working as consultants, experts in environmental institutions, or on their own businesses. These students were organized in five groups, each one responsible for researching two specific dimensions per work, which are part of the real problem to be solved. The dimensions involved were: a) Technologies and innovation; b) Economics, management and marketing; c) Social practices; d) Policies, institutions and governance; e) Human and environmental health. Ethics and values dimension was transversally addressed.

The research questions were: 1) To understand the potentialities and advantages of following project work, based on an inquiry perspective, in trying to solve a real and multidisciplinary problem; 2) To understand the difficulties experienced by students with this type of methodology; 3) To understand the students' opinion concerning the potentialities and advantages or the drawbacks of project work methodology to their professional and personal development; and 4) To understand the perceived trade-offs of working a limited number of dimensions and therefore relying on the colleagues' complementary work to reach the wider perspective that contributes to a result.

Data were collected by direct observation of the working sessions, a questionnaire applied to the students at the end of the units, and individual reflections. Additionally, the evaluation of the final work of the groups was based on several rubrics created for the assessment of the oral presentation and written work. These rubrics were discussed with students and teachers from the beginning of the course.

Results

The Sustainability Science Doctoral Course was designed to progress stepwise in two main phases. In the first phase, curricular unit syllabus and teaching are multidisciplinary although an environment that prompts interdisciplinary thinking among students is promoted. During the course preparation, all professors were very enthusiastic in developing the curricular units using collective and participatory rounds of debate with colleagues with distinct academic backgrounds, ranging from natural/exact sciences to humanities/social sciences, which resulted in final syllabus that can hardly be connected with a specific disciplinary knowledge domain. Equally, during the first edition, all professors were fully engaged with the pedagogical model assumed and were active on preparing extended summaries and selected core materials to frame their topics, and producing dedicated e-learning materials, including professional video recording of short lessons. All materials were made available in the ICT e-learning platform to which students were granted access one week before the corresponding session. Field visits related to project work problems were organized and were successful in joining a multidisciplinary group of professors. Most importantly, "in class" sessions took always place with the simultaneous participation of, at least, three professors with distinct knowledge backgrounds and academic competencies, resulting in debates that successfully challenged concept and methodological confrontations. Evaluation of project works through a methodology rooted in individual evaluation by professors from distinct disciplinary areas followed by discussions to reach consensus grades showed great potential to pave the way for their interdisciplinary thinking.

DISCUSSION

The implementation of IBL method in science classes of 10-13 year old learners discussed in the first research we present here resulted in achievement of learning outcomes similar to the learners' prior accomplishments with use of standard teaching approaches. Examination of scores achieved in test T1 revealed that guided IBL approach did not favor any gender. The method also retained the students' belonging to the ability groups: L1, L2, L3. At the same time medium-term retention of learning achievement, studied as comparison of scores in test T1 and T2, with use of a normalized change revealed high retention of learning over the span

of six months after the guided-inquiry intervention and showed no statistically significant difference between genders and between different ability groups thus confirming effectiveness of IBL approach and its sustainability for learning outcomes. Observation of students during IBL implementation and examination of their worksheets revealed their extreme difficulties in designing a plan of investigation, subsequently confirmed also by the results in T1 and T2. Instead of writing a strict plan, students rather applied a trial-and-error approach when conducting the experiments. Thus, we conclude that at age 10-13 it is unnatural to learners to stop in the middle of inquiry process and write a rigorous plan before conducting an experiment. In order to secure development of planning skills and at the same time – to preserve learners' active involvement in inquiry approach, it would be more adequate and efficient to let them do investigation first and ask them to design a coherent investigation plan afterwards.
In the second research here described, we showed how a coherent investigation plan on innovative topics, including also "Modern Physics", at pre-university level can be fostered by Inquiry-Based Learning approaches, discussing the role of hands-on and minds-on experiments supporting learning. Introduction of such topics faces several challenges from absence of teachers' knowledge to the lack of materials adapted to the proper cognitive level. Here we discussed the test of units on liquid crystals and hydrogels. Students learned the basics (Pavlin, 2013), and were enthusiastic about meeting a new contemporary topic. However, to study the role and effect of inclusion of contemporary science to the pre-university level, more tested units are needed. Nevertheless, we demonstrate that such introduction is possible. As students' knowledge about new findings in science opens a new perspective to science as a relevant subject with a vivid research, the new knowledge may stimulate the awareness of the impact science might have on the society as whole.
Bevins and Price (2016) argue that many models of inquiry are limited and that a more integrated three-dimensional approach that depends on conceptual, procedural and personal learning is required, that is more likely to promote effective learning and a willingness to engage in science. The third research described here helps us to conceptualize IBSE and RRI in diverse science education contexts, under three large-scale EU projects, ESTABLISH (2010), SAILS (2014) and OSOS (2017). The combined learning arising from these three projects are:

(1) Learning science through inquiry can result in better understanding and more broadly applicable scientific knowledge along with the development of transferable skills and competencies.
(2) Many models of IBSE exist, so it is important to adopt an approach that achieves learning outcomes in terms of knowledge, skills, attitudes & values.
(3) Teaching and assessment need to be considered as a dynamic and iterative process so as effectively support IBSE.
(4) Sustained collaboration is crucial in science education – between teachers and educators and across borders, both classrooms and countries.
(5) Schools need to be facilitated to act as shared sites of science learning for which leaders, teachers and the local community share responsibility for embedding social, economic and ethical principles into science education in order to prepare students for active citizenship.

This study highlights the importance of examining how IBSE and RRI are conceptualized and implemented in science education in order to bridge the gap between science education research, educational practices and the varied perceptions of teachers, students, parents and other stakeholders in science education.
The results of the last research here presented clearly show how an Inquiry-Based approach can foster an unifying view of science, at doctoral level. The dynamic and fruitful collaboration that can be achieved when common objectives are planned and pursued in a Sustainability

Science Doctoral Course, and the great potentialities of inquiry perspective in trying to solve a real problem are discussed. Students ' proposals were realistic and viable and were complementary enough to contribute to collectively respond to the global problem. The use of approaches from different areas of knowledge was clear and the project methodology was well understood by the students. Some difficulties concerning team work and information management were observed, particularly during the first work, but significant improvements were attained when the groups addressed the second problem. Students considered the experience to be very rewarding in terms of learning, concerning both the thematic areas and the methodological process, contributing very positively to their personal and professional valorization.

REFERENCES

Ark of Inquiry: Inquiry Awards for Youth over Europe (2013). http://www.arkofinquiry.eu/homepage [Accessed on 17/01/20]

Bencze, L. & Alsop, S. (Eds.). (2014). *Activist science and technology education*. New York: Springer.

Bevins, S., & Price, G. (2016). Reconceptualising inquiry in science education. *International Journal of Science Education*, *38*(1), 17–29. https://doi.org/10.1080/09500693.2015.1124300

Colburn, A. (2000). An inquiry primer. *Science Scop*e, *23*, 42–44.

ESTABLISH (2010). European Science and Technology in Action: Building Links with Industry, Schools and Home www.establish-fp7.eu [Accessed on 10/01/20]

European Commission (2015). *Science education for responsible citizenship. Report of the Expert Group on Science Education*. Luxembourg: European Union. http://ec.europa.eu/research/swafs/pdf/pub_science_education/KI-NA-26-893-EN-N.pdf

García-Carmona, A. & Criado, A. M. (2009). Introduction to Semiconductor Physics in Secondary Education: Evaluation of a teaching sequence. International Journal of Science Education 31, 2205-2245.

Hake, R.R. (1998). Interactive-engagement versus traditional methods: a six-thousand-student survey of mechanics test data for introductory physics courses. *Am. J. Phys.* 66, 64–74

Hattie, J. A. C. (2008). *Visible learning. A synthesis of over 800 meta-analyses relating to achievement.* Routledge, London and New York.

Hazelkorn, E., Ryan, C., Beernaert, Y., Constantinou, C.P., Deca, L., Grangeat, M., Karikorpi, M., Lazoudis, A., Casulleras, R.P. and Welzel-Breuer, M. (2015), *Science education for responsible citizenship. Report to the European Commission of the Expert Group on Science Education.*

IRRESISTIBLE (2013). Including Responsible Research and innovation in cutting Edge Science and Inquiry-based Science education to improve Teacher's Ability of Bridging Learning Environments. http://www.irresistible-project.eu/index.php/en/ [Accessed on 17/01/20]

Lazonder, A.W., Harmsen, R. (2016). Meta-Analysis of InquiryBased learning: Effects of Guidance. *Review of Educational Research 86*, 681-718.

Linn, M. C., Davis E.A., & Bell, P. (2004). Internet Environments for Science Education. Mahwah, NJ.: Lawrence Erlbaum Associates.

Mandrikas, A., Michailidi, E. & Stavrou, D. (2019) Teaching nanotechnology in primary education, Research in Science & Technological Education, online DOI: 10.1080/02635143.2019.1631783

Marx J.D., Cummings K. (2007). Normalized change. *American Journal of Physics*, *75*, 87-91.

Metz, A.M. (2008). Teaching Statistics in Biology: Using Inquiry-based Learning to Strenthen Understanding of Statistical Analysis in Biology laboratory Courses. *CBE-Life Sciences Education* 7, 317-326.

Miner, D.D., Levy, A.J., Century, J. (2009). Inquiry-Based Science Instruction – What Is It and Does It Matter? Results from a Research Synthesis Tears 1984 to 2002. *Journal of Research in Science*

Teaching 47, 474-496.

OECD Learning Framework 2030, (2018). http://www.oecd.org/education/2030/learning-framework-2030.htm [Accessed on 10/01/20]

Osborne, J., Simon, S., & Collins, S. (2003). Attitudes towards science: A review of the literature and its implications. *International Journal of Science Education* 25*,* 1049–1079.

OSOS (2017), Open Schools for Open Societies, www.openschools.eu [Accessed on 10/01/20]

Pavlin J., Vaupotič N., Glažar S. A., Čepič M. & Devetak I. (2010). Slovenian preservice teachers' conceptions about liquid crystals. *Eurasia* 7, 173-180.

Pavlin J., Vaupotič N. & Čepič M. (2013). Liquid crystals: a new topic in physics for undergraduates. *European Journal of Physics* 34, 745 - 761.

Pellegrino, J. W., & Hilton, M. (Eds.) (2012). *Education for life and work: Developing transferable knowledge and skills in the 21st Century*. Washington, DC: National Academic Press.

SAILS (2014). Strategies for Assessment of Inquiry Learning in Science, www.sails-project.eu [Accessed on 10/01/20]

Sharma M.D., Johnston, I.D., Johnston, H.M., Varvell, K.E., Robertson, G., Hopkins, A.M. and Thornton, R. (2010). Use of interactive lecture demonstrations: a ten year study. *Phys. Rev. Spec. Top. Phys. Educ. Res.* 6 020119

Sokołowska D. (2018) Effectiveness of Learning Through Guided Inquiry. In Sokołowska D., Michelini M. (Eds.)

The Role of Laboratory Work in Improving Physics Teaching and Learning (243-255). Cham: Springer.

Sutcliffe, H., (2006). *A report on Responsible Research & Innovation* www.diss.unimi.it/extfiles/unimidire/243201/attachment/a-report-on-responsible-research-innovation.pdf [Accessed on 10/01/20]

Tan Y.S.M., Caleon I.S. (2016). Dealing with the Ambiguities of Science Inquiry. *The Physics Teacher, 54*, 168.

UNESCO (2015*). Rethinking education. Towards a common global good?* Paris: United Nations Educational, Scientific and Cultural Organization

ATOMIC STRUCTURE - THE EFFECTS OF TWO COGNITIVE FACTORS ON SECONDARY STUDENTS' UNDERSTANDING OF THE 'ORBITAL' AND 'ELECTRON CLOUD' CONCEPTS

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The study investigates the role of students' understanding of 'orbital' and 'electron cloud' concepts in the representation of the atomic structure, as well as the effects of the curriculum and the cognitive factors of formal reasoning and filed dependence/independence on such an understanding. Participants were 127 secondary students (grade 12, age 17-18) from Northern Greece. Results show that the quantum approach of the atomic structure prerequisites the conceptualization of the 'electron cloud' and 'orbital' concepts through an appropriate curriculum when students have developed high levels of formal reasoning.

Keywords: Cognitive skills, Mental Models, Conceptual Understanding

INTRODUCTION

Understanding atomic structure through the quantum approach is one of the ultimate targets for science teachers of secondary or even tertiary education. However, such an approach is characterized by a number of difficulties referring to several quantum concepts (e.g. Nakiboglou, 2003; Park & Light, 2009; Emigh et al., 2015). The concepts of 'orbital' and 'electron cloud' are included in such a quantum approach, having as prerequisites the understanding of concepts like 'wave function' and 'probability density' (Emigh et al., 2015) and 'probability' and 'energy quantization' (Park & Light, 2009). However, students have difficulties in understanding such concepts and often conflate characteristics of different models (e.g. Papaphotis & Tsaparlis, 2008; Park & Light, 2009; Tsaparlis & Papaphotis, 2009; Kiray, 2016; Zarkadis et al., 2017; Allred & Bretz, 2019). Since students quantum model ideas are often influenced by the Bohr model ideas, different shapes of orbitals are represented as orbits of different shapes in the Bohr model context (e.g. Park & Light, 2009; Kiray, 2016) or orbitals are represented as a set path of electrons (Park & Light, 2009; Muniz et al., 2018) without understanding energy quantization. On the other hand, some students adopt quantum terms such as the 'orbital' concept to describe the orbit around nucleus in a Bohr model representation (Allred & Bretz, 2019), whereas they have difficulties in distinguishing concepts such as 'orbital', 'shell', 'sub-shell' and 'energy level' (e.g. Taber, 2002). Also, they often identify orbitals as a region (of/in space) where there is a (high) probability for an electron to be found or, where the electrons can move (e.g. Cervellati & Perugini, 1981; Taber, 2002; Nakiboglu, 2003; Stefani & Tsaparlis, 2009; Allred & Bretz, 2019; di Uccio et al., 2019).

In addition, the 'orbital' concept is often confused with the 'probability' concept, since an atomic orbital is defined as the probability of finding an electron (Stefani & Tsaparlis, 2009). Also, orbitals are confused with visual representations of probability envelopes (Taber, 2002) or they are seen as clouds of specific shape (Stefani & Tsaparlis, 2009).

Students often have difficulties in understanding the 'electron cloud' concept, which for some, it seems to be synonymous with the 'orbital' or the 'energy level' concepts (e.g. Allred & Bretz, 2019). The influence of Bohr model is also evident, since students confuse the 'electron cloud' with the concept of a 'shell' (Harrison & Treagust, 2000) and represent electron clouds moving on specific orbits (Tsaparlis & Papaphotis, 2009). Some students represent an orbiting electron cloud (Papahotis & Tsaparlis, 2008), while others represent an *Electronium orbit model,* where certain orbits are depicted around nucleus as nebula due to electrons' very fast rotational movement (Kiray, 2016).

For some students dots of the *electron probability representation* are interpreted either as places where the electron could be or the location of electrons over time, or even as multiple particles (Allred & Bretz, 2019), whereas for some others the electrons are considered as particles represented as dots moving in a circular orbit or a nebulous around the nucleus (Kiray, 2016) indicating a *probability model*. The 'electron cloud' is also considered as concrete concept, since students confuse it with the cloud in the sky (e.g. Harrison & Treagust, 1996; Kiray 2016) or they believe that electron clouds contain electrons (e.g. Harrison & Treagust, 1996; Zarkadis et al., 2017).

However, the understanding of concepts such 'electron cloud' and 'orbital' and the abolishment of the deterministic/mechanistic approach prerequisite the understanding of the 'quantum level' and the development of the visualization/representational abilities (Dangur et al., 2014) and abilities reported as 'high level of abstract thinking' (Cokelez, 2012), high-order cognitive skills (HOCS) (e.g. Zoller & Tsaparlis, 1997) or 'post-formal operations' (e.g. Castro & Fernández, 1987). Since students' mental models' complexity concerning the atomic structure range from the most concrete to the most abstract, it could be considered that students could be also affected by a number of cognitive factors. Individual differences such as *Formal Reasoning (FR)* and *Field Dependence/Independence (FDI)* have been found to be significant predictors of student performance in understanding the particulate nature of matter (Stamovlasis & Papageorgiou, 2012; Tsitsipis et al., 2012), the concept of chemical change (Kypraios et al., 2014) and the atom and its structure (Papageorgiou et al., 2016a, 2016b). However, to our knowledge, no study has investigated the effect of these cognitive factors on students' understanding of specific quantum concepts, such as the 'orbital' and 'electron cloud'. Therefore, it seems quite interesting to investigate the effects of FR on students' understanding of the 'orbital' and 'electron cloud' concepts.

Taken also into account that students' representations of the atomic structure are affected by students cohort characteristics and cognitive factors such as formal reasoning and filed dependence/independence (Papageorgiou et al., 2016a), it was considered as important to investigate the role of students' understanding of 'orbital' and 'electron cloud' in the representation of the atomic structure, as well as the effect of cognitive factors and student cohort characteristics on such an understanding.

RESEARCH QUESTIONS

The present study took place in the context of a wider piece of research targeting students' ideas on the atom and its structure, parts of it have been already published (Papageorgiou et al., 2016a, 2016b). Research questions were:

1. What are the effects of formal reasoning and field dependence-independence on students' understanding of 'orbital' and 'electron cloud', considering their cohort characteristics?

2. To what extent students' understanding of the 'orbital' and 'electron cloud' concepts and possible relevant misconceptions affect students' representations of the atomic structure?

METHODOLOGY

Subjects and Procedure

The present study involves two student cohorts of 127 (in total) voluntary secondary students (grade 12, age 17-18) from Northern Greece. The first cohort comprised of 82 students of the 'technological direction' (TD) and the second, 45 students of the 'science and math direction' (SMD). SMD students were taught more in-depth the quantum mechanical model and related concepts, whereas TD students were taught more in-depth the Bohr model and related concepts. Data were collected during the last semester of the school year through anonymous paper-and-pencil tests for the two cognitive variables and the atomic structure.

Instruments

Students' ability of *Formal Reasoning (FR)* was measured on the basis of the Lawson paper-and-pencil test (Lawson, 1978) lasted 45 min. The test consisted of 15 items dealing with conservation of mass, displaced volume, control of variable), proportional reasoning, combinational reasoning and probabilistic reasoning. A satisfactory internal consistency was found with a Cronbach's alpha of 0.77.

The ability of *Field Dependence/Independence (FDI)* was measured on the basis of the Group Embedded Figures Test (Witkin et al., 1971) lasted 20 min, where students had to dissembled simple figures incorporated in twenty complex ones. Cronbach's alpha reliability coefficient was found to be 0.84.

Students' understanding of the 'orbital' and 'electron cloud' was measured along with their representations of the atomic structure through a paper-and-pencil test especially designed for the piece of research targeting students' ideas on the atom and its structure (45 min duration). Tasks concerning the present study are presented in Table 1. Internal consistency reliability was found acceptable, with a Cronbach's alpha of 0.62.

Table 1. Description of the tasks.

Tasks	Description of the tasks

1	Students were asked to draw and describe the 'atom', if they could observe it through a 'powerful microscope'
2	Students were asked to describe the concept of 'electron cloud' on the basis of what they know or imagine
3	Students were asked to describe the concept of 'orbital' and its relation τo the 'electron cloud'

RESULTS

Students' representations of task 1 were categorized in five general categories of students' mental models as reported in Papageorgiou et al. (2016a): Category A: the *'atom-cell model'*, Category B: the *'particle model'*, Category C: *'nuclear model'*, Category D: the *'Bohr's model'*, Category E: *'quantum model'*.

Table 2. Distribution of students' representations of the atomic structure in tasks1

Cohort	Categories of students' representations											
	«A»		«B»		«C»		«D»		«E»		Missing	
	N	%	N	%	N	%	N	%	N	%	N	%
«TD»	1	1,2	16	19,5	19	23,2	45	54,9	1	1,2	0	0,0
«SMD»	0	0,0	1	2,2	11	24,4	27	60,0	6	13,3	0	0,0

Students (TD and SMD) represented the atomic structure according to *Bohr's* model, reaching high percentages in task 1 (54,9%, 45 students and 60,0%, 27 students, respectively), as shown in Table 2. In task 1, quantum model reached a percentage of 13,3% for the SMD students when only 1,2% for the TD students.

Students' responses to tasks 2 and 3 were categorized in four levels of understanding (LU), taking into account similar categorization schemes (e.g. Nakiboglu, 2003) and is presented below as Table 2.

Table 2. Levels of understanding with the corresponding criteria

LU	Criteria
SA	Responses containing ideas which are all scientifically accepted.
PA	Responses containing incomplete reference to scientific view or coexistence of alternative ideas and scientific view
M	Responses containing alternative ideas/ significant misconceptions
NU	Unclear or wrong responses - No responses

Note. SA = Scientifically Accepted, PA = Partially Accepted, M = Misconception, NU = No Understanding

Only few SMD students provided scientifically accepted responses in task 3 (Table 3), where the electron cloud concept is presented in terms of electron probability density (11.1%, 5 students). The results also show a coexistence of alternative ideas and scientific view in SMD responses, since 'electron cloud' is defined as a region where the electron can move or be found, or as a result of electron's high speed, including however the concept of probability in a hybrid model (17.8%, 8 SMD students). According to Table 3, 53.5% of SMD and 40.3% of TD students, respectively, showed misconceptions, where 40.2% of the SMD and 25.6% of the TD students described the electron cloud as a region of space in an atom, where the electron can move or can be found. In addition approximately 11% (both SMD and TD students) affected by the Bohr's model showing a group of electrons (as a cloud) moving in orbits around the nucleus.

Table 3. Distribution of students into the levels of understanding concerning the 'Electron Cloud' concept

Students levels of understanding and corresponding categories of responses	(SMD) N(%)	(TD) N(%)
A. Sound Understanding	5 (11.1)	-
The density of the 'Electron Cloud' defines the probability of finding an electron in a (certain) position	5(11.1)	-
B. Partial Understanding	8(17.8)	-
1. 'Electron Cloud' is something created (probabilistically) by the electron high speed motion, reflecting possible positions	4(8.9)	1(1.2)
2.'Electron Cloud' is the region where the electron has a high probability to be found.	4(8.9)	1(1.2)
C. Misconceptions	24(53.5)	33(40.3)
1. The space/region/points where the electron can move or be found/accumulated, having the shape of a cloud	18(40.2)	21(25.6)
2. A group of electrons / a cloud moving in orbits around the nucleus	5(11.1)	9(11.0)
3. The orbit/ shell where the electron moves	1(2.2)	3(3.7)
D. No Understanding	8(17.8)	47(57.3)
Total	45(100.0)	82(100.0)

Similarly to the findings concerning the electron cloud concept, only few SMD students provided scientifically accepted responses in task 3 (Table 4), where the orbital concept is presented in terms of probability and wave function concepts (11.1%, 5 students). In agreement with the results for the 'electron cloud' concept it is identified the co-existence of alternative ideas and scientific view in SMD responses, since the 'orbital' is defined as a region where the electron can be found, including however the probability and wave function concepts in a hybrid model (46.6%, 21 students). According to Table 4, 24.3% of SMD and 34.1% of TD students, respectively, showed misconceptions, where orbitals were confused either with other concepts such as 'subshell', 'probability' and 'electron cloud' or they considered as fixed positions or regions of space in an atom where the electron can be found. Students were also affected by the Bohr's model showing an 'orbital' as 'orbit' or 'shell' (8.9%, 4 SMD students and 28.1%, 23 TD students).

Table 4. Distribution of students into the levels of understanding concerning the 'orbital' concept

Students levels of understanding and corresponding categories of responses	(SMD) N(%)	(TD) N(%)
A. Sound Understanding	5 (11.1)	-
Orbitals are solutions of the Schrödinger equation/wave functions, defining the probability of finding an electron in a position – No physical meaning	5(11.1)	-
B. Partial Understanding	21(46.8)	2(2.4)
Orbitals, as solutions of the Schrödinger equation/wave functions, determine the regions where the electron can be found	21(46.8)	2(2.4)
C. Misconceptions: alternative ideas - significant misconceptions	11(24.3)	28(34.1)
1. The orbitals are the subshells s, p, d, f	2(4.4)	-
2. An orbital is the probability of finding an electron in a certain position	2(4.4)	-

3. The orbitals are fixed positions/coordinates/regions, where the electron can be found	2(4.4)	3(3.6)
4. An orbital is similar to an electron cloud concept	1(2.2)	2(2.4)
5. The orbitals are imaginary 2D circles/orbits/shells	4(8.9)	23(28.1)
D. No Understanding	8(17.8)	52(63.5)
Total	45(100.0)	82(100.0)

In response to the first research question, a Categorical Regression Analysis took place with the three tasks as dependent variables and the two cognitive factors and student cohort as independent (Table 5). FR was found to have a statistically significant effect on student performance in tasks 1, 2 and 3, over and above the effect of curriculum. The effect of the cohort (which is related to the corresponding curriculum) was also found significant, especially in task 3. The effects of FDI were not significant.

As for the second research question, Chi-square tests showed significant relationship between student performance in tasks 1 and 2 ($\chi^2(12) = 41.369$, $p < 0.001$, Cramer's $V = 0.33$) and a weaker but also significant relationship between student performance in tasks 1 and 3 ($\chi^2(12) = 21.858$, $p = 0.039$, Cramer's $V = 0.24$). Crosstabulation also showed that, the more complex the representation, moving from model A to E in task 1, the more likely it is to have a higher level of understanding in tasks 2 and 3 (and vice versa).

Table 5. Results of Categorical Regression Analysis

Task	Factor	*Beta*	*df*	*F*	*p*	*Adj. R^2*
1	FR	.308	2	8.029	.001	23.2%
	FDI	.099	3	.456	.714	
	Cohort	-.244	1	9.043	.003	
2	FR	.236	4	5.876	<.001	28.9%
	FDI	-.199	3	1.498	.219	
	Cohort	-.442	1	19.293	<.001	
3	FR	.269	2	9.523	<.001	49.2%
	FDI	.060	2	.181	.835	
	Cohort	-.629	1	75.452	<.001	

Note. FR = Formal Reasoning, FDI = Field Dependence-Independence, *Beta* = Standardized beta coefficient

DISCUSSION AND CONCLUSIONS

Taking into account the effect of curriculum (cohort), as well as the significant relationship between student performance in task 1 and those in tasks 2 and 3 respectively, it seems that quantum approach of the atomic structure prerequisites the conceptualization of the 'electron cloud' and 'orbital' concepts through an appropriate curriculum that is designed for students' ages/grades having possibly acquired abstract thinking and high-order cognitive skills.

As for the individual differences, although visualization abilities are reported to be important for their understanding (Dangur et al., 2014), the effects of FDI were not found significant. However, the effect of FR was found to be significant and since the understanding of such abstract concepts requires a high level of visual-spatial thinking (Wang & Barrow, 2013), it may be interesting to investigate possible effects of other main components of spatial ability, such as spatial visualization and spatial orientation on the understanding of both atom representations and orbital and electron cloud concepts. Since spatial orientation of orbitals requires visualization and mental manipulation in 2D or 3D (Coleman & Gotch, 1998), it is essential to integrate them by multiple visual representations within appropriate teaching contexts. Integration of visual representations (visual-conceptual approach) could possibly promote students' learning of quantum concepts (e.g. Kalkanis et al., 2003; Dangur et al., 2014) by facilitating them in order to make connections among multiple graphical representations acquiring critical representational competences (Rau, 2015).

Although developmental factors, like formal reasoning, seem to play always an important role in the learning process, having a significant effect on students' representations of the atom and also on the electron cloud and orbital concepts, the success of the learning process is actually defined by the role of the teacher and the curricula designers. A science curriculum that takes into account student cohort characteristics and individual differences can provide opportunities for appropriate teaching methodologies in order to have a more effective teaching of these concepts.

REFERENCES

Allred, Z. D. R., & Bretz, S. L. (2019). University chemistry students' interpretations of multiple representations of the helium atom. *Chemistry Education Research and Practice*, *20*(2), 358-368.

Cervellati, R., & Perugini, D. (1981). The understanding of the atomic orbital concept by Italian high school students. *Journal of Chemical Education*, *58*(7), 568.

Castro, E. A., & Fernández, F. M. (1987). Intellectual development beyond formal operations. *International Journal of Science Education*, 9(4), 441-447.

Cokelez, A. (2012). Junior high school students' ideas about the shape and size of the atom. *Research in Science Education*, *42*(4), 673-686.

Coleman, S. L., & Gotch, A. J. (1998). Spatial perception skills of chemistry students. *Journal of Chemical Education*, *75*(2), 206.

Dangur, V., Avargil, S., Peskin, U., & Dori, Y. J. (2014). Learning quantum chemistry via a visual-conceptual approach: students' bidirectional textual and visual understanding. *Chemistry Education Research and Practice*, *15*(3), 297-310.

di Uccio, U. S., Colantonio, A., Galano, S., Marzoli, I., Trani, F., & Testa, I. (2019). Design and validation of a two-tier questionnaire on basic aspects in quantum mechanics. *Physical Review Physics Education Research*, *15*(1), 010137.

Emigh, P. J., Passante, G., & Shaffer, P. S. (2015). Student understanding of time dependence in quantum mechanics. *Physical Review Special Topics-Physics Education Research*, *11*(2), 020112.

Harrison, A. G., & Treagust, D. F. (1996). Secondary students' mental models of atoms and molecules: Implications for teaching chemistry. *Science education*, *80*(5), 509-534.

Harrison, A. G., & Treagust, D. F. (2000). Learning about atoms, molecules, and chemical bonds: A case study of multiple-model use in grade 11 chemistry. *Science Education*, *84*(3), 352-381.

Kalkanis, G., Hadzidaki, P., & Stavrou, D. (2003). An instructional model for a radical conceptual change towards quantum mechanics concepts. *Science education*, *87*(2), 257-280.

Kiray, S. A. (2016). The pre-service science teachers' mental models for concept of atoms and learning difficulties. *International Journal of Education in Mathematics Science and Technology*, *4*(2), 147-162.

Kypraios, N., Papageorgiou, G., & Stamovlasis, D. (2014). The Role of Some Individual Differences in Understanding Chemical Changes: A Study in Secondary Education. *International Journal of Environmental and Science Education*, 9(4), 413-427.

Lawson, A. E. (1978). Development and validation of the classroom test of formal reasoning. *Journal of Research in Science Teaching, 15,* 11–24.

Muniz, M. N., Crickmore, C., Kirsch, J., & Beck, J. P. (2018). Upper-division chemistry students' navigation and use of quantum chemical models. *Chemistry Education Research and Practice*, *19*(3), 767-782.

Nakiboglu, C. (2003). Instructional misconceptions of Turkish prospective chemistry teachers about orbitals and hybridization. *Chemistry Education Research and Practice,* 4(2), 171-188.

Papageorgiou, G., Markos, A., & Zarkadis, N. (2016a). Students' representations of the atomic structure–the effect of some individual differences in particular task contexts. *Chemistry Education Research and Practice*, *17*(1), 209-219.

Papageorgiou, G., Markos, A., & Zarkadis, N. (2016b). Understanding the Atom and Relevant Misconceptions: Students' Profiles in Relation to Three Cognitive Variables. *Science Education International*, *27*(4), 464-488.

Papaphotis, G., & Tsaparlis, G. (2008). Conceptual versus algorithmic learning in high school chemistry: the case of basic quantum chemical concepts. Part 2. Students' common errors, misconceptions and difficulties in understanding. *Chemistry Education Research and Practice*, *9*(4), 332-340.

Park, E. J., & Light, G. (2009). Identifying atomic structure as a threshold concept: Student mental models and troublesomeness. *International journal of science education*, *31*(2), 233-258.

Rau, M. A. (2015). Enhancing undergraduate chemistry learning by helping students make connections among multiple graphical representations. *Chemistry Education Research and Practice*, *16*(3), 654-669.

Stamovlasis, D., & Papageorgiou, G. (2012). Understanding chemical change in primary education: The effect of two cognitive variables. *Journal of Science Teacher Education*, *23*(2), 177-197.

Stefani, C., & Tsaparlis, G. (2009). Students' levels of explanations, models, and misconceptions in basic quantum chemistry: A phenomenographic study. *Journal of Research in Science Teaching: The Official Journal of the National Association for Research in Science Teaching*, *46*(5), 520-536.

Taber, K. S. (2002). Conceptualizing quanta: Illuminating the ground state of student understanding of atomic orbitals. *Chemistry Education Research and Practice*, *3*(2), 145-158.

Tsaparlis, G., & Papaphotis, G. (2009). High-school Students' Conceptual Difficulties and Attempts at Conceptual Change: The case of basic quantum chemical concepts. International Journal of Science Education, 31(7), 895-930

Tsitsipis, G., Stamovlasis, D., & Papageorgiou, G. (2012). A probabilistic model for students' errors and misconceptions on the structure of matter in relation to three cognitive variables. *International Journal of Science and Mathematics Education*, 10(4), 777-802.

Wang, C. Y., & Barrow, L. H. (2013). Exploring conceptual frameworks of models of atomic structures and periodic variations, chemical bonding, and molecular shape and polarity: a comparison of undergraduate general chemistry students with high and low levels of content knowledge. *Chemistry Education Research and Practice*, *14*(1), 130-146.

Witkin H. A., Oltman P. K., Raskin E. and Karp S. A., (1971), *Embedded figures test, children's embedded figures test, group embedded figures test: manual*, Palo Alto, CA: Consulting Psychologists Press.

Zarkadis, N., Papageorgiou, G., & Stamovlasis, D. (2017). Studying the consistency between and within the student mental models for atomic structure. *Chemistry Education Research and Practice*, *18*(4), 893-902.

Zoller, U., & Tsaparlis, G. (1997). Higher and lower-order cognitive skills: The case of chemistry. *Research in Science Education*, *27*(1), 117-130.

DRAWING MENTAL MODELS OF STATIC ELECTRICITY: WHAT WE CAN GAIN

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The interpretations of static electricity phenomena are not obvious, even in higher education. This study was conducted to investigate to what extent could model-based structured inquiries develop prospective teachers' conceptual understanding of static electricity phenomena; friction and contact electricity as well as conductors' and insulators' properties. Learners' drawings of mental models were progressively developed towards more accurate teaching models of the corresponding microscopic procedures. Sixty-eight prospective primary teachers conducted electrostatic experiments focused on different types of electricity, in the context of an Introductory Physics Laboratory Course. The data collected through their worksheets. Qualitative content analysis method and descriptive statistics were used. The analysis showed that learners can surpass their conceptual difficulties regarding static electricity and incorporate complete explanations in their written answers. The proposed teaching models allowed learners to develop adequate explanations including microscopic procedures, such as the electrons' transfer during friction electricity and the different role of electrons in conductors and insulators. The findings implied emphasis on microscopic models during the macroscopic experimental processes.

Keywords: model-based learning, inquiry-based teaching

INTRODUCTION

It is argued that a central role for models and modelling would greatly increase the authenticity of the science curriculum. Models are essential to the production, dissemination and acceptance of scientific knowledge (Gilbert, 2004). Linus Pauling, a two Nobel prizes recipient, once remarked: "The greatest value of models is their contribution to the process of originated new ideas". Scientific models evolve through the processes of scientific inquiry and discourse and can be sophisticated and highly abstract. School science as a curriculum subject represents science to learners and in this process of representation, the models of science become transformed (Justi & Gilbert, 2000). Curriculum models are simplified versions of scientific knowledge which are prescribed as target knowledge for learners at an education level. Teachers use teaching models that may be further simplifications such as standard diagrams, simple physical models, teaching analogies and so forth (Gilbert, Jong, Justi, Treagust, & Driel, 2003) and range from those representing phenomena in the observable macroscopic world to those representing the theoretical entities conjectured to exist at submicroscopic levels and from very simple to intellectually highly challenging ones (Abdo & Taber, 2009).

The study of mental representations constructed by students in their interactions with the world, its phenomena and artefacts, constitutes an important line of research in science education. The main role of a mental model is to allow its builder to explain and make predictions about the physical system represented by it. It must be functional to the person who constructs it, internal, personal, and idiosyncratic (Greca & Moreira, 2000). Teachers try to have their students construct mental models that are coherent with the teaching models and the shared theories presented in the class. In many schools, students draw molecules, cells, waves, planets and other science concepts as part of a dynamic instructional method called drawing mental models (Duit & Glynn, 1996). This method opens windows into students' minds allowing teachers to examine students' mental models of science concepts. Students' initial mental models are simple representations of a concept, but as students learn more, their mental models evolve and become more sophisticated. One advantage of this method is that students' development of understanding can be traced by having them create a series of mental models over a period. Drawing mental models can benefit students in all science disciplines because the process helps students consolidate information about a concept and identify any misconceptions. Considerable research has revealed how individuals update their mental models as they encounter new information (Rapp, 2005). Students' engagement with scientific inquiry and model construction and revision seem to be promising toward achieving progress in science classrooms (Khan, 2007). Therefore, the study aims to investigate to what extent could model-based structured inquiries that focus on microscopic procedures, develop prospective teachers' conceptual understanding of static electricity phenomena; friction and contact electricity as well as conductors' and insulators' properties. This study was conducted in the context of broader research in progress.

METHODOLOGY

This study follows a qualitative descriptive cross-sectional research approach. Qualitative content analysis method (Mayring, 2000) and descriptive statistics were used (e.g. frequencies) to quantify the findings and present a clearer picture of students' conceptual understanding (Gay, Mills, & Airasian, 2012). Fieldwork was carried out at the Department of Primary Education, of the National and Kapodistrian University of Athens, during the winter semester of 2018-19. The sample consisted of 68 second-year university prospective primary teachers (learners) who undertook the Introductory Physics Laboratory Course (IPLC) and were selected due to convenient access. All learners completed individual worksheets as part of their final assessment (response rate 100%). As a result, for this study 68 worksheets were collected and analyzed.

Learners were divided into three classes of 16 persons and one class of 20 persons whose members worked in pairs. The IPLC comprised of five rotation independent two-hour laboratory exercises once a week: 1) taking measurements, 2) mechanics, 3) optics, 4) static electricity, and 5) heat.

In static electricity, the teaching-learning sequence included three experiments. The first experiment was about friction electricity and particularly the phenomenon of rubbing a glass rod with a piece of wool. The second experiment was about contact electricity and particularly the phenomenon of touching the metal disc of the electroscope with the charged rod. The third experiment had to do with differences between inductors and insulators focusing on the different phenomena of touching the metal disc of an electroscope with either the rubbed end of a glass rod (insulator) or the other end and either the rubbed side of the metal cylinder or the other side.

All phenomena were approached in an inquiry-based teaching context (Pedaste et al, 2015). At first, prospective teachers were asked to propose a hypothesis about a phenomenon and its explanation, then they conducted the experiment and drew their *mental* models to explain the phenomenon observed. Subsequently, learners were provided with the corresponding *teaching* models which represented the microscopic procedures under consideration (e.g. PhET Colorado). At this point, they had to compare their drawings to the *teaching* models and discussed their findings with the tutors. Finally, they were asked to write in detail their improved explanation. The tutors highlighted the limits of the *teaching* models, to prevent learners' from developing new misconceptions.

Regarding contact electricity, prospective teachers had to make a hypothesis about what would happen if an electrified glass rod touched the metal disc of the electroscope. Experimentation followed (Fig.1). Prospective teachers were asked to draw their mental models explaining the phenomenon (Fig.2). Just after that, prospective teachers were asked to compare the *mental* models with the *teaching* models, provided by the tutor (Fig.3).

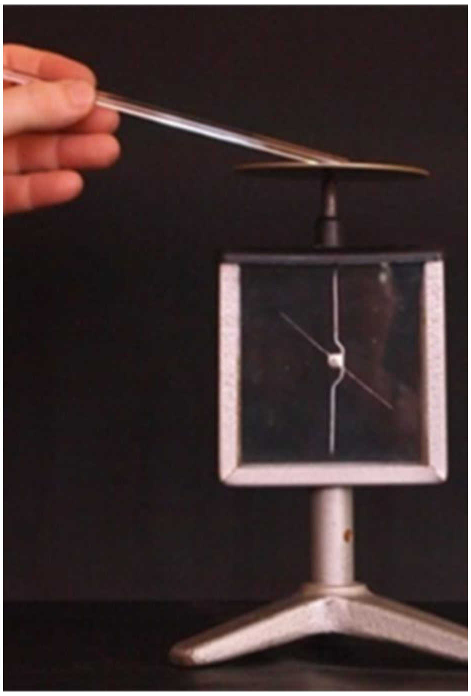

Figure 1. Contact electricity experiment

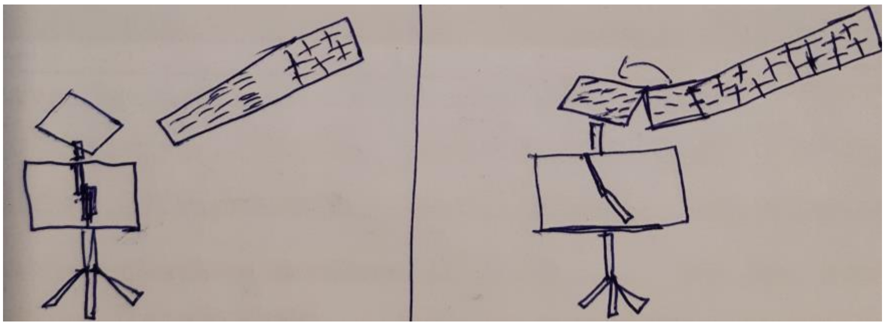

Figure 2. Contact electricity *mental* models

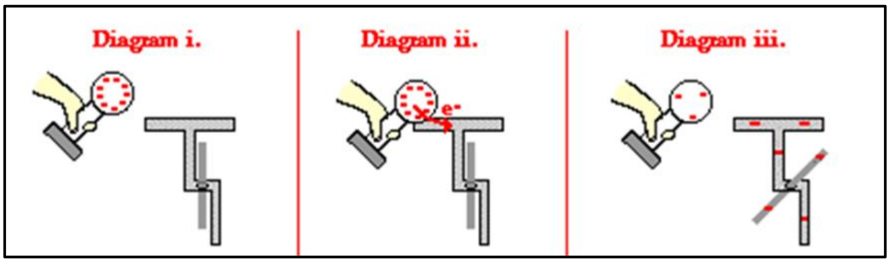

Figure 3. Contact *electricity* teaching models (Physics Tutorial:Charging by Conduction, n.d)

RESULTS

The analysis of the data indicated that the combination of learners' drawings and corresponding *teaching* models of microscopic procedures contributed to the construction and development of a meaningful conceptual understanding of static electricity phenomena. More specifically, regarding friction electricity, during the hypothesis phase 57% of learners attributed friction electricity to electrons transfer, whereas at the end of the teaching-learning sequence, the corresponding percentage increased to 95% (Fig.4). In contact electricity, learners were asked to express their opinion on what could happen if an electrified plastic ruler was in contact with the metal disc of an electroscope. Most learners (59%) stated that the electroscope's plates would open but they could not either write or draw the explanation of why this would happen. After the integration of the teaching models, 87% of learners explained completely the phenomenon referring to electrons transfer from one object to another. In the case of a positively charged object which got in touch with a neutral object, 56% provided a complete answer using the law of conservation of charge while 31% described the mechanism of electron transfer with no reference to the law (Fig. 5).

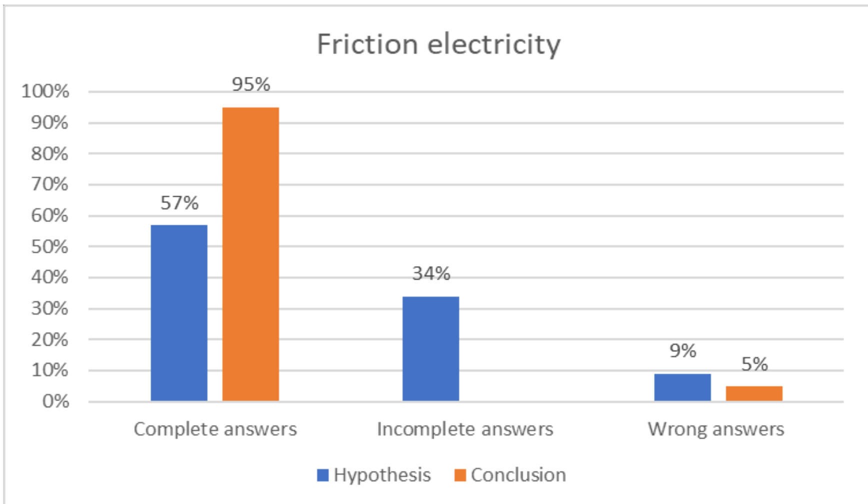

Figure 4. Learners' explanations of friction electricity

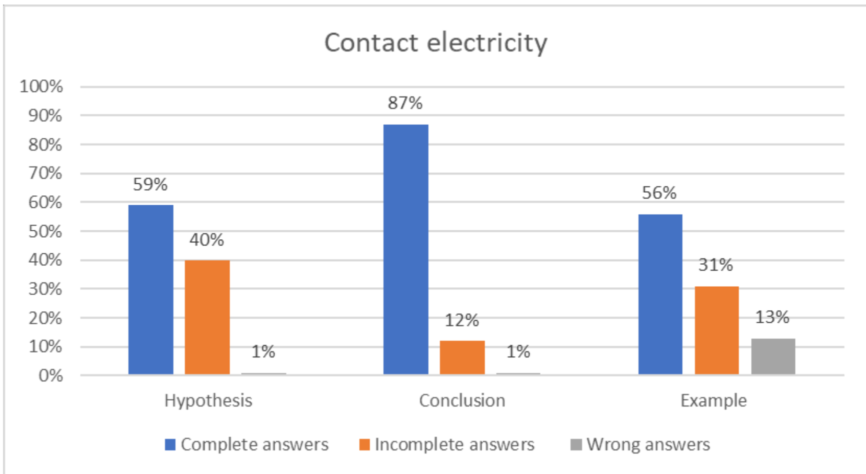

Figure 5. Learners' explanations of contact electricity

Regarding conductors' and insulators' properties, 74% predicted conductors' behavior and 62% insulators' behavior but they could not provide explanations in microscopic level. When learners draw their models and compared them to the corresponding *teaching* models, they gave appropriate answers based on the different role of electrons in conductors and insulators (Fig. 6).

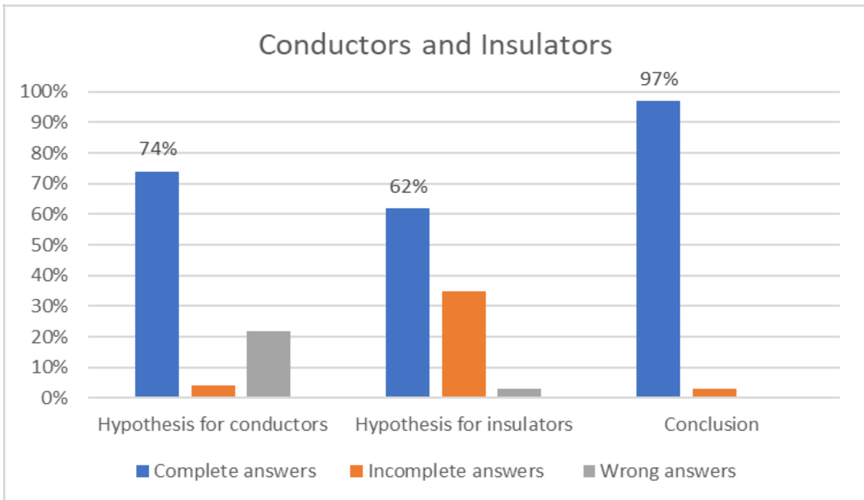

Figure 6. Learners' explanations of conductors' and insulators' properties

CONCLUSION

This study attempted to investigate if model-based structured inquiry teaching of static electricity could help prospective primary teachers surpass their conceptual difficulties related to friction and contact electricity and the properties of conductors and insulators. Following the statistical analysis, it can be suggested that the combination of *mental* models and *teaching* models helped learners construct conceptual understanding, especially in a microscopic level. Also, the findings revealed that learners' initial conceptual difficulties were related to their inefficient knowledge of microscopic procedures. Therefore, when these procedures, such as the role of electrons in conductors and insulators, the role of protons in the shaping of the atomic nucleus etc. became clear, learners incorporated enough scientific explanations in their answers. Further research in the field could shed light on the development of teaching-learning sequences that consider the microscopic procedures, in the area of electricity and beyond, e.g. thermodynamics.

REFERENCES

Abdo, K., & Taber, K. S. (2009). Learners' Mental Models of the Particle Nature of Matter: A study of 16-year-old Swedish science students. *International Journal of Science Education*, *31*(6), 757–786. doi: 10.1080/09500690701799383

Duit, R., & Glynn, S. (1996). Mental modelling. In G. Welford, J. Osborne, & P. Scott (Eds.), *Research in science education in Europe: Current issues and themes* (pp. 166-176). London: Falmer Press

Gay, L. R., Mills, G. E., & Airasian, P. W. (2012). *Educational research: competencies for analysis and applications* (10th ed). Boston: Pearson.

Gilbert, J. K. (2004). Models and Modelling: Routes to More Authentic Science Education. *International Journal of Science and Mathematics Education*, *2*(2), 115–130. doi:10.1007/s10763-004-3186-4

Gilbert, J. K., Jong, O., Justi, R., Treagust, D. F., & Driel, J. H. (2003). Research and Development for the Future of Chemical Education. In J. K. Gilbert, O. Jong, R. Justi, D. F. Treagust, & J. H. Driel (Eds.), *Chemical Education: Towards Research-based Practice* (pp. 391–408). Dordrecht: Kluwer Academic Publishers.

Greca, I. M., & Moreira, M. A. (2000). Mental models, conceptual models, and modelling. *International Journal of Science Education*, *22*(1), 1–11. doi: 10.1080/095006900289976

Justi, R., & Gilbert, J. (2000). History and philosophy of science through models: some challenges in the case of "the atom". *International Journal of Science Education*, *22*(9), 993–1009. doi: 10.1080/095006900416875

Khan, S. (2007). Model-based inquiries in chemistry. *Science Education*, *91*(6), 877–905. doi:10.1002/sce.20226

Mayring, P. (2000). Qualitative Content Analysis [28 paragraphs]. In *Forum Qualitative Sozialforschung/Forum: Qualitative Social Research*, *1*(2). Retrieved from https://doi.org/10.17169/fqs-1.2.1089

Pedaste, M., Mäeots, M., Siiman, L., Jong, T., van Riesen, S., Kamp, E., Manoli, C., Zacharia, Z., & Tsourlidaki, E. (2015). Phases of inquiry-based learning: Definitions and the inquiry cycle. *Educational Research Review*, *14*, 47-61. doi.org/10.1016/j.edurev.2015.02.003

Physics Tutorial: Charging by Conduction. (n.d.). Retrieved January 17, 2020, from https://www.physicsclassroom.com/class/estatics/Lesson-2/Charging-by-Conduction

Rapp D.N. (2005). Mental Models: Theoretical Issues for Visualizations in Science Education. In J.K. Gilbert (Ed.), *Visualization in Science Education* (pp 43-60). Dordrecht: Springer.

GESTALT AND FUNCTIONALITY AS INDEPENDENT DIMENSIONS OF MENTAL MODELS

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In teaching science, models are often used to introduce, elaborate or simplify concepts or real-world phenomena. It is, however, often the case that misconceptions arise from or are facilitated by these teaching models during their transition to mental models of the individual learners. Models are often seen as direct replicas of something real – scaled versions of reality. Even though for structural models, this approach is mostly sufficient, in science, other model types must also be taken into account. For example, in quantum physics, the ability for abstract model building is essential. In an exploratory study with 3108 participants, dispositions towards models in physics in general and mental models of the atomic hull in particular were analyzed. Based on these quantitative data, two independent dimensions of participants' dispositions on mental models were extracted: (i) Functional Fidelity and (ii) Fidelity of Gestalt. Based on these empirical findings, four archetypes for interpreting mental models are proposed.

Keywords: mental models, concepts

INTRODUCTION

The formation of mental models is essential for learning and therefore understanding situations or phenomena more deeply. There are, however, many problems associated with the usage of models in science education, one of which is an overly literal interpretation of the models given to students (e.g. Grosslight, Unger, Jay & Smith, 1991; Treagust, Chittleborough & Mamiala, 2002; Tsaparlis & Papaphotis, 2009). But not only models explicitly given by instructors can be a problem for learners – their own mental models can be a hindrance in learning processes as they often are not easily given up in favor of completely new ideas (e.g. Petri & Niedderer, 1998). By considering these two common findings in science education, one has to ask whether these two are in some way linked: Is there a correlation between learners' problems with letting go of older mental models in favor of new ones and the overly literal interpretation of models as given by instructors? For trying to answer this question, two steps in preparation are needed: Firstly, a definition of the term 'mental model' in the context of this research has to be given. Secondly, a topic has to be chosen where it is the case that learners show a resilience to let go of their mental models. These two aspects will be addressed before a further analysis of the link between mental models and models as given by instructors is carried out.

Mental models

The first step necessary for further delving into the subject of mental model interpretations is to clearly define what the term 'mental model' means in this context. The term 'mental model' has been previously used on many occasions, both in psychology (e.g. Johnson-Laird, 1983; Horst, 2016) and educational research (e.g. Nersessian, 1992; Greca & Freire, 2000). Here, we will use the following definition: *A mental model is the individual coding of a functionality via* *a gestalt*. This definition was chosen as it entails the common ideas associated with mental models or similar concepts in the corresponding literature: A mental model is in most cases characterized by a certain structural component and another abstract, functional one. These have been dubbed as 'gestalt' and 'functionality' respectively. The idea that mental models use some sort of 'gestalt' dates back to Piaget (1951), who proposed that symbolic 'signifiers' codify behavior and information. In most cases, the 'gestalt' part is seen as a visual characteristic (Levy & Trevarthen, 1976; Nersessian, 2002), in some cases it is linked to other modal characteristics such as sensori-motor patterns (Ke, Monk & Duschl, 2005) or auditory patterns (Mayer, 2001). 'Functionality' is an aspect that seems mostly associated with a relational, abstract, functional idea, that is encoded via certain 'gestalts'. As Aebli (1968) interpreted it, the 'signified' is an internalized operation. This core idea – a gestalt or a sensory pattern encoding some function, some operation – can be found in many instances in the corresponding literature. An overview of the other often used phrases for the terms 'gestalt' and 'functionality' in different areas of research is given in table 1. Models given by instructors are often seen as having the same two properties except that they are not individual to the learner.

Table 1. Uses of ideas similar to 'gestalt' and 'functionality' in the context of mental models in different disciplines.

Author	Area of research	Term comparable to 'Gestalt'	Term comparable to 'Functionality'
Piaget (1951, p. 273)	Psychology	signifier	signified
Aebli (1968, p. 56)	Educational Psychology	image/ symbolic representation	operation
Horst (2016, p. 84)	Philosophy/ Psychology	representation	systematic relational information of domain
Levy & Trevarthen (1976)	Neurology	appearance	function
Nersessian (2002, p. 141)	Educational Science/ Physics Education	representation/symbol	behaviour/operation

Selected exemplary subject of research

The planetary atomic model was used as an instance of a mental model that has been found to be resistant to being discarded in favour of a more functional mental model. This case is an example for a conceptual barrier addressed in several studies in the context of quantum physics (e.g. Petri & Niederrer, 1998; Müller, 2003; Krijtenburg-Lewerissa, Pol, Brinkman & Joolingen, 2017): A more advanced model that learners develop is a mental model of circular electron trajectories. It has been given several names, ranging from 'solar system model' to 'Bohr's model' (Fischler & Lichtfeldt, 1992; Harrison & Treagust, 1996; Nicoll, 2001;

Nakiboglu, 2003; Park & Light, 2009; Stevens, Delgato & Krajcik, 2010), although the trajectory concept at its core still remains the same. This model seems to be the most dominant mental model of the atomic hull's structure that is held by students, even by the time they leave school (Müller, 2003).

During quantum physics courses, another radically different mental model emerges and competes with the previous knowledge: Students often develop a 'quantum mechanical model' (Papageorgiou, Markos & Nikolaos, 2016), which has more abstract characteristics such as 'orbitals' (Taber, 2002a; Taber, 2002b; Nakiboglu, 2003) or 'electron clouds' (Harrison & Treagust, 1996; Müller & Wiesner, 2002), representing the stochastic nature the wave-function, which contradicts the deterministic nature of well-defined trajectories. In most cases, this new model is not favoured, and the previous mental model remains the prevailing one. Therefore, we chose this common case as an instance for a mental model that is often not discarded in face of a more sophisticated one.

METHODOLOGY

To examine a possible link between reluctance to discard mental models and understanding of physical models, we decided to use modified questions of the 'models as exact replicas' (ER) dimension from the 'Students' Understanding of Models in Science' (SUMS) instrument by Treagust et al. (2002) and questions from the evaluation of the Munich Concept (Müller, 2003) on mental models of the atomic hull. The test instrument consisted of 15 questions with a four-point Likert-esque scale with the options being: strongly disagree (1), disagree (2), agree (3), strongly agree (4). An additional option of 'don't know' was given to not force participants to answer in a case of uncertainty or no prior knowledge. For analysis of the collected data, the Statistical Package for Social Scientists 25 (SPSS 25, 2017) was used.

The study was conducted via an online platform. The participants had to answer the items of the study before access to an online course on visualizations of quantum mechanics was provided (see for an English version quantumreflections.com). In total, 3108 people in Germany participated in the study (27 July 2017 to 30 March 2018) and also completed it (in addition, 924 persons started the questionnaire, but did not finalize it). Their professions ranged from pupils to university professors.

The analysed dataset was appropriate for evaluation via factor analysis, as shown elsewhere (Ubben & Heusler, 2019). Therefore, we used a multivariate analysis with several different rotations, though the results were so similar that we used the results from a varimax rotation in exemplary function. A more thorough description of the studies' methodology is given by Ubben and Heusler (2019).

RESULTS

Our analysis shows that strong correlations between a reluctance to discard mental models and understanding of physical models exist, as they both load on the same factors about equally. However, the key result is more general: by using factor analysis, two independent factors characterizing participants' views on mental models have been extracted. The two factors are best described as 'Fidelity of Gestalt' and 'Functional Fidelity'. All strong correlations with the two factors can be read from figure 2.

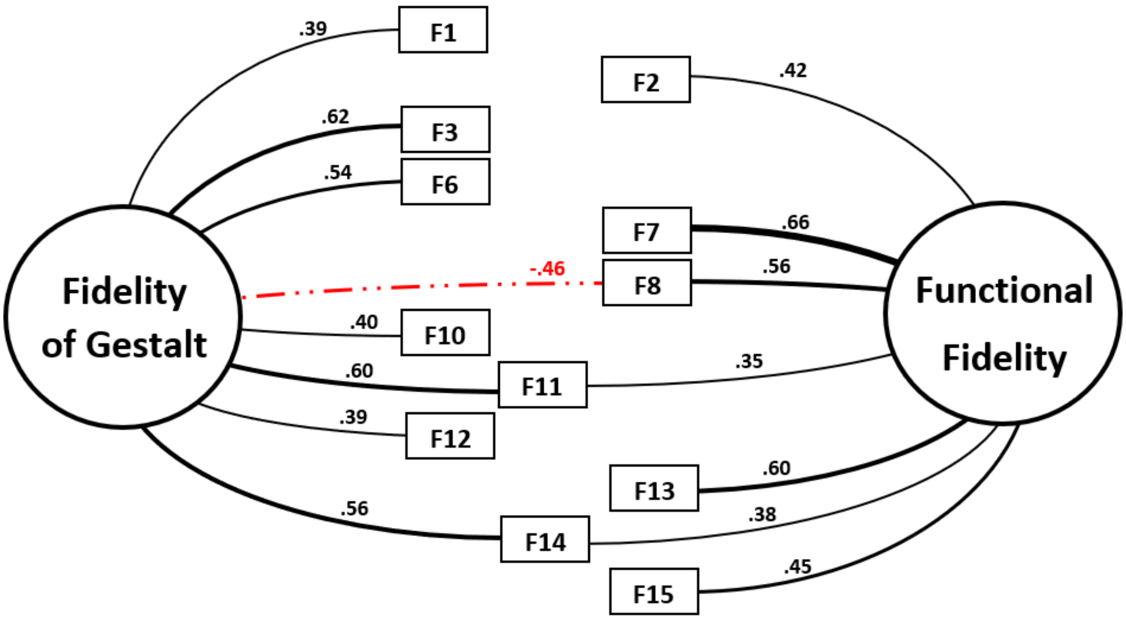

Figure 2. All strong item correlations ($r_s > 0.35$) of the test items with the two factors *Fidelity of Gestalt* (FG) and *Functional Fidelity* (FF). Even though F1 and F12 were excluded during the extraction of the factors, they still correlate highly with FG. The strong negative correlation of F8 with FG was highlighted in red. For a more thorough description of the analysis, see Ubben & Heusler (2019).

Fidelity of Gestalt

The 'Fidelity of Gestalt' trait (FG) describes how far the mental models in physics of the participants were thought of as exact visual representations of phenomena - of exact depictions of how things look. Examples for items of this trait are: 'Electrons within the atomic hull move along set trajectories with high velocities around the core.' (F3) and 'Models in physics show something real in manageable size.' (F11). If someone, for example, were to have an image of the 'planetary model' and thought of it as picturing reality, they would have a high expression of this trait in the given context. If someone, however, were to have an image of the 'planetary model' but would not take it literal, but more metaphorical, they would have a low expression of this trait in the given context.

Functional Fidelity

The ‘Functional Fidelity’ trait (FF) describes how far the mental models in physics of the participants were thought of as appropriate descriptions of how phenomena work — what abstract concepts underly the corresponding models. Examples for items of this trait are: ‘Possible locations of an electron within the atomic hull are described by its orbital.’ (F7) and ‘Every part of a model in physics should be able to tell what it represents.’ (F13). If someone, for example, were to have an image of the ‘planetary model’ and thought of it as describing the behaviour of electrons, they would have a high expression of this trait in the given context. If someone, were to have an image of the ‘planetary model’ but would not think of it as describing how electrons behave in the atomic shell, they would have a low expression of this trait in the given context.

Because the two factors ‘Fidelity of Gestalt’ and ‘Functional Fidelity’ are not correlated to each other (see Ubben & Heusler, 2019), four types of relating one’s mental models to reality are theoretically possible (see also figure 3):

- The *non-developed type* does not understand the model as either depicting or describing external reality. This might show as one not having a meaningful concept of something and only being able to recite or reproduce e.g. meaningless facts or automatisms without meaning. One could for example repeat the word ‘atomic shell’ but not relate it to ‘external reality’ in gestalt and functionality (see e.g. Griffiths & Preston, 1992).
- The *architectural model type* mainly understands a mental model as depicting ‘external reality’ but does not ascribe value for the processes the mental model codifies. One could for example imagine the atom as looking like a static electron cloud (e.g. Harrison & Treagust, 1996)
- The *dual type* sees a mental model as both depicting and describing things in ‘external reality’. This is consistent with the finding of learners often seeing models as replicas of reality. One might for example imagine the atom as a tiny planetary system and think that it describes and depicts ‘external reality’ aptly (see e.g. Ke et al., 2005)
- The *functional type* sees mental models only as describing something in ‘external reality’ more or less *aptly* (see for a similar idea Horst, 2016, p. 86). This means that the appearance is not seen as relevant, but how the mental model works and behaves. For example, a mental model of the atom might be only seen as behaving like the ‘external reality’ to a certain extent (e.g. comments on ‘most sophisticated models’ by Zarkadis, Papageorgiou & Stamovlasis, 2017, p. 894)

DISCUSSION

There are two aspects to be further addressed in the context of our findings:

(i) The relation between mental models and reality as described by the two factors.
(ii) The four archetypes of mental model interpretations.

Though the results have been gained from questions on model understanding in physics as well as mental models of the atomic shell only, there are many similar cases in the literature on science education in general, as will be shown elsewhere.

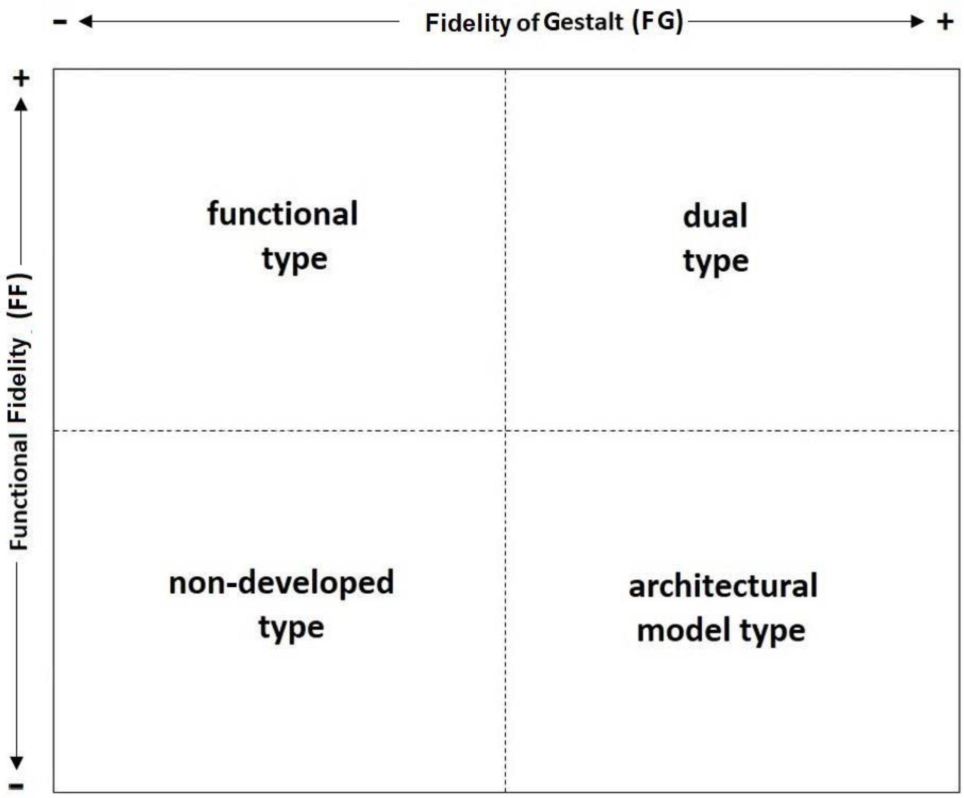

Figure 3. The main types of mental models as described by the FF and FG scales. From high trait expression (+) to low trait expression (−), the four archetypes of relating mental models' properties to 'eternal reality' arise.

Mental models and 'external reality'

As previously presented, mental models in the sense of our research can be characterized as being individual mental constructs that have the properties 'gestalt' and 'functionality'. Our study implies that these to aspects can be interpreted as addressing two different relations to 'external reality' (see e.g. Craik, 1943). A mental model can be seen as being the same as or different from the appearance of something in 'external reality', given by the trait expression of *Fidelity of Gestalt*. Accordingly, a mental model can be seen as functioning the same as or different from something in 'external reality', given by the trait expression of *Functional Fidelity*. Modelling the relation between mental model and 'external reality' with two independent relations is also consistent with findings from neurology: It was shown that the brain has certain parts specialized for 'appearance mapping' and certain parts for 'functional mapping' (Levy & Trevarthen, 1976; for a more recent overview see Gazzaniga, 2005).

At first glance, mental models one holds are different from the models given e.g. by physics teachers. Both – mental models and models in physics – however did not cluster into two distinct categories during the factor analysis of our data. On the contrary: In both in the 'Fidelity of Gestalt' and the 'Functional Fidelity' case, the two highest correlating items are from the SUMS (Treagust et al., 2002) and Müller (2003) respectively. This means, that the two extracted factors can characterize dispositions towards both mental models and models in physics. If one considers that models given by the teacher or a researcher have once been mental models themselves but were externalized for communicative and educational purposes, the similarities of those two is not surprising but, in a way, expected.

The four types of relating mental models to 'external reality'

A progression from the non-developed type to the functional type via firstly the architectural model type and secondly the dual type seems likely. In fact, these steps can be found in several theories on understanding (e.g. Aebli, 1968; Greca & Freire, 2000). The reason for many people having problems with letting go of mental models in favour of ones that give better explanations can be understood by these steps: A high perception of the model *depicting* reality, could make it harder to accept a radically different depiction of reality. It might therefore help to first try to reduce the 'Fidelity of Gestalt' before trying to teach via another gestalt. After that, showing that the new model is more apt at describing how the thing from 'external reality' behaves (conceptual change) might become easier. Support for this hypothesis will be laid out elsewhere in detail.

Whilst many mental models relating to everyday perception can probably be seen as being perceived high in regards to 'Fidelity of Gestalt' and 'Functional Fidelity', mental models used for thinking about problems and processes in science do not have to be seen as being high in 'Fidelity of Gestalt': In fact, many mental models of scientific processes are described by mathematics and their gestalts are thus not like the external reality – however, their functionality is more or less apt.

Conclusion

To summarize, the relations between mental models and 'external reality' can be characterized by two independent traits: 'Fidelity of Gestalt' and 'Functional Fidelity'. Both are criteria by which a mental model is judged in relation to 'external reality'. These two traits are not only able to describe characteristics of mental model understanding, but also for understanding physical models in general.

REFERENCES

Aebli, H. (1968). *Psychologische Didaktik* (3rd ed.). Stuttgart: Ernst Klett.

Craik, K. (1943). *The nature of Exploration.* Cambridge: Cambridge University Press.

Fischler, H. & Lichtfeldt, M. (1992). Modern physics and students; conceptions. *International Journal of Science Education, 14,* 181–190.

Gazzaniga, M. (2005). Forty-five years of split-brain research and still going strong. *Nature Reviews Neuroscience*, 6, 653–659.

Greca, I.M. & Freire, O. (2000). Mental models, conceptual models, and modelling. *International Journal of Science Education, 22*, 1-11.

Griffiths, A.K. & Preston, K.R. (1992). Grade-12 Students' Misconceptions Relating to Fundamental Characteristics of Atoms and Molecules. *Journal of Research in Science Teaching, 29*, 611-628.

Grosslight, L., Unger, C., Jay, E. & Smith, C. L. (1991). Understanding models and their use in science: conceptions of middle and high school students and experts. *Journal of Research in Science Teaching, 28,* 799–822.

Harrison, A. G. & Treagust, D. F. (1996). Secondary students' mental models of atoms and molecules: implications for teaching chemistry. *Science Education, 80*, 509–534.

Horst, S. (2016). *Cognitive Pluralism.* London: MIT Press.

Johnson-Laird, P. N. (1983). *Mental Models: Towards a cognitive science of language, inferences, and consciousness*. Cambridge: Cambridge University Press.

Ke, J. L., Monk, M. & Duschl, R. (2005). Learning introductory quantum physics: sensori-motor experiences and mental models. *International Journal of Science Education, 27*, 1571-1594.

Krijtenburg-Lewerissa, K., Pol, H. J., Brinkman, A. & Joolingen, W. R. (2017). Insights into teaching quantum mechanics in secondary and lower undergraduate education. *Physical Review Physics Education Research, 13*, 010109.

Levy, J. & Trevarthen, C. (1976). Metacontrol of Hemispheric Function in Human Split-Brain Patients. *Journal of Experimental Psychology: Human Perception and Performance, 2*, 299-312.

Mayer, R. E. (2001). *Multimedia Learning*. Cambridge: Cambridge University Press.

Müller, R. & Wiesner H. (2002). Teaching quantum mechanics on an introductory level. *American Journal of Physics*, 70, 200-209.

Müller, R. (2003). *Quantenphysik in der Schule*. Berlin: Logos.

Nakiboglu, C. (2003). Instructional misconceptions of Turkish prospective chemistry teachers about orbitals and hybridization. *Chemistry Education Research and Practice, 4*, 171–188.

Nersessian, N. (2002). The cognitive basis of model-based reasoning in science. In P. Carruthers, S. Stich, & M. Siegal (Eds.), The Cognitive Basis of Science (pp. 133-153). Cambridge: Cambridge University Press.

Nicoll, G. (2001). A report of undergraduate's bonding misconceptions. *International Journal of Science Education, 23*, 707–730.

Papageorgiou, G., Markos, M. & Nikolaos, Z. (2016). Students' representations of the atomic structure – the effect of some individual differences in particular task contexts. *Chemistry Education Research and Practice, 17*, 209–219.

Park, E. J. & Light, G. (2009). Identifying atomic structure as a threshold concept: student mental models and troublesomeness. *International Journal of Science Education, 31*, 233–258.

Petri, J. & Niedderer H. (1998). A learning pathway in highschool level quantum atomic physics. *International Journal of Science Education, 20*, 1075-1088.

Piaget, J. (1951). *Play, dreams and imitation in childhood.* London/ New York: Routledge.

SPSS 25 (2017). *IBM SPSS Statistics for Windows, Version 25.0. IBM Corp*. Armonk: IBM Corp.

Stevens, S. Y., Delgato, C. & Krajcik, J. S. (2010). Developing a hypothetical multi-dimensional learning progression for the nature of matter. *Journal of Research in Science Teaching*, 47, 687–715.

Taber, K. S. (2002a). Conceptualizing quanta—illuminating the ground state of student understanding of atomic orbitals. *Chemistry Education: Research and Practice Europe, 3*, 145–158.

Taber, K. S. (2002b). Compounding quanta: probing the frontiers of student understanding of molecular orbitals. *Chemistry Education: Research and Practice Europe, 3*, 159–173.

Treagust, D., Chittleborough, G. & Mamiala, T. (2002). Students' understanding of the role of scientific models in learning science. *International Journal of Science Education, 24*, 357–368.

Tsaparlis, G. & Papaphotis, G. (2009). High-school students' conceptual difficulties and attempts at conceptual change: the case of basic quantum chemical concepts. *International Journal of Science Education, 31,* 895–930.

Ubben, M. S. & Heusler, S. (2019). Gestalt and Functionality as Independent Dimensions of Mental Models in Science. *Research in Science Education.* Advance online publication. https://doi.org/10.1007/s11165-019-09892-y

Zarkadis, N., Papageorgiou, G. & Stamovlasis, D. (2017). Studying the consistency between and within the student mental models for atomic structure. *Chemistry Education Research and Practice, 18*, 893-902.

THE EXTENDED THEORETICAL FRAMEWORK OF MATHEMATICAL WORKING SPACE: TASK ANALYSIS ON A CHEMISTRY PROBLEM

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The theoretical framework of the Extended Mathematical Working Space (Extended MWS) allows to analyse the tasks implemented during a few steps modelling cycle of a physics or chemistry problem. The analysis of the work will be also carried out with the anthropological theory of the didactic (ATD) to compare the two theoretical frameworks in the a priori analysis of the tasks to be performed by the students. Then, only the extended MWS model will be used for post-analysis. We will analyse a teaching sequence with an experimental part dealing with solution chemistry in secondary education. The construction of graphs makes it possible to work on the notion of stoichiometry with a dynamic geometry software, GeoGebra, and to deduce the mass titter of a pharmaceutical product. The methodological framework used is didactic engineering. We will see that it is possible to propose a new register of semiotic representation with graphics to help solve problems using GeoGebra.

Keywords: Interdisciplinarity, Learning Theory, Chemistry

INTRODUCTION

We are interested in a pedagogical sequence including a practical session work carried out in a class of 21 students in Terminale S (Grade 12) in a high school of Picardie Maritime in the north of France (Gauchon, 2008). The notion of stoichiometric relationship corresponds to the disciplinary work targeted here. It concerns the dosage of diiodine by a sodium thiosulphate solution in the presence of a coloured indicator. Equivalence corresponds to the situation when all the two species have reacted. It is shown experimentally by the change in colour of the dosed solution when equivalence is reached. Knowing the quantity of sodium thiosulphate added at equivalence, it is possible to deduce from this, using an algebraic relationship, the concentration of diiodine initially present. Based only on a semiotic genesis, a novice observer sees a change in colour. He is conscious that something is happening, but he can' t explain it. The instrumental genesis is associated with the manipulation of the material. The experimenter follows a protocol leading to the colour change. The only activation of this genesis does not allow the understanding of the actions that he is led to carry out. The notion of equivalence is difficult to make the students understand (the two chemical species have reacted completely to equivalence; it is not necessarily a simple equality between the quantities of each chemical species). Several semiotic registers can be used to facilitate the understanding of this notion: tables, graphs, algebraic relations, natural language, or in this case a much more "visual" experience for the students. The work of Duval (1993) has shown from both a cognitive and a semiotic point of view that the understanding of a concept is improved when at least two registers of representation are mobilized and when translations between registers are favoured. Thus, a semiotic register based on graphs seemed to us to be mobilizable for our teaching sequence. We also take inspiration from the work of Cazes and Vandebrouck (2014). They have studied the use of GeoGebra, on the progress of a sequence designed to teach functions in a context of classical kinematics. We make the hypothesis that an expert visualizes the equivalence of a chemical dosage by associating it intimately with the notion of stoichiometry. It could thus be relevant to use the advancement and stoichiometric numbers during a reasoning process using graphs representing the advancement *x* as a function of time *t* with GeoGebra. Our study will thus use this software to represent and use *x*(*t*) graphs. We hypothesize that the task to be performed by the students to find an unknown concentration could be facilitated at the beginning of the learning process by using an instrumental genesis of a different nature than the experimental device using GeoGebra. The teaching sequence with an experimental part dealing with solution chemistry in secondary education will be thus analysed using two theoretical frameworks (Extended MWS and ATD) in order to specifically analyse interactions between the cognitive plane and the epistemological planes of chemistry or mathematics. An a priori analysis based on the study of the tasks to be performed by the students was then carried out. The post-analysis of a student's work will be presented. The methodological framework used in this study will be didactic engineering.

METHOD

The Mathematical Working space (MWS) was developed to better understand the didactic issues around mathematical work in a school environment by Kuzniak, Tanguay & Elia (2016).

The epistemological plan contains a set of representations (signs used), a set of artefacts (drawing instruments or software) and a theoretical reference set (definitions and properties). The cognitive plane contains a visualization process (representation of space in the case of geometry), a construction process (function of the tools used) and a discursive process (arguments and evidence). Mathematical work results from an articulation between the cognitive and epistemological planes through instrumental genesis (operationalization of artefacts), semiotic genesis (based on the register of semiotic representations), and discursive genesis (presentation of mathematical reasoning). The different phases of mathematical work associated with a task can be highlighted by representing three vertical planes on the MWS diagram. Semiotic-instrumental interactions lead to a process of discovery and exploration of a given academic problem. Those of an instrumental-discursive type favour mathematical reasoning in relation to experimental evidence. Finally, those of the semiotic-discursive type are characteristics of the communication of mathematical results as well as more elaborate reasoning. The MWS diagram was transformed by Moutet (2018, 2019a, 2019b) by adding an epistemological plane corresponding to the rationality framework of physics (figure 1) or of chemistry (Moutet, 2019a, 2019c). It was chosen to keep only one cognitive plane because we assume that it is independent of the epistemological plane associated with it. We also hypothesized that students' conceptions of mathematics and physics can be described using a personal extended MWS. This framework makes it possible to specifically analyse the interactions between the cognitive plane and the epistemological planes of chemistry or mathematics.

We also used another theoretical framework. The anthropological theory of didactics (ATD) was developed by Chevallard (1999). Any human activity can be described by a praxeology. A type of task, noted T, requires a technique τ in order to be carried out successfully. The block $[T/\tau]$ of praxeology is called the practical-technical block and is associated with what is generally referred to as know-how. The technology, noted θ, makes it possible to describe "rationally" the technique used by ensuring that the task T is well processed. Finally, the theory, noted Θ, makes it possible to theoretically justify the discourse of the technology. The $[\theta/\Theta]$ block is identified with a knowledge. Praxeology associated with a task type T can therefore be described by a task T, a technique τ, a technology θ and theory Θ, all noted $[T/\tau/\theta/\Theta]$. Some praxeologies age, some theoretical and technological components are less used as new technologies emerge, leading to abandon techniques and/or develop new ones in order to accomplish certain types of tasks. The ATD studies questions associated with the performance of specific tasks. This leads to the development of new praxeologies whose efficacity can be evaluated.

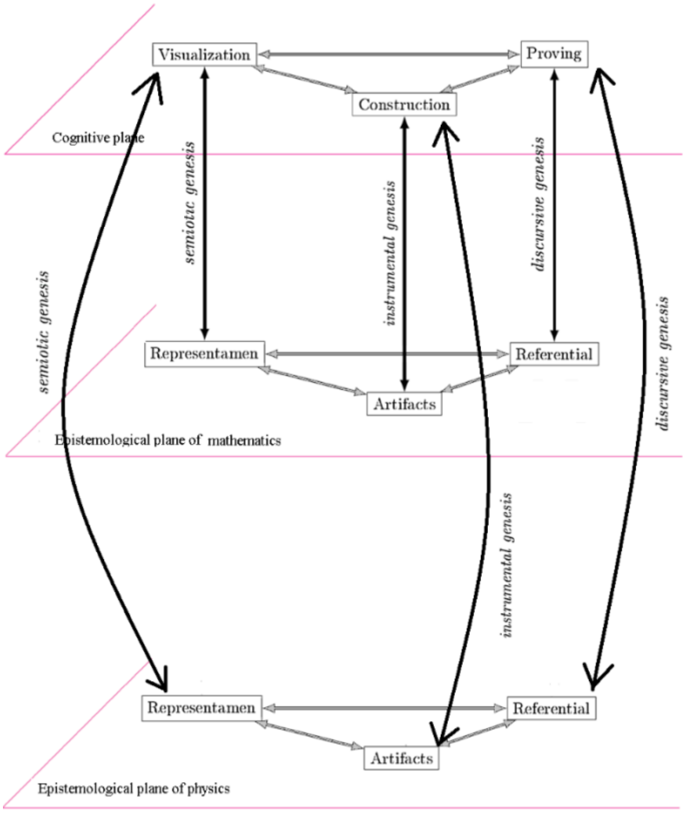

Figure 1. Extended MWS Model.

The methodological framework used is didactic engineering (Artigue, 1988). It is structured in four stages:

1. The preliminary analyses consist in performing an epistemological study of the different concepts that will be addressed in the teaching sequence and to review the difficulties of students that may be listed in the literature.
2. A priori analysis and conception consist in developing a teaching sequence (with one or more pilot sessions) and analysing the different tasks that students will have to perform using an appropriate theoretical framework.
3. The experimentation phase makes it possible to describe the conditions for data collection (audio recording, videos, interviews or analysis of paper and pencil activities, etc.) as well as the context of the study (number of students, grade level, type of school, etc.). Here the teacher is also the researcher involved in the study. Generally, the sample of students involved remains relatively small. It is not possible to carry out a statistical study of the responses obtained.
4. Post-analysis and validation allow the analysis of the tasks carried out by the students to solve the problem they have been assigned. Comparison with the a priori analysis allows us to validate or not the hypotheses that were formulated when the research questions were established.

A first teaching sequence developed by Moutet (2018, 2019a, 2019b) was destined for students in the final year of secondary school (grade 12) in France, on the topic of special relativity following the work of de Hosson, Kermen & Parizot (2010). Another problem in chemistry, is also studied here (Moutet, 2019a, 2019c). Data collections can be videos, audio recordings or GeoGebra files. We used the modelling cycle proposed by Blum & Leiss (2005, figure 2) to position our teaching sequences. We have already realized a sequence in physics studying the passage from the "real model" to the "real results" and here we want to develop a sequence in chemistry allowing a description with a more complete modelling cycle from the "real situation" to the "real results".

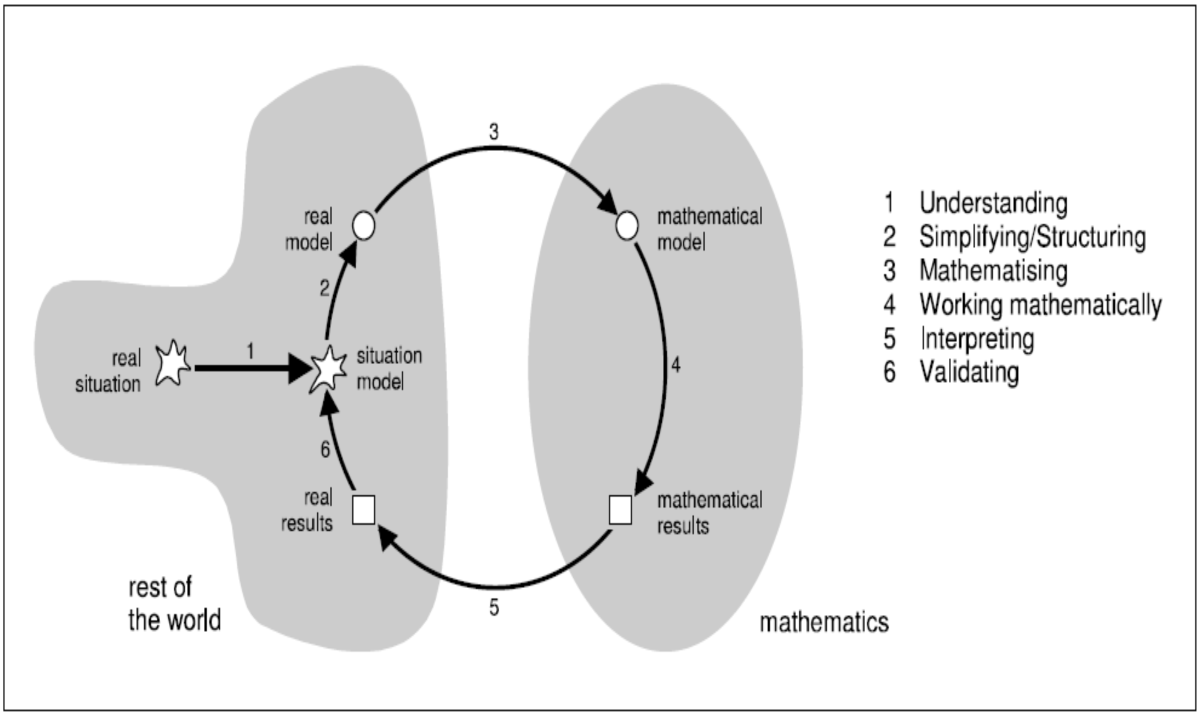

Figure 2. Blum and Leiss modelling cycle (2005).

In this model, derived from the didactics of mathematics, a "real situation" corresponds to a contextualized situation associated with everyday life. It can be, for example, a photo, a text, a video or a mixture of all three. The step corresponding to the "situation model" is also described by Borromeo Ferri (2006) as the "mental representation of the situation". It corresponds to a step in which the students understand the task to a greater or lesser degree and carry out a mental reconstruction of the situation. It is not only the description of the situation encountered, since elements of knowledge begin to be mobilized by the students. The "real model", which can rather be considered as an "idealized model", is obtained by idealizing and simplifying the data from the problem. This step has a strong connection with the "situation model", which explains why it is mostly constructed at an internal level in the individual. A simplified representation of the situation in a diagram, for example, corresponds to an external representation. Here the "real situation" would correspond to the experimental dosage with the observed colour change. The "situation model" would be associated with the understanding of the existence of a chemical reaction during this dosage. The "real model" would be associated with understanding the chemical equation of the dosage, the chemical species reacting and the pertinent parameters to be considered. This is the mathematical step usually involving an algebraic register that we propose to modify using a geometric register.

Two research questions guided this work: 1) How does the extended MWS framework allow the analysis of the sets of rationality frameworks between mathematics and chemistry, during a sequence with students in the final year of secondary school via a geometric approach? 2) To what extent does the analysis of the use of dynamic geometry software by the extended MWS framework, show that it promotes a conceptualization in students?

RESULTS

Students should check the mass percentage of diiodine in a newly manufactured bottle of betadine. In fact, diiodine molecules form a complex with the polyvidone molecule. It is the percentage of iodinated polyvidone that is determined in the betadine solution. Students must perform a determination with a sodium thiosulfate solution and use GeoGebra to automate the determination of the mass titter. Two additional documents are given. They provide information on betadine and reminders on titrations and equivalence. The chemical reaction equation of the titration is also provided. The instruction given to the students is described in the following. A first session takes place in the chemistry laboratory where the students concretely perform the studied dosage in groups of two. They collect the value of the equivalent volume without having had time to evaluate their measurements. A second session takes place in the computer room in groups also to answer three questions.

You are part of a control laboratory in a pharmaceutical manufacturing plant and you must check the mass titter in iodinated polyvidone in a newly manufactured betadine bottle. To do this, you must make a dosage with a sodium thiosulphate solution 2 Na^+, $S_2O_3^{2-}$. You must use software to automate the determination of this mass titter.

1. Represent the quantities of matter of the reactants that have reacted at any time as a function of a reaction quantity. Use GeoGebra to represent the corresponding graphics.
2. Using GeoGebra's "cursor" tool, locate the quantity of sodium thiosulfate solution matter introduced at equivalence and then display on the software the molar concentration in diiodine of the diluted betadine extract.

3. Display on the software the mass titter in iodinated polyvidone of the analysed betadine, conclude.

On GeoGebra, the line of the equation $y = 2.x$ is associated with the amount of thiosulphate mater $S_2O_3^{2-}$ and the line of the equation $y = x$ is associated with the amount of diiodine matter I_2. Cursors are used to identify on the graph, using a horizontal line, the amount of thiosulphate matter added to the equivalence and then to deduce the unknown concentration of diiodine (figure 3). The construction of graphs makes it possible to work on the notion of stoichiometry by graphically observing the relationship between the quantities of matter of the reagents. The GeoGebra file of the activity is available for download using the hypertext link below:

https://drive.google.com/file/d/1DmeAGKjXWUHeWFJ3Gn17mS5QmSu2Ry0F/view?usp=sharing

The a priori analysis is carried out using the ATD theoretical framework and is compared with the recently developed extended MWS framework to test its pertinence. We will then analyse only the work to be done by the students in the computer room. The tasks T, the techniques used τ, technology θ and theory Θ will be detailed for each question.

The various tasks performed are described below. $T_{1\text{-}1}$: It is necessary to know how to use the reaction progress; $T_{1\text{-}2}$: It is necessary to know how to use the graphical representation of the quantities of reagents matter that have been consumed; $T_{2\text{-}1}$: Students must identify the amount of $S_2O_3^{2-}$ matter; $T_{2\text{-}2}$: Students must graphically deduce the amount of diiodine matter and then the diluted concentration of betadine is calculated; T_3: Students should use the dilution to display the iodinated polyvidone mass titter.

The various techniques used are described below. $\tau_{1\text{-}1}$: Students must use the reaction progress $x(t)$; $\tau_{1\text{-}2}$: Students must construct with GeoGebra the lines $x(t)$ and $2.x(t)$ corresponding to the quantities of I_2 and $S_2O_3^{2-}$ matter; $\tau_{2\text{-}1}$: Students must construct a cursor to locate the quantities of $S_2O_3^{2-}$ matter introduced using a horizontal segment cutting the line $y=2.x(t)$; $\tau_{2\text{-}2}$: Students must construct a vertical segment and then a horizontal segment cutting the line $x(t)$ to identify the quantities of diiodine matter. They then deduce the diluted diiodine concentration by dividing the amount of matter by the volume and displaying it on GeoGebra; τ_3: Students deduce the concentration of diiodine by considering the dilution factor and then display the mass titter of iodinated polyvidone on GeoGebra.

The technology uses the graphical representation of the reaction progress as a function of time, the use of cursors and display with GeoGebra. Finally, it is the theory of chemical equilibrium in aqueous solution that is mobilized each time.

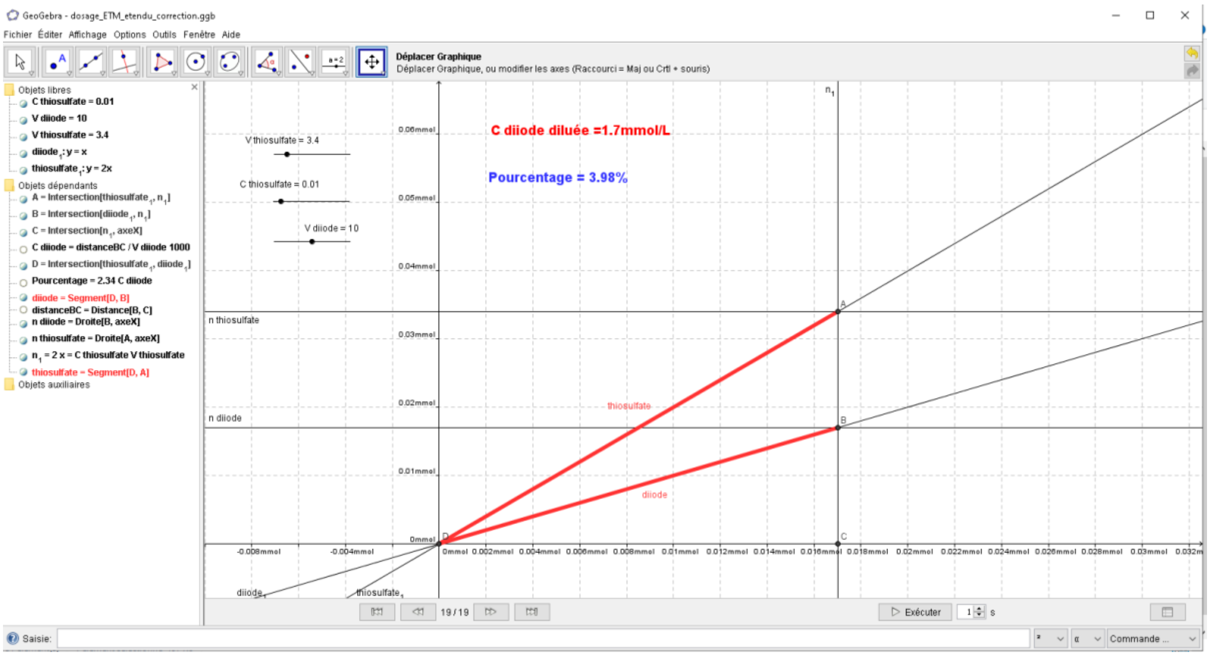

Figure 3. GeoGebra file screenshot.

We use the MWS extended model with an epistemological plane of chemistry (figure 4). The black arrows describe the different genesis on the extended MWS diagram when performing the tasks necessary to solve the problem.

The epistemological plane of chemistry and the cognitive plane are mobilized during the beginning of the resolution of the first question because students must use the reaction progress $x(t)$. A semiotic genesis (use of the symbol of advancement) and a discursive genesis (theoretical knowledge of reaction advancement) are mobilized.

In the second part of the first question, the students must then construct with GeoGebra the lines $x(t)$ and $2.x(t)$ corresponding to the quantities of I_2 and $S_2O_3^{2-}$ matter. The construction of these two lines requires a semiotic genesis and an instrumental genesis between the epistemological plane of mathematics and the cognitive plane. The meaning of these two lines requires genesis (semiotic and discursive) between the epistemological plane of chemistry and the cognitive plane.

In the second question, students must construct a cursor to locate the quantities of $S_2O_3^{2-}$ matter introduced using a horizontal segment cutting the line $y=2.x(t)$. The construction of the cursor requires a semiotic genesis and an instrumental genesis between the epistemological plane of mathematics and the cognitive plane. The epistemological planes of chemistry and the cognitive plane are used when calculating the quantity of $S_2O_3^{2-}$ matter and displaying it graphically (semiotic and discursive genesis).

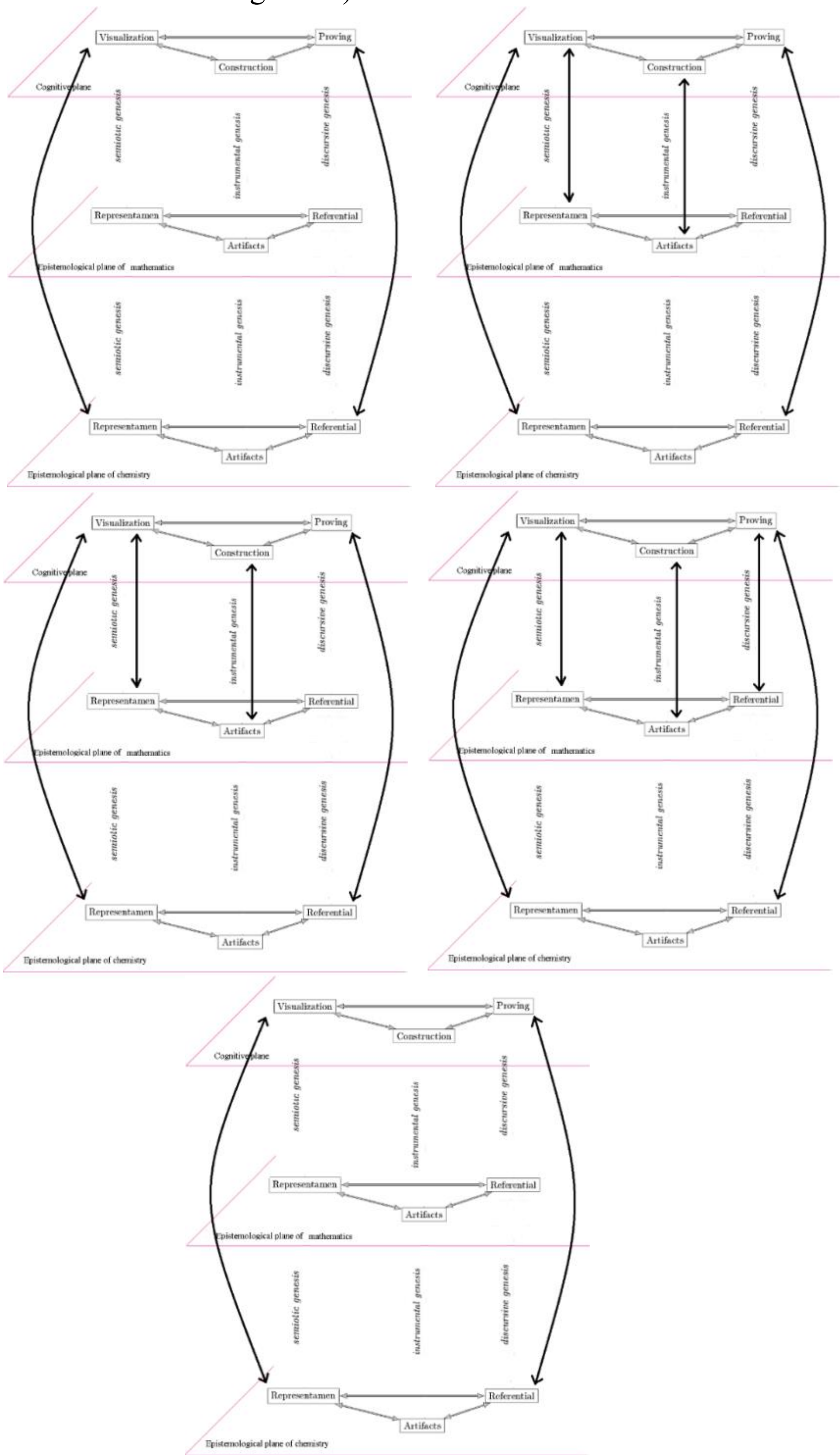

Figure 4. A priori analysis of the tasks with extended MWS.

At the end of the second question, the students graphically deduce the quantity of diiodine matter (semiotic, instrumental and discursive genesis between the epistemological planes of mathematics and the cognitive plane) and then the diluted concentration of diiodine in betadine is calculated (semiotic and discursive genesis between the epistemological planes of chemistry and the cognitive plane).

In the last question, students must use the dilution to display the iodinated polyvidone titter in betadine. It is the epistemological planes of chemistry and the cognitive plane that are involved (semiotic and discursive genesis).

DISCUSSION

We have seen that the ATD makes it possible to analyse the different types of tasks that students must perform during the teaching sequence. However, the rationality frameworks involved are not well clarified. The theoretical framework of the extended MWS allows the same description of tasks and consider the rationality frameworks of mathematics or chemistry as well as the cognitive plane. The interactions between two planes are also described by three types of genesis (semiotic, instrumental or discursive).

Then, the extended MWS framework allows to analyse the tasks assigned to the students and those carried out by them. This study makes it possible to highlight the sets of rationality frameworks when solving problems in chemistry treated by a geometric approach. The GeoGebra dynamic geometry software allows to implement here an additional semiotic genesis with its dynamic aspect. The cursor favours the change of the equivalent volume measured during the dosage and students see the result directly on the screen. An instrumental genesis different from the paper-pencil activity is also involved when constructing graphs representing the quantity of reactants matters as a function of time. Finally, we hypothesize that GeoGebra, by making it easier to draw conclusions on the stoichiometric relationships of a chemical reaction, allows the activation of an original discursive genesis.

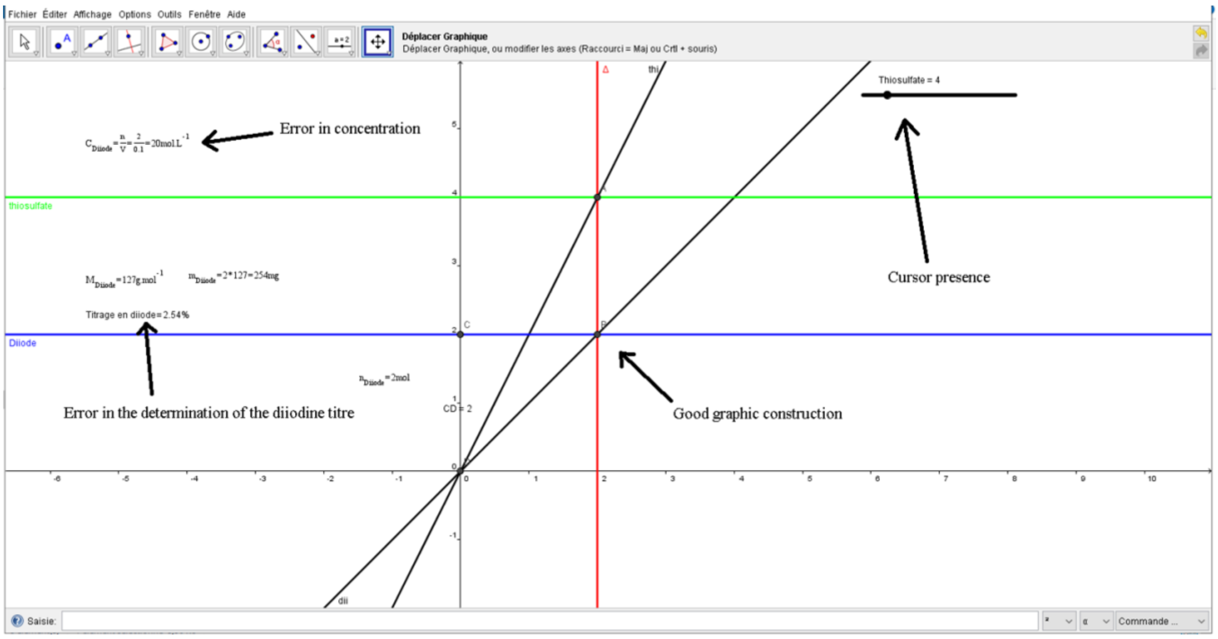

Figure 5. Analysis of a student's work.

The GeoGebra file of the work of a group of students in trouble is available for download using the hypertext link below:

https://drive.google.com/open?id=1I8CQux45Af9brSRBhn_cWH6uUauyY9hB

The black arrows describe a genesis on the extended MWS corresponding to a correctly performed task, the black arrows crossed out an incorrectly performed task and the dotted arrows, a partially successful task. We see that the work required is imperfectly done (figure 6). The group of students represents on GeoGebra the lines $x(t)$ and $2.x(t)$ and the line to identify the amount of thiosulphate matter added to the equivalence. Students incorrectly calculate the amount of material by using mL instead of L (dotted arrow representing the discursive genesis associated with the task at the beginning of the second question).

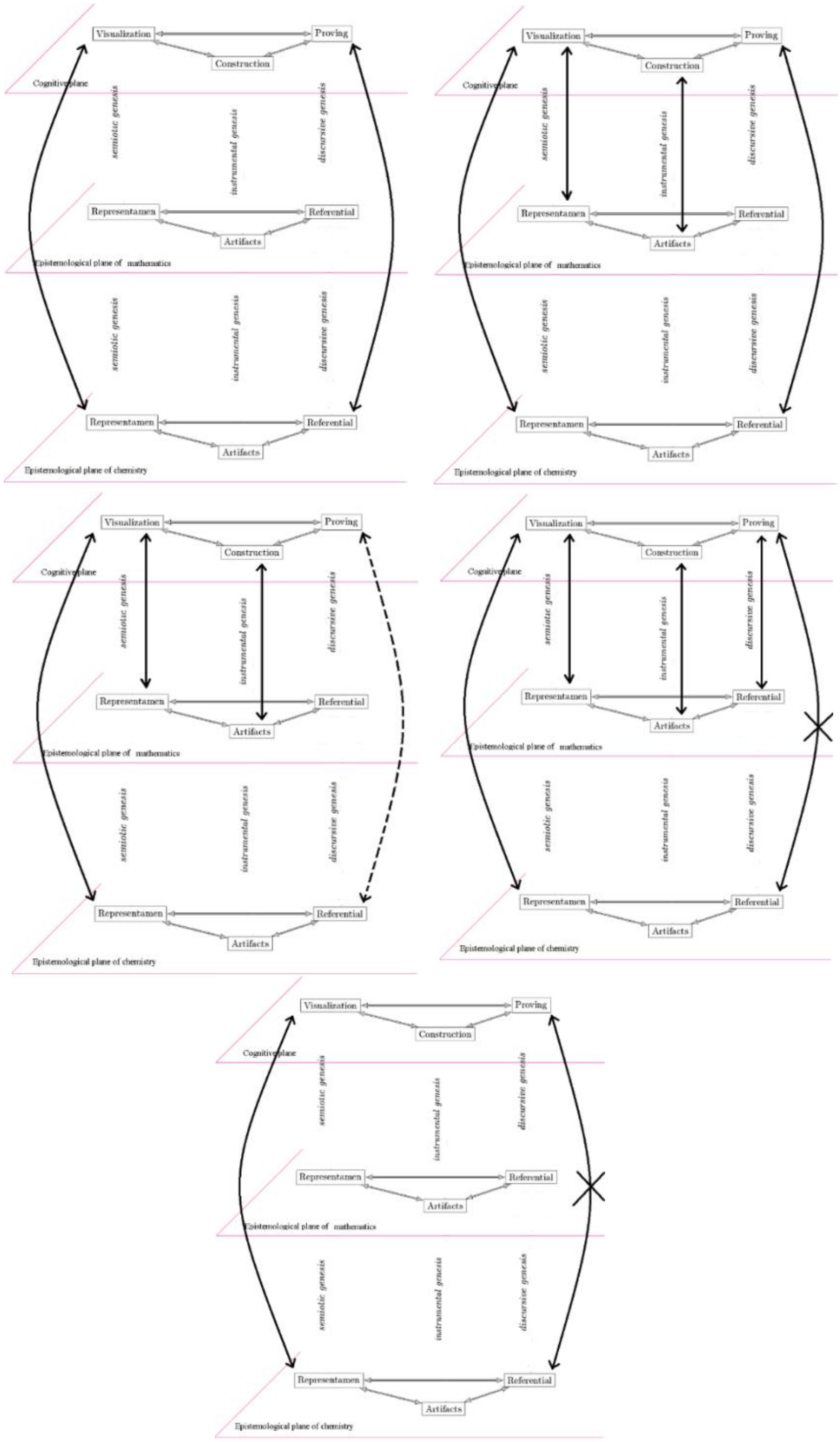

Figure 6. Post-analysis of the tasks performed by a student.

Then the geometrical reasoning is correctly carried out but the calculation of the diluted concentration of diiodine and the mass titter of iodinated polyvidone are incorrect (black arrows crossed out representing the discursive genesis associated with the task at the end of the second question and the task of the last question). Stoichiometry, on the other hand, is correctly established between the reagents by graphical construction.

CONCLUSIONS

The extended MWS framework allowed us to perform a more complete analysis, and assessment of the types of tasks associated with certain stages of the modelling cycle than ATD, during a problem involving chemistry of aqueous solutions. It considers the mobilization of the epistemological planes of mathematics and chemistry for each of the tasks requested with three geneses (semiotic, instrumental and discursive). It also led us to show that GeoGebra develops specific geneses in relation to a paper-pencil activity. It's also possible to propose new strategies when using of GeoGebra with another register of semiotic representation when working with problems solving. Unfortunately, this does not allow all students to succeed even if the work on stoichiometry that was the goal here seems to be well done.

REFERENCES

Artigue, M. (1988). Didactic engineering. *Recherches en didactique des mathématiques*. Grenoble, La pensée Sauvage éditions, *9*(3), 281-308.

Blum, W., & Leiss, D. (2005). « Filling up » - the problem of independence-preserving teacher interventions in lessons with demanding modelling tasks. In M. Bosch (Ed.) *Proceedings for the CERME 4*, Spain. 1623–1633.

Borromeo Ferri, R. (2006). Theoretical and empirical differentiations of phases in the modelling process. *ZDM mathematics Education*, *38*, 86-95.

Cazes, C., Vandebrouck, F. (2014). Vil Coyote rattrapera-t-il Bip - Bip ? Un exemple d'introduction de fonctions à partir d'une situation concrète. *Repères*. Irem. *95*, 5-22.

Chevallard, Y. (1999). The analysis of teaching practices in anthropological theory of the didactic. *Recherches en didactique des mathématiques*. Grenoble, La pensée Sauvage éditions, *19*, 221-266.

Duval, R. (1993) Registres de représentation sémiotique et fonctionnement cognitif de la pensée. *Annales de Didactique et de Sciences Cognitives de l'IREM de Strasbourg*, *5*, 37-65.

de Hosson, C., Kermen, I., & Parizot, E. (2010). Exploring students 'understanding of reference frames and time in Galilean and special relativity. *European Journal of Physics*, *31*, 1527–1538.

Gauchon, L. (2008). Understanding titrations - Representations of grade 11 and 12 scientific students and the effects of some variables, (Doctoral dissertation, University Paris Diderot, France). Retrieved from https://tel.archives-ouvertes.fr/tel-00954787/document

Kuzniak, A., Tanguay, D., & Elia, I. (2016). Mathematical Working Spaces in schooling: an introduction. *ZDM mathematics Education*, *48*, 721–737.

Moutet, L. (2018). Analysis of a teaching sequence of special relativity: the contribution of the extended MWS model. *Annales de didactique et de sciences cognitive*, *23*, 107–136.

Moutet, L. (2019a). The extended theoretical framework of Mathematical Working Space: potentialities in physics and chemistry. In Vivier, L., Montoya Delgadillo, E., Richard, P.R., Gómez-Chacón, I., Kuzniak, A., Maschietto, M. & Tanguay, D. (Eds). *Actes du Sixième Symposium sur le Travail Mathématique* (ETM6, 13-18 décembre 2018) (pp. 207-218). Valparaíso, Chile: Pontificia Universidad Católica de Valparaíso.

Moutet, L. (2019b). The extended theoretical framework of Mathematical Working Space (extended MWS): potentialities in physics. In Jankvist, U. T., Van den Heuvel-Panhuizen, M., & Veldhuis, M. (Eds.). (2019). *Proceedings of the Eleventh Congress of the European Society for Research in Mathematics Education* (CERME11, February 6 – 10, 2019) (pp. 1240-1247). Utrecht, the Netherlands: Freudenthal Group & Freudenthal Institute, Utrecht University and ERME.

Moutet, L. (2019c, July). The extended theoretical framework of MWS: use in physics and chemistry, *Paper presented at the meeting of ICTMA19*, Hong-Kong, China.

INSTRUCTING SECONDARY SCHOOL STUDENTS IN 'TRIPLET' CONCEPT MAPPING FOR CHEMISTRY

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A sociocultural perspective was utilized to explore if concept mapping using macroscopic, symbolic and submicroscopic aspects (often referred to as the 'chemistry triplet') can be used to promote development of expert knowledge in secondary school chemistry students by facilitating multilevel thinking. An additional aim was to explore the possibilities of using sociocultural theory to study the development of conceptual meaning and its contextual influences. The method was well received by students, and all students produced acceptable maps. Students with difficulties defining symbolic concepts as representations found participation in the study particularly useful. The method appeared to be suitable for studying both the effect of social roles and communication practices in the classroom, suggesting that triplet concept mapping can be utilized to study the contextual influences on the development of conceptual meaning, as well as to promote knowledge integration in chemistry at secondary school level.

Keywords: concept mapping, instructional strategies, conceptual understanding

INTRODUCTION

It has been well established within chemistry education research that students have difficulties emulating what Johnstone (1991) calls the 'multilevel' thinking within the chemistry domain (see for instance Becker, Stanford, Towns, & Cole, 2015; Kozma & Russell, 2005; Stieff, Ryu, & Yip, 2013), namely the ability to think and work with chemical symbols, the tangible world of chemistry and the theoretical, particulate models that are used to explain it. These three aspects of chemistry reasoning known as the 'macroscopic', 'symbolic' and 'submicroscopic' – jointly named the 'chemistry triplet' – have been the focus of several interpretations by chemistry researchers (Talanquer, 2011). Originally proposed as levels of thinking leading to working memory overload (Johnstone, 2006), the model has also been interpreted as levels of representation and utilized for the development of representational competence (Gilbert & Treagust, 2009), or as a mixture of conceptual and representational domains, where the focus has been on the representational, symbolic domain working as a communicative and facilitating resource (Taber, 2013). Depending on the interpretation of what the chemistry triplet entails, suggestions on how to further student reasoning within chemistry could entail teachers being explicit about the meanings of models, representations, analogies and their limitations (Taber, 2017) or encouraging students to develop their representational skills (such as in the study by Thomas, 2017). The development of this type of 'expert' knowledge in chemistry has been described by Anderson and Schönborn (2008) as knowledge integration, an essential aspect of deep learning.

So far, however, a sociocultural perspective on the chemistry triplet and how this may be utilized in chemistry teaching is missing in the research literature. From a sociocultural perspective, the idea of the triplet can be viewed as a way of utilizing models for reasoning about macroscopic or sub-microscopic perspectives of events, where the models used for thinking about these perspectives have both limits and affordances for thinking (Vygotsky, 1934/1987; Wertsch, 1991) Through the use of these models learnt through social interaction, students develop the meanings or words and symbols carried within a community (Davydov, 1995), often referred to as 'concepts' (Clarà, 2017). It is important to note that, although symbolic representations such as graphs or equations play an important part as facilitators for thought, words and their perceived meanings also function in the same way (Vygotsky, 1934/1987). As a sociocultural perspective can focus on social context and the development of meanings, this theoretical framework facilitates the study of contextual influences on chemistry teaching and learning. This in turn can facilitate the study of how sociocultural factors, such as communicative classroom practices, can influence conceptual development. The study of contextual influences on the development of conceptual understanding has been suggested to be an important aspect of furthering research in science education (Duit & Treagust, 2012).

The purpose of the primary study presented in this paper was to explore from a sociocultural perspective how secondary school students relate to the triplet concept, and whether triplet concept mapping is a feasible tool for developing knowledge integration in chemistry at secondary school level. First introduced by Novak & Gowin (1984), concept maps are metacognitive tools used for learning and assessment (ibid.; Novak, 2002). Their construction are based on Ausubel's assimilation theory of learning, which states that meaningful learning of a concept means establishment of the concept's relationship to other, to the student already known, concepts, as a result of school instruction (Ausubel, Novak, & Hanesian, 1978; Novak & Gowin, 1984). Hence, the construction of concept maps has the potential to show the learner's current conceptualisation of an idea within instruction. Within concept maps, the propositions (the statement constructed by connecting two or more concepts using linking words) are regarded essential aspects of the maps (Cañas, Novak & Reiska, 2012), and are crucial for meaningful knowledge comparisons between individuals (Ruiz-Primo, Schultz, Li & Shavelson, 2001). A concept map can therefore be used to elucidate how students think about for instance chemical processes through their choice of words or models expressed in the map. If the idea of the triplet has been presented as a scaffold in this process, triplet concept mapping can be used to elucidate how students engage in dialogue between their personal understandings embodied by words and symbols in the concept map, and the knowledge integration aspect of expert knowledge (Anderson & Schönborn, 2008) represented by the triplet scaffold. Concept maps have been proposed by Schwendimann (2015) to be effective tools for promoting knowledge integration, and knowledge integration maps across knowledge domains in biology have been shown previously to be effective in visualizing complex knowledge connections (Schwendimann & Linn, 2016).

For this paper, triplet concept mapping was taught to a class studying chemistry at the International Baccalaureate Diploma Programme. The concept of the triplet was adapted for upper secondary school according to the framework presented by Thomas (2017). The research questions posed were: 1. 'How do the students in this class relate to the triplet concept when utilizing some common chemistry concepts to define a neutralization reaction?', and 2. 'How can triplet concept mapping, when introduced through a 60-minute class, be feasible exercise to stimulate knowledge integration in chemistry at upper secondary school?'

METHODS

From sociocultural perspective, concept maps can be seen as a type of dialogue with the instructor or knowledge domain, where students utilize models and words (i.e. mediational means; Wertsch, 1991), and appropriating them ('making one's own'; Bakhtin, 1935/1981, p. 294; Wertsch, 1991) to engage in this dialogue in various ways depending on the type of dialogue they perceive is taking place. For instance, an authoritarian discourse, such as the study of an expert concept map, can induce passivity because it does not allow for expression of the personal voice, whereas an *expert skeleton concept map*, that gives some initial concepts that function as a scaffold for student understanding (Cañas, Novak, & Reiska, 2012), can be seen as an exercise that invites dialogue. Each concept map can from the same sociocultural perspective also be said to be expressed within a certain speech genre, for instance the speech genre of physics, biology or chemistry, where each genre includes a certain set of models for reasoning around the subject matter (Wertsch, 1991). Therefore two decisions were made: firstly, to use an expert skeleton of the triplet concept to invite dialogue during the concept mapping exercise in this study, and secondly, also to communicate the speech genre clearly while teaching concept mapping to the students.

For the study, concept mapping was taught during a 60-minute lesson by the researcher to 12 students at the International Baccalaureate Diploma Programme at a school in Sweden according to the previously established method by Ruiz-Primo (2001), but modified according to the above rationale to contain only chemistry examples and practice maps. In addition, due to time limitations, only one concept map was constructed collectively (on the topic of atoms), and questions regarding concept mapping were dealt with in the classroom as they arose while the students constructed individual scaffolded triplet maps with five given concepts and two optional concepts (on the topic of exothermic reactions). Purely theoretical questions were not answered, but for the practice map, the students were allowed to discuss the topic with their neighbors. As previously mentioned, the triplet scaffold (see figure 1) was constructed according to the template developed for upper secondary school level by Thomas (2017). This framework divides the triplet domains into observational/tangible/macroscopic, communicative/symbolic, and theoretical/particulate, which means it is an interpretation close to the original framework presented by Johnstone (1991). The exercise was introduced as a way of learning about the theory of knowledge of chemistry (which is part of the Diploma Programme curriculum).

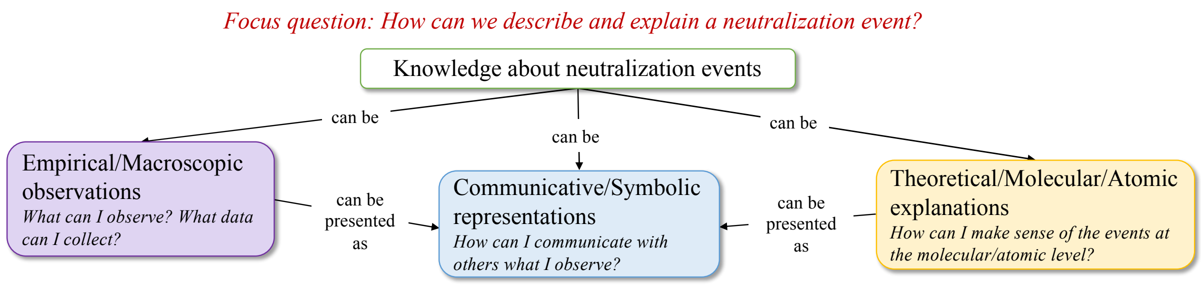


Figure 1. The triplet scaffold used for the concept mapping exercise in the study, adapted from Thomas (2017).

The final scaffolded map on neutralization reactions was constructed individually and in silence, also using five given concepts ('proton transfer', 'acid particles', 'base particles', 'pH' and 'color change'), but where students were encouraged to add two or more concepts. In the instructions given, students were asked to first place the concepts in the appropriate region of the map using Post-its^{TM}, and then to connect the concepts and connect to the top using linking arrows and linking words (according to the procedures outlined by Novak & Cañas, 2008; Novak & Gowin, 1984). An example map showing examples of what type of concepts belonged to each region of the concept map was also given out. The maps produced were according to the class teacher representative of the students' knowledge of neutralization reactions. The concept mapping session was regarded effective as 11/12 students used all concepts provided, and all students used labelled lines and provided one or more valid propositions (Ruiz-Primo, Schultz, & Shavelson, 1997).

In the analysis of how the concepts were placed in relation to the triplet, an interpretive stance was taken on the analysis placement of the concepts, where pH could be viewed as both a macroscopic and a symbolic concept depending on the context, and consideration was given to both how the concepts were linked to the scaffold in terms of linking arrows and how the concepts were placed spatially. This avoided misinterpretation of spatially skewed maps.

During the second part of the study, the students participated in a mandatory 90-minute practical on acid-base titration. This practical took place during the next chemistry lesson the day after the concept mapping class. The ordinary teacher held the practical, which was started by only a very brief introduction to the neutralization reaction (involving acetic acid solution and sodium hydroxide solution), with no mention of the aim of the lab. After the practical the students (N=11) filled in a survey concerning their experiences with concept mapping and their perception of the aim of the lab. In the survey, the students also gave their gender, whether they spoke the school language at home, their achievement level (although some wished to withhold this piece of information), and whether they had constructed concept maps previously. These factors have previously been shown to impact achievement in science or chemistry (Chandran, Treagust and Tobin, 1987; Lopez et al., 2014; van Laere, Aesert & van Braak, 2014).

The concept maps and the survey responses were coded using NVivo software. Descriptive coding and process coding was used, and the codes and categories were then explored in terms of dimensions and variables (Miles, Huberman & Saldana, 2014). For the analysis of the definition of concepts as being macroscopic (observational), symbolic, or submicroscopic (theoretical/particulate), interpretive analysis was necessary rather than spatial analysis, as quite a few maps were skewed in terms of disposition, and the use of the concept pH depended on the context (as an expression connected to concentration, or as a measured variable).

RESULTS AND DISCUSSION

Examining sociocultural dimensions of triplet interactivity

When examining the data from the concept maps, it was clear even from this small data set that it was possible to examine sociocultural effects on degrees of student dialogue with the idea of the triplet. The two dimensions that emerged from the data in this particular study in terms of triplet dialogue were *dialogic interaction with the triplet scaffold*, which was categorized into five levels of interactivity (see table 1 and examples in figure 2) and *degrees of defined symbolic meaning*, which was categorized into five levels of specificity (see table 2).

Table 1. Categories used for differentiating varying degrees of dialogic interaction with the triplet scaffold for the two concept maps (exothermic reaction/neutralization) with degree of interaction divided by gender.

Dialogic interaction with triplet	Female (n=5)	Male (n=7)	Total (n=12)
Dialogue with scaffold concepts	0/0	4/3	4/3
Partial dialogue with scaffold concepts	1/1	2/2	3/3
Example-based concept map	3/3	1/1	4/4
Scaffold connection as afterthought	0/1	0/1	0/2
No dialogue with top	1/0	0/0	1/0
Total individuals	5	7	12

Increasing interaction

Concepts cohesively linked with all three scaffold concepts were regarded as the highest dialogic interaction, links to one or two scaffold concepts in a cohesive concept map were regarded as partial dialogic interaction, concept maps based on the example given out to the class were regarded as passively interactive, and non-cohesive concept maps with unlabeled arrows connecting to the triplet scaffold were regarded as the least dialogic. As seen in table 1, there appeared in this sample to be a gender difference in types of dialogue with the triplet scaffold. This could be interpreted as female and male students taking on more passive and active roles, respectively, in the dialogue with the triplet concept, although more data would be needed to confirm this tendency.

The dimensions of specificity of symbolic meaning were derived from how symbolic concepts were placed in the concept maps. Meanings varied from well defined (no mixed meanings), to one double (macroscopic/symbolic) meaning being given through a double scaffold connection, to symbolic concepts being placed as either macroscopic observations or particles, and finally to poorly defined (symbolic concepts being placed as both macroscopic observations and as particles in relation to the triplet scaffold) in the concept maps.

Although four of the students were aware of not understanding the differences in meaning between observational concepts, symbolic concepts and particulate model concepts, the students showing the most confusion regarding symbolic meaning in their concept maps were unaware of their difficulty (see table 2).

Table 2. Differences in symbolic meaning expressed in the students' concept maps, divided by perceived difficulties of different aspects of concept mapping reported in the student survey (N=11).

Degrees of defined symbolic meaning	**What students found difficult to understand during concept mapping**					
	All parts of mapping	Observations/ Symbols/ Models	What concepts are	What linking words are	How to make a proposition	Nothing
Well defined		X			X	
One double meaning		X				
Symbols as observations		X				
Particles as symbols	X	X		X		X
Poorly defined			X	X		X
Total individuals	1	4	1	2	1	2

Meaning increasingly specific

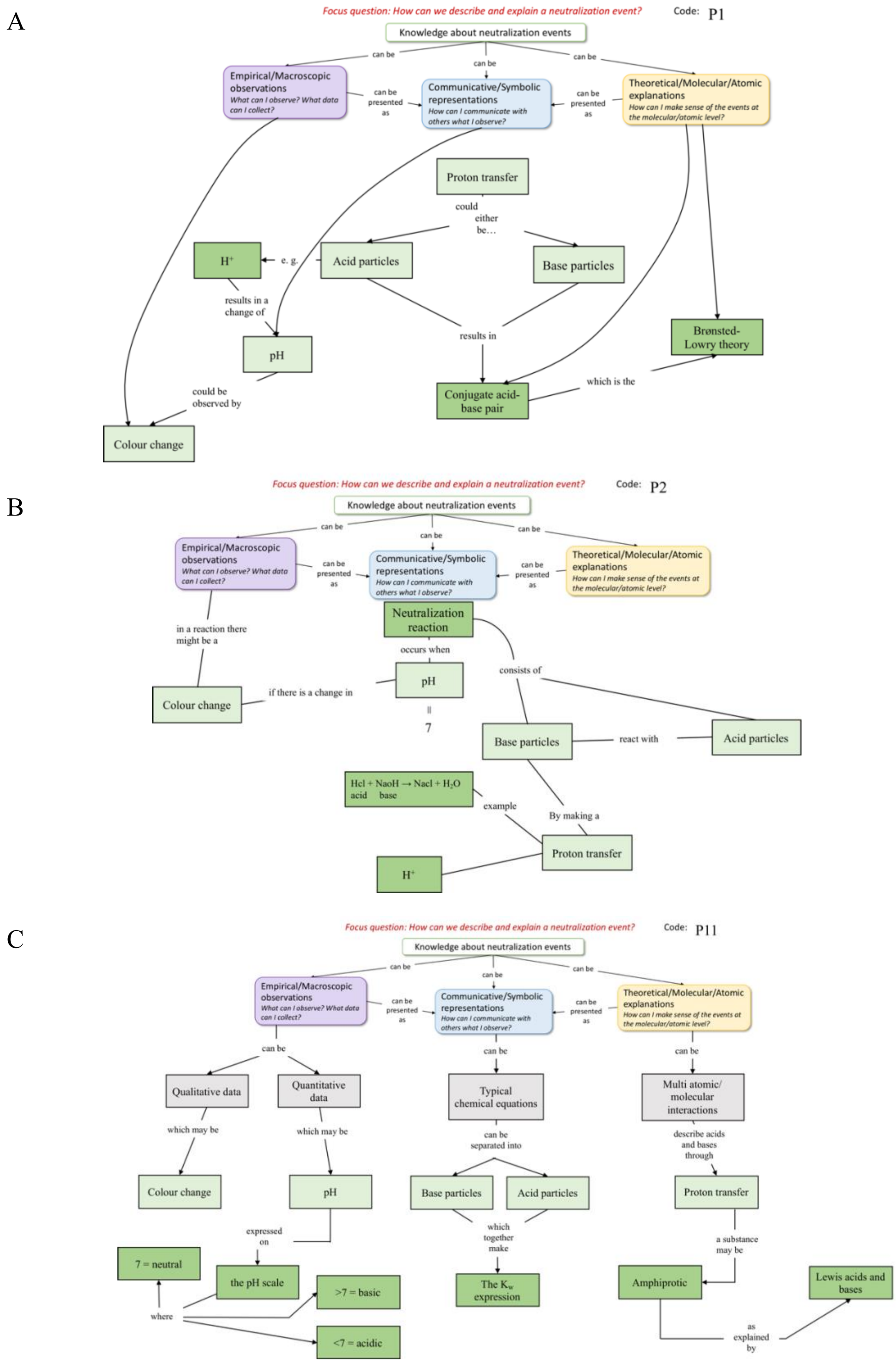


Figure 3. Examples of different degrees of dialogic interaction in the triplet concept maps produced by the students. A. Scaffold connection as afterthought (lowest degree of dialogic interaction); B. Partial dialogue; C. Model-based map (second lowest degree of dialogic interaction). Color key: grey concepts = copied from the example; light green concepts = starting concepts; dark green concepts = student's own added concepts.

In conclusion, the sociocultural framework utilized to examine how the students interacted with the triplet concept was able to detect both a variability in dialogic interaction in terms of passive and active voice, as well as a variability in definition of meaning of the symbolic representations used by the students. From a sociocultural perspective, both dialogic agency and the development of word meaning are dependent on the contextual factors surrounding social interactions (Vygotsky, 1987; Wertsch, 1991).

Examining the utility of triplet concept mapping for knowledge integration

Although the concept mapping class of 60-minutes was effective in teaching the techniques of concept mapping according to established definitions found in the literature (see Ruiz-Primo, Schultz, Li, & Shavelson, 2001; Ruiz-Primo et al., 1997), there was a slight change in how the students related to the triplet scaffold between the two concept maps produced (see table 1). This could be a sign of students having more difficulty relating to the triplet model as they are learning a new topic, but also that triplet concept mapping can improve knowledge integration for some students. With regard to how the students perceived the usefulness of concept mapping, most students (10/11) found participating in the study useful. The students having the most difficulty in defining symbolic meaning also found the concept mapping exercise the most useful (see table 3).

Table 3. Differences in symbolic meaning expressed in the students' concept maps, divided by the perceived usefulness of participating in the concept mapping class prior to an acid-base titration practical as reported in the student survey (N=11).

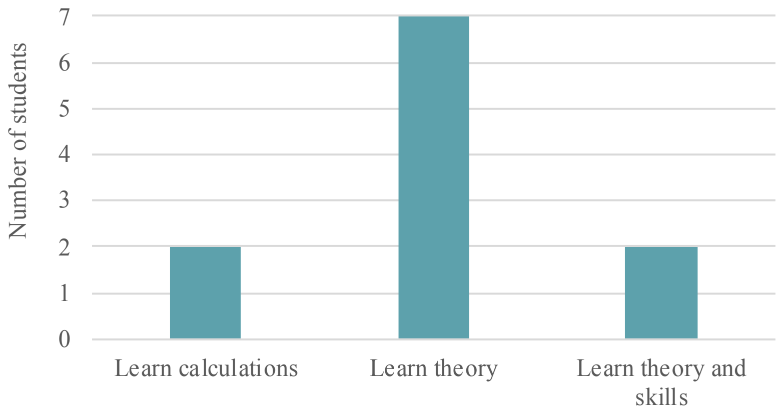
Meaning increasingly specific

Degrees of defined symbolic meaning	**Perceived usefulness of participating in the study** Quite a lot	A little	Very little
Well defined	0	1	1
One double meaning	0	1	0
Symbols as observations	1	0	0
Particles as symbols	1	3	0
Poorly defined	3	0	0
Total individuals	5	5	1

The aim of the practical undertaken the day after the concept-mapping class was perceived as mostly theoretical by the students (see figure 4), which was surprising considering the technical focus of the lab (finding the acetic acid concentration of common household vinegar through multiple titrations). This could be interpreted as a sign of knowledge integration taking place, as a high amount of theoretical thinking is unusual for students participating in science practicals (Lunetta, Hofstein, & Clough, 2007).

It would appear from this study that triplet concept mapping is a feasible method for knowledge integration that students find useful, even if they do not immediately perceive difficulties in differentiating between the three types of concepts in the study. However, it is suggested that triplet concept mapping is accompanied by social dialogue between both peers and teachers to increase meaningful understanding of the triplet model as well as dialogic interactivity.

Figure 4. Categories of students' answers to the question 'What do you think was the goal of today's laboratory exercise?' in the student survey (N=11).



CONCLUSIONS

From a sociocultural perspective, the development of student thinking occurs through reasoning utilizing cultural tools of social origin (Davydov, 1995). Hence, if students are to learn to master expert-like thinking through knowledge integration (Anderson & Schönborn, 2008) in terms of the different meanings represented by the chemistry triplet, this thinking needs to be actively encouraged through social interaction and meaningful class practices. The study presented in this paper successfully utilized a sociocultural perspective to explore the possibilities of studying contextual influences on concept development through triplet concept mapping. From this theoretical perspective, the teacher and the classroom culture can be seen as intimately connected to the students' learning, which can be defined as appropriation of cultural tools within a certain social context (Wertsch, 1991). Within this context, differences in dialogic agency and how language is used to convey meaning become important markers for how differences in language background, social class, gender or achievement level affect learning pathways within the same classroom. With its possibilities of capturing precisely these aspects of classroom learning, triplet concept mapping appears to be a useful tool for the study of conceptual development in chemistry in relation to the learning environment.

In this paper a plausible set-up for teaching triplet concept maps for knowledge integration in 60 minutes was also demonstrated, although more extensive peer and teacher dialogue is recommended to improve student agency and communication of meanings in the classroom. Indeed, previous concept-mapping knowledge integration attempts in biology has shown that high peer interactivity through dialogue produces better results than the studying of expert concept maps (Schwendimann & Linn, 2016). Previous research utilizing long-term efforts of integrating the idea of the triplet in teaching practice long-term has also shown that students can find the idea of triplet levels in chemistry initially difficult and may need time to work with the idea to appreciate it fully (Thomas, 2017). Further comparative studies would be needed to assess triplet concept mapping as a pre-lab exercise, although this study shows great promise for future research in this area as the students had a high focus on theoretical learning during the practical.

In the particular student group studied, differences were found with regard to dialogic interaction with the triplet concept, as well as how symbolic representations were defined in the classroom. However, given the small scale of this study, a larger qualitative study would be needed to fully explore differences in how students relate to chemistry triplet, taking into account classroom aspects such as social roles and how language is used to reason around chemical processes. As differences in classroom dialogic agency between genders has been well established previously (Howe & Abedin, 2013), it would be particularly interesting to study how differences in classroom dialogic agency can influence students' internal dialogic relationship with the knowledge domain of chemistry.

REFERENCES

Anderson, T. R., & Schönborn, K. J. (2008). Bridging the educational research-teaching practice gap. Conceptual understanding, part 1: The multifaceted nature of expert knowledge. *Biochemistry and Molecular Biology Education*, *36*(4), 309–315. Doi: 10.1002/bmb.20209

Ausubel, D. P., Novak, J. D., & Hanesian, H. (1978). *Educational psychology: A cognitive view*. (R. & W. Holt, Ed.). New York, NY.

Bakhtin, M. M. (1981). *The dialogic imagination: Four essays by M. M. Bakhtin* (C. Emerson & M. Holquist, Trans.). (M. Holquist, Ed.). Austin, TX: University of Texas Press.

Becker, N., Stanford, C., Towns, M. H., & Cole, R. (2015). Translating across macroscopic, submicroscopic, and symbolic levels: the role of instructor facilitation in an inquiry-oriented physical chemistry class. *Chem. Educ. Res. Pract.*, *16*(4), 769–785. Doi: 10.1039/C5RP00064E

Cañas, A. J., Novak, J. D., & Reiska, P. (2012). Freedom vs. restriction of content and structure during concept mapping - possibilities and limitations for construction and assessment. In *Concept Maps: Theory, Methodology, Technology. Proceedings of the Fifth International Conference on Concept Mapping* (Vol. 2, pp. 247–257). Retrieved from http://eprint.ihmc.us/245/

Clarà, M. (2017). How instruction influences conceptual development: Vygotsky's theory revisited. *Educational Psychologist*, *52*(1), 50–62. Doi: 10.1080/00461520.2016.1221765

Davydov, V. V. (1995). The influence of L. S. Vygotsky on education theory, Research, and practice (S. T. Kerr Transl.). *Educational Researcher*, *24*(3), 12–21. Doi: 10.3102/0013189X024003012

Duit, R., & Treagust, D. F. (2012). How can conceptual change contribute to theory and practice in science education? In B. J. Fraser, K. G. Tobin, & C. J. McRobbie (Eds.), *Second international handbook of science education* (pp. 107–118). Dordrecht: Springer.

Gilbert, J K, & Treagust, D. F. (2009). Introduction: Macro, submicro and symbolic representations and the relationship between them: Key models in chemical education. In J. K. Gilbert & D. F. Treagust (Eds.), *Multiple representations in chemical education* (pp. 1–8). Dordrecht: Springer Netherlands.

Howe, C., & Abedin, M. (2013). Classroom dialogue: A systematic review across four decades of research. *Cambridge Journal of Education*, *43*(3), 325–356. Doi: 10.1080/0305764X.2013.786024

Johnstone, A. H. (1991). Why is science difficult? Things are seldom what they seem. *Journal of Computer Assisted Learning*, *7*, 75–83. Retrieved from Doi: 10.1111/j.1365-2729.1991.tb00230.x

Johnstone, A. H. (2006). Chemical education research in Glasgow in perspective. *Chemical Education Research and Practice*, *7*(2), 49–63. Doi: 10.1039/b5rp90021b

Kozma, R., & Russell, J. (2005). Students becoming chemists: Developing representational competence. In John K Gilbert (Ed.), *Visualization in Science Education* (pp. 121–145). Dordrecht: Springer. Doi: 10.1007/1-4020-3613-2_8

Lunetta, V. N., Hofstein, A., & Clough, M. P. (2007). Learning and teaching in the school science laboratory: An analysis of research, theory and practice. In S. Abell & N. Lederman (Eds.), *Handbook of research on science education* (pp. 393–441). Mahwah, NJ: Lawrence Erlbaum Associates.

Novak, J. D. (2002). Meaningful learning : The essential factor for conceptual change in limited or inappropriate propositional hierarchies leading to empowerment of learners. *Science Education*, *86*, 548–571. Doi: 10.1002/sce.10032

Novak, J. D., & Cañas, A. J. (2008). *The theory underlying concept maps and how to construct them* (Technical Report IHMC CmapTools 2006-01 Rev 01-2008). Retrieved from http://cmap.ihmc.us/Publications/ ResearchPapers/TheoryUnderlyingConceptMaps.pdf

Novak, J. D., & Gowin, D. B. (1984). *Learning how to learn*. New York, NY: Cambridge University Press.

Ruiz-Primo, M. A., Schultz, S. E., Li, M., & Shavelson, R. J. (2001). Comparison of the reliability and validity of scores from two concept-mapping techniques. *Journal of Research in Science Teaching*, *38*(2), 260–278. Doi: 10.1002/1098-2736(200102)38:2<260::AID-TEA1005>3.0.CO;2-F

Ruiz-Primo, M. A., Schultz, S. E., & Shavelson, R. J. (1997). *Concept map-based assessment in science: Two exploratory studies* (CSE Technical Report 436). Los Angeles, CA: University of Californa, Graduate School of Education & Information Studies.

Schwendimann, B. A. (2015). Concept maps as versatile tools to integrate complex ideas: From Kindergarten to higher and professional education. *Knowledge Management and E-Learning*, *7*(1). Retrieved from http://www.kmel-journal.org/ojs/index.php/online-publication/article/download/271/271

Schwendimann, B. A., & Linn, M. C. (2016). Comparing two forms of concept map critique activities to facilitate knowledge integration processes in evolution education. *Journal of Research in Science Teaching*, *53*(1), 70–94. Doi: 10.1002/tea.21244

Stieff, M., Ryu, M., & Yip, J. C. (2013). Speaking across levels – generating and addressing levels confusion in discourse. *Chem. Educ. Res. Pract.*, *14*(4), 376–389. Doi: 10.1039/C3RP20158A

Taber, K. S. (2013). Revisiting the chemistry triplet: drawing upon the nature of chemical knowledge and the psychology of learning to inform chemistry education. *Chemistry Education Research and Practice*, *14*(2), 156–168. Doi: 10.1039/C3RP00012E

Taber, K. S. (2017). Teaching and learning chemistry. In K. S. Taber & B. Akpan (Eds.), *Science education: An international course companion* (pp. 325–341). Rotterdam: Sense Publishers.

Talanquer, V. (2011). Macro, Submicro, and Symbolic: The many faces of the chemistry "triplet." *International Journal of Science Education*, *33*(2), 179–195. Doi: 10.1080/09500690903386435

Thomas, G. P. (2017). 'Triangulation:' an expression for stimulating metacognitive reflection regarding the use of 'triplet' representations for chemistry learning. *Chem. Educ. Res. Pract.*, *18*(4), 533–548. Doi: 10.1039/C6RP00227G

Vygotsky, L. S. (1987). *Thinking and Speech.* (N. Minick, Trans.). (R. W. Rieber & A. S. Carton, Eds.), *The collected works of L. S. Vygotsky. Volume 1: Problems of general psychology*. New York, NY: Plenum Press.

Wertsch, J. V. (1991). *Voices of the mind: A sociocultural approach to mediated action*. Cambridge, MA: Harvard University Press.

THE NECESSITY OF BEING AWARE OF ANOMALOUS DATA – CONCEPTUAL DEVELOPMENT WITHIN PEER COLLABORATION

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The purpose of this paper is to shed light on the impact of discursive processes on conceptual development in a collaborative learning situation in chemistry. Conceptual development is seen as the process of constructing new conceptions or reorganise existing ones (Duit et al., 2012) which can be promoted by instructed peer collaboration (Schraw et al., 2006). We see following factors as influencing: a) adequate cognitive differences of the prior knowledge, b) argumentative complexity of the students' discursive processes, c) awareness of each other's conceptions and d) an appropriate quality of response to productively draw conclusions from each other's conceptions.

In this paper, we present a 4-step qualitative analysis, which was applied to two groups. The approach systematically revealed different dependencies of successful collaboration. We found deep insights into the quality of discursive processes as well as into the students' engagement in discussing diverse ideas (see Hundertmark, 2012). The results showed that conflicting conceptions and a complex structure of the conversation were predictive for a deep collaborative process. Comparing the two groups, a higher complexity of the conversational structure interrelates to the higher awareness of the partners' conceptual understanding as well as to more fruitful response regarding the conceptual development. So far, awareness and the quality of the students' response to each other's conceptions seem to be one relevant aspect regarding the success of collaboration.

Keywords: Conceptual Development, Collaborative Discourse, Qualitative Analysis

INTRODUCTION AND THEORETICAL BACKGROUND

The purpose of this paper is to shed light on the impact of discursive processes on conceptual development in a collaborative learning situation in chemistry. According to Taber (2001) and Duit, Gropengießer, Kattmann, Komorek, and Parchmann (2012) conceptual development is seen as the process of constructing new conceptions or reorganise existing ones that are based on learners' everyday experiences. Peer collaboration can additionally be used to promote conceptual development among students as they discuss and compare their conceptional understanding (e.g. Schraw, Crippen, & Hartley, 2006). It is assumed that reflection on one's own as well as on one's partners' understanding can foster effective conceptual reorganisation (Land & Zembal-Saul, 2003). These processes could be supported by methods or tools that help to make conceptions visible (Fischer, Bruhn, Gräsel, & Mandl, 2002; Linn, 2000; Roth & Roychoudhury, 1992). For a goal-oriented and instructed collaborative peer-to-peer collaboration process that leads to fruitful conceptual development, following factors are relevant:

a) Adequate cognitive difference: To have a reason for discussion and subsequent argumentation processes, the students need a particular conflict potential regarding their prior knowledge (e.g. Howe & Zachariou, 2019). Nevertheless, it is argued that the degree of difference requires to be appropriate, which means that students' conceptions should not be too similar or too different (Webb et al 1996). In the first case, there would be no need for discussion. In the second case, it would either be too challenging to create mutual understanding, or the group will rather accept a solution of one of the group members.

b) Argumentative complexity: The degree of engagement in discursive argumentation is associated with the depth of the responses to different concepts and further discursive development of the shared conceptions. Complex structures, where students argumentatively construct their common conceptions, are of higher collaborative quality. Whereas conversation, mainly characterised by mutually naming of initial ideas, are less structured and of lower collaborative quality (Hundertmark, 2012).

c) Awareness: In order to effectively talk about each other's conceptions and to agree upon a shared solution, the students need to be aware of differences between of their own and the partners' conceptions (Howe, Tolmie, Greer, & Mackenzie, 1995). In our study, we use the terms congruent or anomalous conceptions to express similarity or difference of conceptions.

d) Quality of response: At least, differences in learners' conceptions are necessary but not sufficient for fruitful discursive processes. Collaborative conceptual development also depends on the way how students productively draw conclusions from each other's (anomalous or congruent) conceptions (Howe & Zachariou, 2019). Responses vary in terms of different qualities and aims. A simple agreement or rejection of a partners' statement without evidence is of less quality than a chain of (conceptual) arguments that goes back and forth. In addition to b) that rather focus on a structural level this aspect takes also a conceptual dimension into account.

Within our study, the four aspects a – d serve as framework for analysing discursive processes in a collaborative learning situation. We used pre-structured worksheets that ask students to explicate their ideas multimodally through short texts, symbolic representations and drawings. Within a previous individual phase (IP), the students work on the tasks for themselves, which means, that they externalise and reflect their ideas individually. In a subsequent collaborative phase (CP), all individual solutions are presented to each other to collaboratively agree on one shared solution, which the groups fixed on an additional worksheet. The collaboration processes are supported by a collaboration script (Kollar, Fischer, & Hesse, 2006) in which learners are guided in sharing their knowledge and achieving a shared solution. The combination of an individual and a collaborative phase is seen as essential to ensure students active involvement in conceptual development processes (Heeg, Hundertmark, & Schanze, in press; Olsen, Rummel, & Aleven, 2019) and gives the students a frame to consciously reflect on each other's understanding (e.g Fellows, 1994).

RESEARCH QUESTIONS

To what extend are the following factors influencing successful collaboration: a) differences in prior knowledge, b) degree of engagement in discursive argumentation, c) awareness of anomalous data, d) reactions while confronting anomalous data?

METHOD

Data collection and participants

The study took place in different grammar schools (Gymnasium) in Germany. Negotiation processes of 30 dyads (grade 8 to 9, age 13 to 15) were audiotaped. The underlying phenomenon of the task is the combustion of carbon in a closed system (e.g. Özmen & Ayas, 2003). This topic had been covered in class prior to study.

The focusses of this paper are on the presentation of the instruments and the methodological approach. To demonstrate our procedures, results of two dyads are presented in detail. These two groups serve as exemplary types: they both start on a comparable level as they bring comparable prerequisites into the CP, based on their IP results. However, they show a distinctive progression, which can be traced back to the discursive process.

Data analysis

We used an in-depth qualitative analysis to take the process-related effects with collaborative learning into account. Differences of students' conceptions from each other and in comparison, to their shared solution have been quantitatively evaluated. Regarding aspects a-d of the RQ, the process of successful collaboration is described based on a four-step coding scheme

a) Adequate cognitive difference: For analysing the differences in students' prior knowledge, we took the answers of the IP worksheets into account and assign students' answers to a category scheme of students' conceptions (based on a literature review). This analysis took the adequateness of the content (adequate - partly adequate - inadequate) as well as the level of representation (macroscopic to submicroscopic) into account. A significant difference is given, e,g, if one student shows few adequacies on a content level as well as individual representations only on the macroscopic level whereas the partners' solution is of high adequacy on a sub-microscopic level. The potential of conflict that leads to a fruitful argumentative discussion about the students' conceptions is considered as high, if the students of one group show many strikingly different ideas that are conflictive to the partners' ideas. (e.g. coal is destroyed vs coal becomes gaseous).

b) Argumentative complexity: In a first step, we analysed the transcripts from the CP in order to find typical elements of argumentative structures like *Claim, Reason, Description/Explanation, Question, Assumption or Acceptance*. Therefore, a coding scheme developed by Hundertmark (2012) was adapted. These elements were arrayed chronologically within a flow chart, each side for one student. References to statements that was made in earlier parts of the discussion were displayed by arrows (see Fig. 1-3). Within these prepared transcripts, typical conversational patterns were analysed and categorised. A total of 14 different conversational patterns like *Monologue* (see Fig. 1), *Acknowledgement* (see Fig. 2), *Elaborative Conversation* (see Fig. 3) were identified and assigned to three different levels of complexity (low, medium and high complexity of conversational pattern). The *Monologue* has the lowest complexity as there are no references to statements of the partner. The pattern *Elaborative Conversation* is an example of higher structural complexity as it highlights that both students are involved in more in-depth content related discourse.

Figure 1. Conversational Pattern "Monoloque"

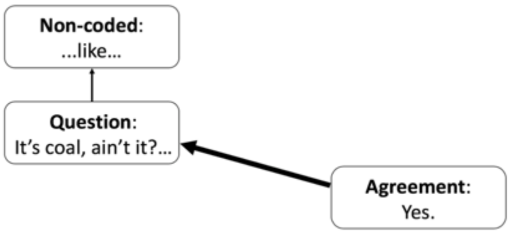

Figure 2. Conversational Pattern "Acknowledgement"

c) Awareness: Students' single statements were examined in detail regarding their awareness of equality or differences. Categories were built inductively based on Maying (2015). Different types of comments are obtained and assigned to different groups of awareness. For the analysis, we classified, whether awareness to anomalous or congruent conceptions was found or not. For our study, it was only relevant whether there is any indication of awareness of abnormality or normality. To illustrate the procedure, we refer to an example from Fig. 3, where students 1 questioned: *"…but it won't turn into ashes, will it?"*. The response of student 2 *"…I thought it was going to turn into ashes…"* point out his / her awareness of Inequality between the two statements.

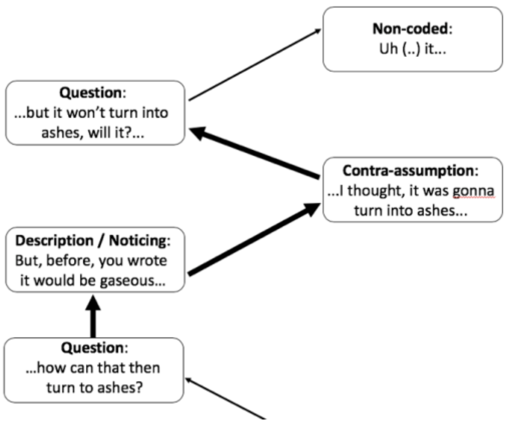

**Figure 3. Conversational Pattern "Elaborative Conversation.
Arrows highlighted in bold represent awareness of anomalous/congruent conceptions.**

d) Quality of response: This step of analysis evaluated in-depth these students' conversations, that followed a coded awareness of anomalous or congruent conceptions. As an example in the conversation part presented in Fig. 3 the statement *"…I thought, it was gonna turn into ashes…"* was interpreted as a conflicting response to the partners' conception (awareness of anomalous data) and therefore categorized as *a confrontation of opposing ideas*. These categories then were assigned according the complexity of content related argumentation in three different levels. Level-I-Responses are of low complexity and show little content relation (e.g. *statement of unknowing, acceptance of a comment*). In contrast, Level-III-Responses have a high complexity and a content-related argumentative character (e.g. *search for common ground, naming an argument for s.o. own idea*). Level-III-Responses are seen to have a higher potential for conceptual development within the discursive process.

In our study, the *success of collaboration* was determined by a positive development in student solutions when comparing worksheet results from the IP with the CP.

RESULTS

In Table 1 relevant data is aggregated from the two selected dyads. We present the results again following the four aspects of the framework.

a) The first line of Table 1 shows the degree of differences between the students' individual conceptions and its potential for a conflict. It is classified high for both groups and build a sound basis for a possible subsequent discursive process.

b) For both groups, the conversational patterns were mostly structured by type II (Group 1: 22, Group 2: 4) and III (Group 1: 16, Group 2: 4). Though, the amount of single conversational patterns differed significantly between the groups (Group 1: 42, Group2: 9), which leads to the conclusion that the argumentative process of Group 1 was more complex and more back and forth than for Group 2.

c) During the conversation, the students of Group 1 perceived 68 times anomalous conceptions of each other. 12 times congruent conceptions were noticed. For Group 2, the awareness of anomalous conceptions was counted 7 times and 2 times for congruent conceptions. In conclusion, the awareness of the partners' conceptions was rated very high for Group 1 and low for Group 2.

d) Most of the responses were classified as Level-III-Responses (50,9%) and Level-II-Responses (44,9%) in Group 1, which represented a high potential for further development of the students' conceptual understanding due to the discursive processes. In contrast in Group 2 half of the responses were classified as Level-II-Responses and the other half were evenly distributed between Level I and II. Overall, the responses of the Group 2 students represent a medium potential for further development of conceptual understanding.

At least, the overall results show differences between the groups regarding the success of collaboration (ranking of students' solution in the worksheets from IP compared to CP). The shared solution (CP) of Group 1 improved (showed higher scientific accuracy) than each individual (IP) solution, though, the shared solution was still not entirely correct. Also, the CP results of Group 2 are different to the IP results. However, regarding the adequacy (partly adequate in the CP) one student partly improved compared to his IP results, while the partner remains on the same level.

Table 1. Overview of the condensed results with regard to the analysis scheme a.-d. Interpretation of the results are summarised symbolically: high rated: +, medium rated: o, low rated:-.

	Group 1 (BP-TK)	Group 2 AA-OK
a) Differences in Prior Knowledge:		
Difference between Individuals' Conceptions	**Medium** differences in prior conceptions	**Medium** differences in prior conceptions
Probability of Conflict	**high probability** of conflict regarding discursive processes	**high probability** of conflict in regard to discursive processes
Interpretation	+	+
b) Degree of Discursive Argumentation:		
Absolute Number of Conversational Pattern	**42** single patterns	9 single patterns
Classification of Conversational structures	Type I = 2, **Type II = 22** **Type III = 16**	Type I = 1 **Type II = 4** **Type III = 4**
Rating of Complexity	Medium to high complexity of argumentative structure	medium complexity of argumentative structure
Interpretation	+	o
c) Awareness		
Perception of Anomalous Conceptions (absolute number)	68	7
Perception of Congruent Conceptions (absolute number)	12	2
Interpretation	+	-
d) Quality of Response		
Assignment to Levels of Response	Level 1: 4,05% Level 2: **44,9** % Level 3: **50,9** %	Level 1: 25% Level 2: **50**% Level 3: 25%
Probability for Development of the Conceptions	Both high	Medium
Interpretation	+	o
Success of Collaboration		
Improvement from IP to CP	Both improved	Partly improvement or constant results.

CONCLUSIONS

For a fruitful discursive collaboration aiming at conceptual development, an appropriate diversity of their conceptional understanding seems to be a sound basis. Students' conceptual understanding neither should be too similar nor too varied regarding the technical correctness. Furthermore, discursive conversations are triggered when conflicting ideas collide (e.g. mass is destroyed vs. mass cannot be destroyed). Nevertheless, all conceptions should be made explicit within a group, which highlights the need for instructed externalisation practices.

In our study we compare two dyads discussing tasks about the concept of combustion. Both groups show similar prior knowledge regarding their differences in individual conceptions about combustion, which indicates a potential conflict resulting in an intensive discursive conversation. Nevertheless, our data show that conflicting conceptions and a complex structure of the conversation alone are not predictive for the overall collaborative success, as both groups perform differently. This calls for deeper analysing the engagement on a content level. In this respect, however, there are significant differences between the groups. The argumentative processes of the groups profoundly differ concerning their complexity. Also, qualitative differences between the groups are evident in terms of awareness and response: the group with higher complexity of conversation more often show awareness of the partners' conceptual understanding as well as more fruitful response regarding the conceptual development. This leads to an interrelation between the quality of discursive collaboration and conceptual development (success of the collaboration on the level of CP results compared to IP results in the worksheets). Consequently, it is required to analyse more systematically, if the frequency of awareness and the quality of response to the partners' expressed conceptual understanding are predictive for a successful collaborative process, which is being proven by analysing further groups.

In this study, we associated the conceptual development facing the group performance by comparing the individual solutions and the collaborative solution. Next, we need to ask for the transfer of these results to the individual level, which requires an evaluation of the individual students' improvement after collaboration.

So far, our findings point to a promising methodical procedure. We used a 4-step analysis that systematically reveals different dependencies of successful collaboration. The analysis of the conversational structures is complex but useful as it gives deep insights into the quality of discursive processes as well as into the students' engagement in discussing diverse ideas (see Hundertmark, 2012). Nevertheless, the analysis of the conversation shows that taking the argumentative processes on the content level into account is necessary. So far, awareness and the quality of the students' response to each other's ideas and conceptions seem to be one relevant aspect regarding the success of collaboration.

ACKNOWLEDGEMENT

The authors would like to thank all students and teachers involved in the study for their contribution to this project.

REFERENCES

Duit, R., Gropengießer, H., Kattmann, U., Komorek, M., & Parchmann, I. (2012). The Model of Educational Reconstruction – a Framework for Improving Teaching and Learning Science1. In D. Jorde & J. Dillon (Eds.), *Science Education Research and Practice in Europe* (pp. 13–37). Rotterdam: Sense Publishers.

Fischer, F., Bruhn, J., Gräsel, C., & Mandl, H. (2002). Fostering collaborative knowledge construction with visualization tools. *Learning and Instruction*, *12*(2), 213–232.

Fellows, N. J. (1994). A window into thinking: using student writing to understand conceptual change in science learning. *Journal of Research in Science Teaching, 31*(9), 985-1001.

Heeg, J., Hundertmark, S., & Schanze, S. (in press). The interplay between individual reflection and collaborative learning: Seven essential features for designing fruitful classroom practice that develop students' individual conceptions. *Chemistry Education Research and Practice*.

Howe, C., Tolmie, A., Greer, K., & Mackenzie, M. (1995). Peer Collaboration and Conceptual Growth in Physics: Task Influences on Children's Understanding of Heating and Cooling. *Cognition and Instruction*, *13*(4), 483–503.

Howe, C., & Zachariou, A. (2019). Small-group collaboration and individual knowledge acquisition: The processes of growth during adolescence and early adulthood. *Learning and Instruction*, 60, 263-274.

Hundertmark, S. (2012). *Einblicke in kollaborative Lernprozesse: Eine Fallstudie zur reflektierenden Zusammenarbeit unterstützt durch die Methoden Concept Mapping und Lernbegleitbogen*. *Studien zum Physik- und Chemielernen: Vol. 140*. Berlin: Logos-Verl.

Kollar, I., Fischer, F., & Hesse, F. W. (2006). Collaboration Scripts – A Conceptual Analysis. *Educational Psychology Review*, *18*(2), 159–185.

Land, S. M., & Zembal-Saul, C. (2003). Scaffolding reflection and articulation of scientific explanations in a data-rich, project-based learning environment: An investigation of progress portfolio. *Educational Technology Research and Development*, *51*(4), 65–84.

Linn, M. C. (2000). Designing the Knowledge Integration Environment. *International Journal of Science Education*, *22*(8), 781–796.

Mayring, P. (2015). *Qualitative Inhaltsanalyse: Grundlagen und Techniken* (12., überarb. Aufl.). *Beltz Pädagogik*. Weinheim: Beltz.

Olsen, J. K., Rummel, N., & Aleven, V. (2019). It is not either or: An initial investigation into combining collaborative and individual learning using an ITS. *International Journal of Computer-Supported Collaborative Learning*, *3*(3), 1–29.

Özmen, H., & Ayas, A. (2003). Students' difficulties in understanding of the conservation of matter in open and closed-system chemical reactions. *Chemistry Education Research and Practice*, *4*(3), 279–290.

Roth, W.-M., & Roychoudhury, A. (1992). The Social Construction of Scientific Concepts or the Concept Map as Device and Tool Thinking in High Conscription for Social School Science. *Science & Education*, *76*(5), 531–557.

Schraw, G., Crippen, K. J., & Hartley, K. (2006). Promoting Self-Regulation in Science Education: Metacognition as Part of a Broader Perspective on Learning. *Research in Science Education*, *36*(1-2), 111–139.

Taber, K. S. (2001). The Mismatch between Assumed Prior Knowledge and the Learner's Conceptions: A typology of learning impediments. *Educational Studies*, *27*(2), 159–171.

Webb, N. M., & Palincsar, A. S. (1996). *Group processes in the classroom.* In D. Berliner & R. Calfee (Eds.), Handbook of educational psychology (pp. 841–873). New York: Macmillan.

USING THE PEER-INTERACTION-METHOD TO DIAGNOSE AND FOSTER STUDENTS' CONCEPTIONS ABOUT COMBUSTION - AN IN-DEPTH ANALYSIS ON PROMINENT STUDENTS' CONCEPTIONS AND THEIR DEVELOPMENT

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Learners show a multitude of (alternative) conceptions about many chemistry topics like processes of combustion that determine further learning processes. Teachers, therefore, need methods to diagnose these (alternative) conceptions in their classroom and to support their students' development towards scientifically adequate conceptions. Collaboration is one possible and fruitful method for supporting conceptual change processes among learners. The Peer Interaction Method (PIM) is a collaborative teaching-learning setting that helps to diagnose and foster students' conceptions at the same time. The PIM is a two-stepped method, consisting of a previous individual (IP) and a subsequent collaborative phase (CP). Currently, however, little is known about the extent to which students develop their conceptions as a result of collaborative processes. This paper aims at introducing the peer interaction method (PIM) as an instructional design to support the identification of prominent students' conceptions and their development as a result of this intervention.

Therefore, completed working sheets (N=136 students grade 8-9, grouped in 68 dyads) from one implementation were collected and analysed using a manual, consisting of 55 different conceptions about combustion. This analysis serves to identify students' conceptions before and after the collaboration. 14 different alternative conceptions can be identified, which are addressed at least five times in total by the students in their IP and CP worksheets. Six of these conceptions can be assigned to two broader content categories (e.g., "coal is destroyed"). Solely conceptions from the type "coal is destroyed" can be significantly less diagnosed in the worksheets after the CP. This finding does not apply to the other prominent alternative conceptions. Possible reasons and implications for teaching and research are discussed.

Keywords: Learners' conceptions, processes of burning and combustion, collaborative learning

INTRODUCTION AND THEORETICAL BACKGROUND

Learners have a multitude of everyday conceptions about many chemistry topics that determine further learning processes (e.g. Taber, 2019). Referring to the process of combustion, some of these conceptions are considered as being of central importance for the conceptual development, as reported in the literature (Özmen & Ayas, 2003; Prieto, Watson, & Dillon, 1992). It has been a consensus for decades that learners' conceptions are resistant even if students are instructed to change (e.g. Wandersee, Mintzes, & Novak, 1994). There is, however, no general agreement on the reasons for this resistance (e.g. Özdemir & Clark, 2007). In some cases, a firm anchoring of individual conceptions, due to students' everyday experiences, is named to be a possible reason (Amin, 2009; Niebert & Gropengiesser, 2015). Following Wandersee et al. (1994), we define those learners' conceptions, which are not congruent with a subject-related reference frame, as learners' alternative conceptions.

To support students' conceptual development towards scientifically adequate conceptions, teachers need methods to diagnose students' alternative explanations in their classroom. The first step in the evaluation process is to make them externally accessible (Driver, Asoko, Leach, Scott, & Mortimer, 1994). In general, learners are rarely aware of their conceptions, and they show difficulties in expressing them for several reasons. Therefore, reflection and externalization processes need to be supported by reasonable instructions to multimodally represent their ideas (e.g., text, drawing) (Prain, Tytler, & Peterson, 2009; Treagust, Chittleborough, & Mamiala, 2003). Also, mutual negotiation processes within collaborative learning scenarios are seen as being helpful (Hundertmark, 2012) if a previous individual confrontation and externalization processes occurred (Driver et al., 1994). However, only a few studies explicitly consider a previous and extensive individual phase (e.g. van Boxtel, van der Linden, & Kanselaar, 2000).

Collaboration is seen as fruitful for students to jointly (re)construct their conceptual knowledge (Schraw, Crippen, & Hartley, 2006; Tao & Gunstone, 1999) and to support a conceptual change among learners (e.g. Howe, Tolmie, Greer, & Mackenzie, 1995). Successful collaboration requires that all learners actively participate in the learning process and take responsibility for a common goal (e.g. van Boxtel et al., 2000). In order to structure a complex collaborative learning processes, Kollar, Fischer, and Hesse (2006) suggest the implementation of specific collaboration scripts.

Based on these essential features, we developed the Peer-Interaction-Method (PIM) as a two-stepped collaborative teaching-learning format (Heeg, Hundertmark, & Schanze, submitted), which can be used to simultaneously diagnose and foster students' individual conceptions (see Figure 1). The PIM consist of a previous individual (IP) and a subsequent collaborative phase (CP).

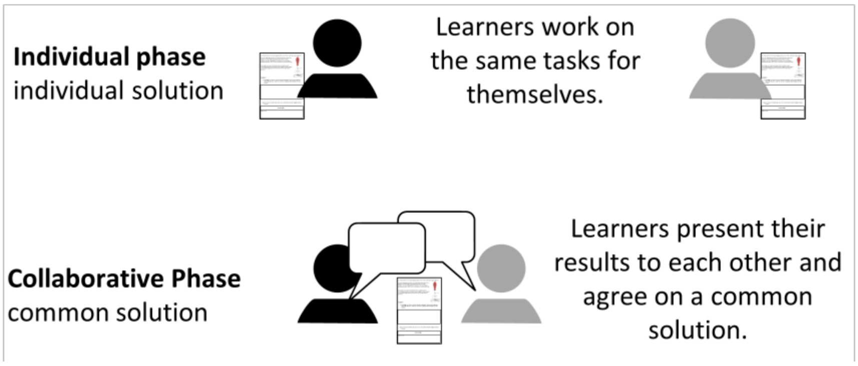

Figure 1. The two phases of the PIM illustrated here for dyads.

This paper aims at introducing the peer interaction method (PIM) as an instructional design to support the identification of prominent students' conceptions and their development as a result of this intervention. Currently, in the field of chemical education, little is known about the extent to which students develop their conceptions due to collaborative processes. Regarding this desideratum, this paper gives insights into students’ conceptual development due to collaborative negotiation processes.

RESEARCH QUESTIONS

RQ1: To what extent are learners encouraged by the PIM to externalize their individual conceptions, and which of these alternative conceptions can be identified as prominent ones?

RQ2: To what extent are the prominent learners' alternative conceptions developing as a result of the collaborative phase?

METHOD

Participants, data collection and analysis

The study took place in several high schools (Gymnasium) in Germany. IP and CP worksheets of 136 students (55.1% female, grade 8-9 and grouped in 68 dyads) were collected and analysed by two raters (κ = .83) using a coding manual which consists of 55 already published scientifically adequate as well as alternative conceptions about combustion (Heeg, Hundertmark, & Schanze, in press). The students who participated in this study were recruited voluntarily by their teachers and free to choose their partner. All students were familiar with the underlying phenomena; accordingly, the conceptions were raised after instruction. The worksheets consist of four different tasks (T1: multiple-choice with T2: open ended second tier question, T3: reaction scheme, and T4: drawing task see Figure 2). All tasks include the combustion of (char-)coal in a closed system (Heeg, Hundertmark, & Schanze, in press).

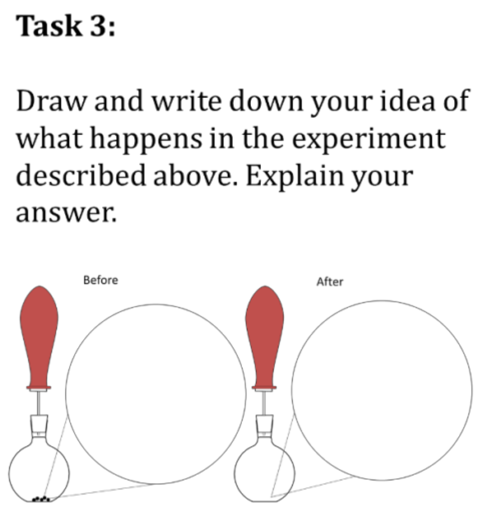

Figure 2. The drawing task (task 3).

RESULTS

RQ1: Externalization of (prominent) learners' conceptions

In total, 14 out of these 23 alternative conceptions are diagnosed minimum five times in the learners' worksheet (IP and CP) and are defined here as prominent learners' alternative conceptions (see table 1). These 14 prominent conceptions have been diagnosed a total of 539 times in across the worksheets.

The result of an exploratory factor analysis (KMO=.612, oblimin rotation) shows that only two factors (categories), each with three variables (conceptions), can be found, in which the eigenvalue of the factors is greater than 1 and the factor loadings greater 0.4 (Stevens, 2012). Subsequently, these six prominent alternative conceptions can be assigned to the two different categories *coal is destroyed*, and *coal becomes gaseous*. Reliability analysis using Cronbach' s-Alpha show values of .76 for category 1 and .74 for category 2. This does not apply to the remaining eight students' conceptions which, for example, relate to aspects like *gases weigh less than solids* (C3) or *ash is a product* (C26). The results in table 1 also show that category 2 conceptions can be found in more than half of all worksheets.

Table 1. Overview over the 14 prominent learners' conceptions.

Conception	N	% (N=204)
Category 1: Coal is destroyed		
Coal atoms are destroyed / Coal is destroyed *without* mentioning the emergence of new substances (C15a)	33	16.18
Carbon dissolves and there is no substance left (C19)	32	15.69
Submicroscopic entities (e.g. atoms) are destroyed / macroscopic entities (e.g. substances) are destroyed without mentioning the emergence of new entities (C1)	22	10.78
Category 2: Coal becomes gaseous		
The appearance or properties of some reactant have changed, the substance (e.g. coal) still exists (C14)	121	59.31
Coal changes its condition of aggregation (e.g. it evaporates) (C11)	110	53.92
The product is a different gas than carbon dioxide (C30)	110	53.92
Category 3: Other prominent conceptions		
Gases weigh less than solids (C3)	33	16.18
The product mixes with the oxygen (C36)	19	9.31
Due to the buoyancy of gases, the flask weighs less (C5)	15	7.35
Carbon monoxide is the only product (C27)	14	6.86
Due to another modification of the substance, the flask weighs less (C6)	10	4.9
Ash is a product (C26)	8	3.92
Gases weigh nothing (C4)	7	3.43
Oxygen molecules are destroyed / Oxygen is destroyed *without* mentioning the emergence of new substances (C16a)	5	2.45

Additionally, the six prominent conceptions (conceptions from categories 1 and 2) are distributed over three tasks within the worksheets (T2-T4). Concerning the residual eight conceptions (category 3), only C5 and C26 were frequently represented. Out of the 14 prominent alternative conceptions, a maximum of 8 conceptions can be diagnosed simultaneously in the worksheets (see Figure 2). In most worksheets (24%), three different alternative conceptions can be identified parallelly. But, in about 22 percent, none of the 14 prominent alternative conceptions can be found in the worksheets.

RQ2: Development of (prominent) conceptions

The total number of prominent alternative conceptions per worksheet decreases significantly from IP to CP (see figure 3) when tested with Wilcoxon Signed Rank test ($z = 3{,}76$, $p < .000$). Besides, conceptions from the category *coal are destroyed* can be significantly less diagnosed in the worksheets after the CP (see table 3) with medium effect sizes. These results have not been confirmed for the other prominent conceptions.

Table 3. Development of some prominent learners' conceptions.

Conception	Wilcoxon test	IP (N=136) %	CP (N=68) %
Category 1: Coal is destroyed			
Submicroscopic entities (e.g. atoms) are destroyed / macroscopic entities (e.g. substances) are destroyed without mentioning the emergence of new entities (C1)	z = 2.35, p = .019, d = .41	11.76 %	5.88 %
Coal atoms are destroyed / Coal is destroyed *without* mentioning the emergence of new substances (C15a)	z = 2.60, p = .009, d = .46	20.59 %	7.35 %
Carbon dissolves and there is no substance left (C19)	z = 2.88, p = .004, d = .51	16.91 %	8.82 %

Concerning conceptions of category 2 a positive development is found. Among other factors, this development is interrelated to the extent to which the learners already showed these conceptions in the individual phase (see table 4). Overall, medium size connections between these factors can be found for conceptions from the category 2 (for the other prominent conceptions see Appendix 1).

Table 4. Occurrence of conceptions from category 2 in the CP in dependence of the IP results.

	C11 (%)		**C14 (%)**		**C30 (%)**	
	Not diagnosed in the CP	**Diagnosed in the CP**	**Not diagnosed in the CP**	**Diagnosed in the CP**	**Not diagnosed in the CP**	**Diagnosed in the CP**
Not diagnosed in the IP	90	10	95	5	91	9
Diagnosed in only one IP	45	55	40	60	56	44
Diagnosed in both IP	43	57	22	78	29	71
Cramér's V	V = .43, p = .002		V = .53, p < .0001		V = .42, p = .003	

The results from Table 4 show that if only in one learners' IP worksheet a specific conception can be found, this conception cannot be diagnosed in the common product in between 40 (C14) to 56 percent (C30) of the cases.

DISCUSSION AND OUTLINE

Previously published scientifically accepted as well as alternative conceptions build the basis for the development of this coding manual (Heeg, Hundertmark, & Schanze, in press). Hence, the coding manuals' purpose was to evaluate students' conceptions deductively, which helped to ensure the validity of the survey.

Analysis of the data shows that 14 different alternative conceptions occur more frequently than other conceptions in the context of this study. Six of these 14 prominent alternative conceptions can additionally grouped into two major content categories (factors). However, the explained variance by these two factors is only about 29 percent. Based on this and due to the small sample size, these results have to be replicated in further studies.

The results of this study also illustrate that the learners' IP worksheets show, on average, only in one about 20 percent no indication for prominent alternative learners' conceptions. This is even more remarkable since the entire survey took place after instruction. In addition, the results indicate a co-existence of diverse conceptions on the same topics and at the same time for the same students which is consistent with Taber (2019).

As previously mentioned, some conceptions (C1, C15a, C19) developed positively due to the PIM. However, this study did not investigate whether and to what extent this is a sustainable effect. Chinn and Brewer (1993) were able to show that learners, when confronted with different conceptions (anomalous data), use different coping strategies. Part of these strategies can, for example, be a superficial acceptance. In this context, Tao and Gunstone (1999) show that learners must recognize a meaning in the new conceptions in order for a long-term change to take place.

Regarding all prominent alternative conceptions, however, it has to be stated that they do not significantly change. When planing their lessons, teachers should take these results into account. In general, instructions need to build upon those prominent conceptions to help students' conceptual development. The data also indicates that some learners' conceptions (e.g. C11, C14, C30) do hardly develop within this intervention and the instruction before. One possible reason for this could be that these everyday conceptions are firmly anchored in the students' daily world (Amin, 2009; Niebert & Gropengiesser, 2015). Consequently, the students hold on using these conceptions instead of the scientifically adequate ones (see also Andersson, 1990; Prieto et al., 1992). Therefore, more theory-based learning offers should be developed and evaluated, especially for these conceptions to support learning processes as these conceptions do not change without tailormade external learning prompts.

The study leaves open how the processes of collaboration and negotiation influence the students' conceptual development. However, the results indicate that there are positive conceptual developments, even if both learners have shown indicators for a specific prominent alternative conception on their individual worksheets. Yet, we do not know the reason for this. Therefore, we analyse audiotapes of the collaborative phase from 30 (out of the 68) dyads. The question of this analysis refers to the collaborative and discursive conditions that promote the development of specific conceptions. We currently assume that willingness to reach an agreement, the awareness of different or comparable conceptions between the learners as well as the quality of response to the partners' conceptions are predictive.

REFERENCES

Amin, T. G. (2009). Conceptual Metaphor Meets Conceptual Change. *Human Development*, *52*(3), 165–197. https://doi.org/10.1159/000213891

Andersson, B. (1990). Pupils' Conceptions of Matter and its Transformations (age 12-16). *Studies in Science Education*, *18*(1), 53–85. https://doi.org/10.1080/03057269008559981

Chinn, C. A., & Brewer, W. F. (1993). The Role of Anomalous Data in Knowledge Acquisition: A Theoretical Framework and Implications for Science Instruction. *Review of Educational Research*, *63*(1), 1–49.

Driver, R., Asoko, H., Leach, J., Scott, P., & Mortimer, E. (1994). Constructing Scientific Knowledge in the Classroom. *Educational Researcher*, *23*(7), 5–12. https://doi.org/10.3102/0013189X023007005

Heeg, J., Hundertmark, S. & Schanze, S. (in press). The interplay between individual reflection and collaborative learning. Seven essential features for designing fruitful classroom practice that develop students' individual conceptions. *Chemistry Education Research and Practice.*

Howe, C., Tolmie, A., Greer, K., & Mackenzie, M. (1995). Peer Collaboration and Conceptual Growth in Physics: Task Influences on Children's Understanding of Heating and Cooling. *Cognition and Instruction*, *13*(4), 483–503. https://doi.org/10.1207/s1532690xci1304_2

Hundertmark, S. (2012). Einblicke in kollaborative Lernprozesse: Eine Fallstudie zur reflektierenden Zusammenarbeit unterstützt durch die Methoden Concept Mapping und Lernbegleitbogen. Studien zum Physik- und Chemielernen: Vol. 140. Berlin: Logos-Verl.

Kollar, I., Fischer, F., & Hesse, F. W. (2006). Collaboration Scripts – A Conceptual Analysis. *Educational Psychology Review*, *18*(2), 159–185. https://doi.org/10.1007/s10648-006-9007-2

Niebert, K., & Gropengiesser, H. (2015). Understanding Starts in the Mesocosm: Conceptual metaphor as a framework for external representations in science teaching. *International Journal of Science Education*, *37*(5-6), 903–933. https://doi.org/10.1080/09500693.2015.1025310

Özdemir, G., & Clark, D. B. (2007). An Overview of Conceptual Change Theories. *EURASIA Journal of Mathematics, Science & Technology Education*, *3*(4), 351–361.

Özmen, H., & Ayas, A. (2003). Students' difficulties in understanding of the conservation of matter in open and closed-system chemical reactions. *Chemistry Education Research and Practice*, *4*(3), 279–290. https://doi.org/10.1039/B3RP90017G

Prain, V., Tytler, R., & Peterson, S. (2009). Multiple Representation in Learning About Evaporation. *International Journal of Science Education*, *31*(6), 787–808. https://doi.org/10.1080/09500690701824249

Prieto, T., Watson, R., & Dillon, J. (1992). Pupils' understanding of combustion. *Research in Science Education*, *22*(1), 331–340. https://doi.org/10.1007/BF02356913

Schraw, G., Crippen, K. J., & Hartley, K. (2006). Promoting Self-Regulation in Science Education: Metacognition as Part of a Broader Perspective on Learning. *Research in Science Education*, *36*(1-2), 111–139. https://doi.org/10.1007/s11165-005-3917-8

Stevens, J. P. (2012). Applied multivariate statistics for the social sciences: Routledge.

Taber, K. S. (2019). Alternative Conceptions and the Learning of Chemistry. *Israel Journal of Chemistry*, *59*(6-7), 450–469. https://doi.org/10.1002/ijch.201800046

Tao, P.-K., & Gunstone, R. F. (1999). Conceptual change in science through collaborative learning at the computer. *International Journal of Science Education*, *21*(1), 39–57. https://doi.org/10.1080/095006999290822

Treagust, D. F., Chittleborough, G., & Mamiala, T. (2003). The role of submicroscopic and symbolic representations in chemical explanations. *International Journal of Science Education*, *25*(11), 1353–1368. https://doi.org/10.1080/0950069032000070306

Van Boxtel, C., van der Linden, J., & Kanselaar, G. (2000). Collaborative learning tasks and the elaboration of conceptual knowledge. *Learning and Instruction*, *10*(4), 311–330. https://doi.org/10.1016/S0959-4752(00)00002-5

Wandersee, J., Mintzes, J. J., & Novak, J. D. (1994). Research on alternative conceptions in science. In D. L. Gabel (Ed.), *Handbook of research on science teaching and learning: A project of the National Science Teachers Association* (pp. 177–210). New York, NY: Macmillan.

Appendix 1:

Table 5. Occurrence of prominent alternative conceptions in the CP in dependence of the IP results.

	C1 (%)		C3 (%)		C4 (%)		C5 (%)		C6 (%)		C15a (%)		C16a (%)		C19 (%)		C26 (%)		C27 (%)		C36 (%)	
	ND*	D	ND	D	ND	D	ND	D	ND	D	ND	D	ND	D	ND	D	ND	D	ND	D	ND	D
None IP	98	2	88	12	98	2	100	0	98	2	98	2	100	0	94	6	100	0	97	3	97	3
Only one IP	70	30	73	27	80	20	75	25	50	50	84	16	75	25	87	13	83	17	86	14	43	57
Both IP	-	-	33	67	-	-	-	-	0	100	100	0	-	-	0	100	-	-	0	100	50	50
Cramér's V	V = .43, p < .000		V = .32, p = .32		V = .28, p = .19		V = .48, p < .000		V = .69, p < .000		V = .26, p = n.s.		V = .49, p < .000		V = .40, p = .004		V = .39, p = .001		V = .51, p < .000		V = .58, p < .000	

* ND: not diagnosed in the CP worksheet, D: diagnosed in the CP worksheet

FOSTERING DIVERSITY AND CULTURAL AWARENESS EMANATED FROM LEARNING ONE'S CONTEXT

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In recent years, technology - enhanced learning environments bring parts of the world into the classroom. This paper values the importance of integrating cultural elements into the construction of scientific knowledge through educational practices, especially during the first school years of an individual. The evidence is drawn from a research project based on the implementation of a context effect-innovative learning strategy involving the use of technology to facilitate exchanges between learners around the globe. In our study case, putting synchronous and asynchronous forms of communication into practice between students in Guadeloupe and in Quebec, we identify the extent of children's active construction of scientific and global knowledge nurtured within intercultural experiences. Participants were asked to supply answers (during the post-test questionnaire phase) related to their impressions and the milestones acquired during communication with diverse cultures -peoples and contexts. As a result, the intricate world of their understanding inspired by their intercultural exchanges has been qualitatively classified into different categories and presented in this article for further exploration.

Keywords: Culture, Context-effects, Collaborative Online Learning

INTRODUCTION

Societal and cultural factors have an important impact on children's development, in particular when they form their identity and when they shape their mental representations of the world. As one's cognitive development is built upon the interpretation of different schemas (Piaget, 1926), children tend to interpret their environment by elucidating information within the intellectual experiences they undergo. In a social-constructivist approach, young children construct actively their own learning and making sense of the world when interacting and collaborating with others (Vygotski & Sève, 1985). Alongside, cultural artifacts -as means of society's values, events, symbols- provide a vital framework for individuals to collect units of knowledge of other people's way of living and share meanings with them. In the realm of education, the intercultural dimension is portrayed as one of the more important objectives of learning procedure: one's decentration from their own cultural-based assumptions by reconceptualizing their worldviews in consistency with appreciating other people's contexts (Scarino et al., 2009). Regarding scientific thinking, learners can reflect on and investigate their natural environment by making inquiries (Cariou, 2009) which will then help them to answer specific questions leading to the development of a general and worldwide content (Gauch, 2009). Considering all the aforementioned, the outpouring of scientific interest and work of people is enhanced by the implementation of learning experiences putting them in collaboration - a procedure whose communication is undoubtedly nurtured when one creates and exchanges meanings across cultures, across contexts. Acknowledging the huge potential of new technologies into teaching and learning practices, it is now possible for learners around the world to maintain ties with their peers and to construct their knowledge and views in a computer-supported collaborative environment. The advances in virtual collaboration reveal many opportunities for connecting online learners in the spirit of real-world and authentic learning situations (Bonk & Cunningham, 1998). In some respects, exploiting the collaborative aspect of learning and meaning making mediated by technology (Baker, 2003; Dillenbourg, 1999) children are prone to develop a positive aspect towards community participation and as an extension towards the concept of global citizenship for civil society.

THEORETICAL FRAMEWORK

General theoretical model and context-effects

This study is a part of a larger project, under the name "Technologies Éducatives pour l' Enseignement en Contexte -TEEC" (in French), "Educational Technologies for Teaching in Context" (in English). It is funded by the French National Research Agency (ANR) and the Quebec Research Funding for society and culture (FRQSC). Its objectives entail the development and implementation of a learning approach based on context-effects between learners in Guadeloupe and in Quebec (Forissier et al., 2017). In essence, students from different contexts collaborate together in short-term research projects, linked to different scientific disciplines: geothermal energy, sustainable development, linguistics, socio-history. Their exchanges (oral or written) flourish through synchronous and asynchronous communication environments. In each experimentation, students who are normally in small groups, they are asked to investigate a particular aspect of a given object of study strongly related to their enriched context. During their inquiry process, they interpret information of their context by exchanging and discussing on diverse topics with their peers. In this way, they relate their findings to the findings of others, and they enrich their knowledge by situating their unit of knowledge in respect of relevance and meanings. Throughout students' exchanges during these research practices, a conceptual change is expected by grounding a clash between students' perceptions in those particular contexts, hereby an emergence of a context effect, in the study of the same object or concept (Merlo-Leurette & Forissier, 2009).

Review on cultural competences

Online interactions and collaborations offer huge potentials for developing students' skills. The work of Marope et al. (2017) states that future curricula (4.0) will be based upon learners' competencies such as social and cultural awareness but the need of understanding the demands of learner's context is essential. Having learners from Guadeloupe and Quebec as participants in these experimentations has raised our interest, among other things, in investigating the perspectives of cultural competences issued of their exchanges. For defining the latter, we cite the work of Cross et al. (1989) which refers to cultural competence as "a set of congruent behaviors, attitudes, and policies that come together in a system (..) and enable that system (..) to work effectively in cross-cultural situations". According to Jason (2014) , this is "an ongoing process by which individuals and systems respond respectfully and effectively to people of all cultures, languages, classes, races, sexes, ethnic backgrounds, religions, sexual orientations, abilities and other diversity factors". Undergoing this process means that an individual should go through different phases, known as a cultural continuum (Cross, 2012), from cultural destructiveness to cultural proficiency. Some phases in between those two extremes refer to cultural incapacity, to cultural blindness or to cultural pre-competence. In essence, according to Hall (1989). "In its many forms, culture (..) designates what we pay attention to and what we ignore". As a result, individuals tend to adopt different communication strategies into a process which is called "contexting' by which they filter and evaluate the kind of information they would like to obtain or share with others (Zakaria & Cogburn, 2010). The same work adds that when individuals from diverse cultural backgrounds communicate, the understanding of this process is what helps on overcoming or minimizing cultural differences.

RESEARCH METHOD & DESIGN

The general methodology of the TEEC project is the one of Design-Based Research – DBR (Bourdeau, 2017). Data concerning the influence of context-effects on participants' learning outcomes were collected by pre-test and post-test questionnaires.

Study's focus and research questions

This work focuses in particular on two in-situ experimentations that took place in primary schools: one focusing on linguistics (object of study: folktales of Antilles, of Québec) and the other one on education for sustainable development (object of study: sugarcane, maple syrup). Following the iterative feature of DBR (Akker, 2006), when designing the post-test questionnaire, we added a number of questions in order to measure validly children's' feedback and retain their impressions emphasizing on their own context and the context of their peer team. The general content of additional questions is displayed in the Figure 1 and they are further explained in detail later on this article (cf. Content analysis approach).

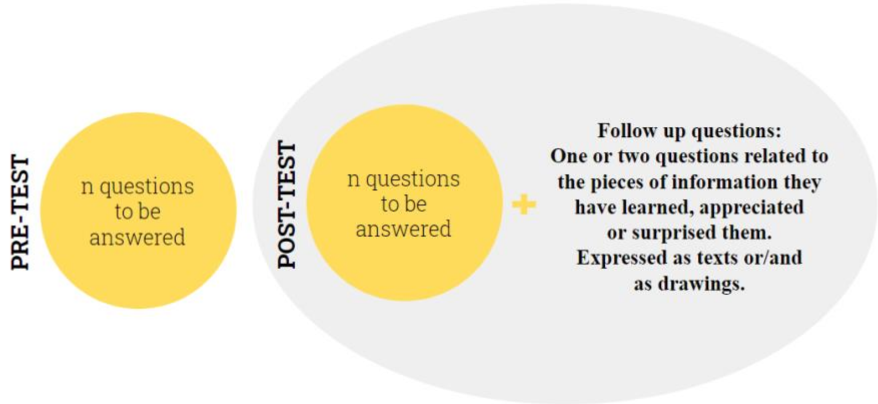

Figure 1. Additional questions in post-test questionnaires for each experimentation.

The main research questions addressed in this study are summarized as follows:

RQ1: Which kind of context is elaborated during the scientific learning and understanding of young learners from different contexts?

RQ2: What type of elements of cultural understanding emerge after the completion of a didactic and collaborative experience between young learners from different contexts?

Content analysis approach

First of all, we provide an overview of the questions asked to the participants of this study. For the experimentation "Linguistics" the question was the following:

- Write in a few words or/and draw what impressed (or surprised) you during the exchanges with the students of the other class.

For the experimentation in "Education for Sustainable Development" the questions were the following:

- What did you learn during the exchanges with the students of the other class?
- Write in a few words or/and draw what impressed you (in our context, in the other context).

These are considered as open questions and the drawing task was proposed as in some cases is an effective communication tool for young children (Farokhi & Hashemi, 2011). For the purpose of examining the RQ1, we perform an inductive content analysis (Bengtsson, 2016) of the answers provided. For each participant, written texts or/and drawings in response to one follow-up question were processed as a single unit of analysis. For the RQ2, our analysis is inspired by the framework on cultural dimensions proposed by (Overall, 2009) which was in fact designed for library and information science (LIS) scholars.

FINDINGS

This study involves children aged 10-12 years old from Guadeloupe and Quebec who participated in the two aforementioned experimentations. The data retrieved from their answers (N=43 from Guadeloupe, N=46 from Quebec) in the questions mentioned before during their post-test questionnaires. Their replies were formed after participating in learning situations, involving verbal and nonverbal communication during synchronous sessions (regular videoconferences) and information shared respectively in an asynchronous communication platform, in our case the social learning platform called Edmodo (www.edmodo.com).
In respect of our exploratory research design, our analysis focuses on identifying patterns and characterized the elements emerged during their intercultural exchanges.

Highlighting the context-effects

When examining the answers given, distinctions are drawn between three different scales (micro, meso, macro). We highlight that these effects have been categorized upon the ideas expressed in their replies. More specifically, we investigate if the content was demonstrating a concept embodied either by observing their real environment or by exchanging with the learners from the other context. The categories are the following:

1. Related to *didactic context (course)*: elements representing the subject content learning and teaching, content knowledge related to the object of study (folktales, sugarcane/maple syrup) of the experimentations they have participated
2. Related to *educational context (institutional settings)*: elements representing the existing conditions and the culture of the school, educational practices and strategies occurring in the school environment
3. Related to the *socio-cultural context (society)*: elements representing climate, language, habits, traditions and lifestyle in the outside world

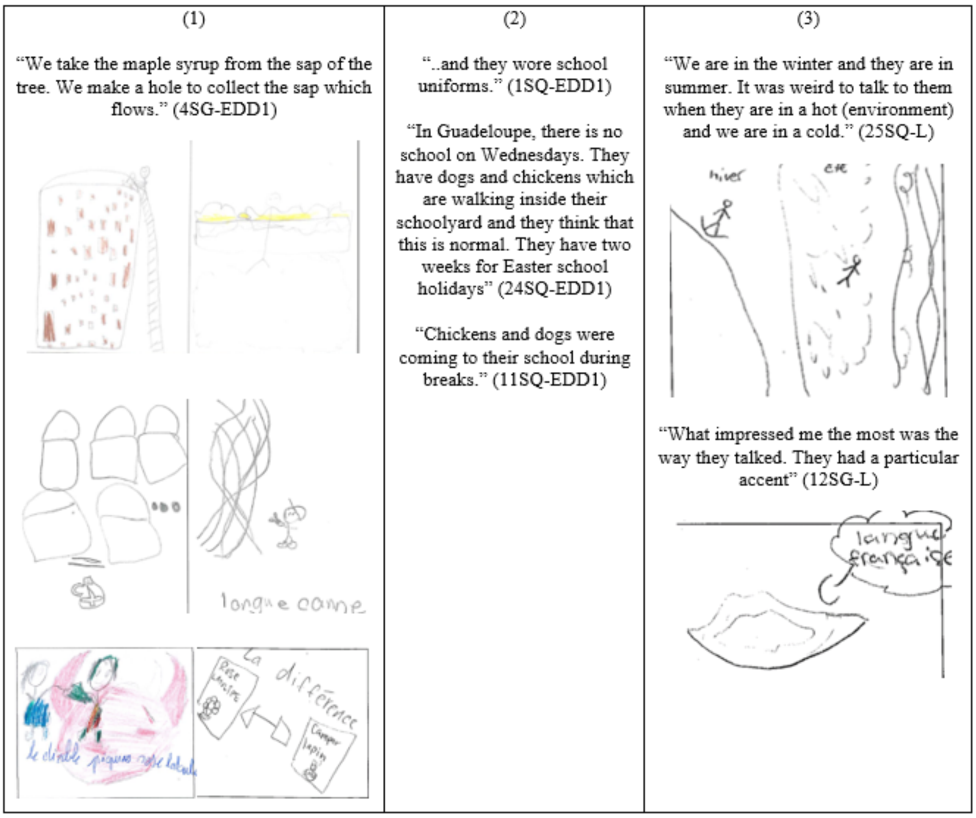

Figure 2. Examples of didactic (1), educational (2), socio-cultural (3) context.

Figure 2 depicts a small sample of the answers provided from the student of the two contexts for each category. We need to note that in general children illustrate examples of things they saw during the videoconferences, information communicated to them from their peers via verbal or non-verbal cues, aspects they observed during their field trips with their classmates.

Cultural competences in perspective

As mentioned before for investigating the presence of cultural competences stemming from the exchanges between learners from Guadeloupe and Quebec, our work is inspired by the framework proposed by (Overall, 2009). According to this article, cultural competences encompass three dimensions: the cognitive, the interpersonal and the environmental one. Along with the classification we performed during the previous section, we believe that most answers included in the third category (cf. socio-cultural context) could be further analyzed into the perspective of cultural competence as those elements exhibit a form of cultural understanding and awareness. Hence, in this section we present a sample of examples that demonstrate cultural competences in the following categories:

1. *Cognitive dimension*: Elements showing individual perceptions for their culture in the alignment with the culture of others, their general knowledge about the culture of others.
2. *Interpersonal dimension:* Elements showing emotions and abilities to collaborate and communicate with others.
3. *Environmental dimension:* Elements showing the understanding of different conditions of a culture (environment, language, natural resources)
4. *Not classified:* Examples that could not be classified in the dimensions mentioned before.

To illustrate these dimensions, in the Figure 3 we present a sample of the answers provided by learners from both contexts.

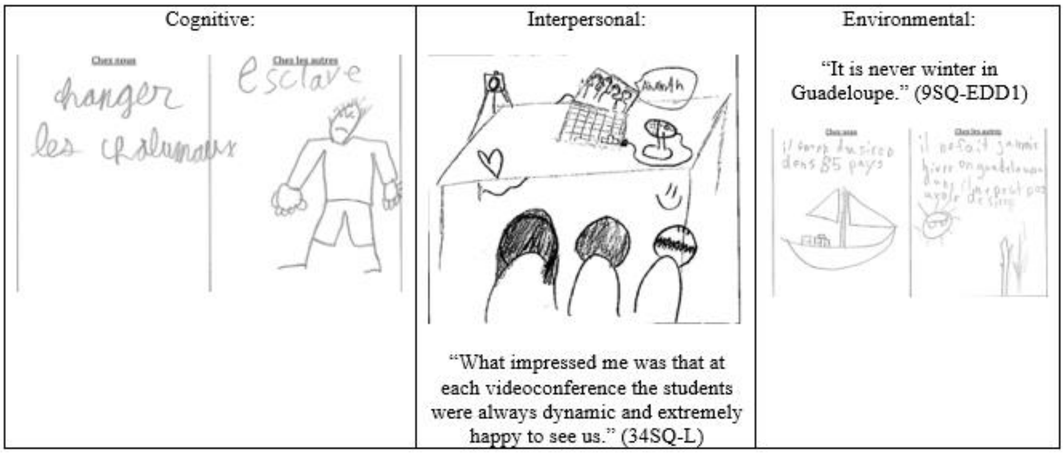

Figure 3. Examples of dimensions of cultural competences.

DISCUSSION

This study demonstrates some preliminary results on the different types of context that can be found in an evaluation phase of a learning experience involving an international audience, in our case students from Guadeloupe and Quebec. However, it is important to highlight some of the limits of this study:

a) In this case study we have a small sample size.
b) Our contexts are Guadeloupe and Quebec, so we cannot generalize all findings for other contexts in interaction.
c) No post-interviews were conducted after the completion of the post-questionnaires.

It provides an insight on the context-effects that can be evoked during this procedure and additionally on the use of these data to further investigate the cultural competences introduced to young learners. The analysis on cultural competences need to be further explored.

CONCLUSION

As child expression is in their nature, there is a huge need of providing them more exciting pedagogical opportunities which will enable them to co-create their worldwide perceptions and build their knowledge in collaboration and in a creative way. Interpreting and revealing elements of their feedback on a research project which supports their intercultural development in practice validates the identification of all these artifacts promoting cultural diversity awareness among them. Sfard (1998) points out the importance for a learner to participate in various social-meditated activities (participation metaphor in learning theories) within a community of knowledge. Transforming learning in the era of computer-mediated environments into making-meaning events rich in discussions and intercultural exchanges is a challenging task for the future. Up to this point, the advances in technological tools can instill empowerment to children regarding the exciting adventure that they will face in the future. The development of learning practices such the one described can embrace innovation in education, more specifically in scientific investigations, along with opening a channel of communication with others. To conclude, as Byram et al. (2001) highlights: "it is not the purpose of teaching to try to change learners' values, but to make them explicit and conscious in any evaluative response to others".

ACKNOWLEDGEMENT

This work has been supported by the project ANR-FRQSC no 2017-QF-210862. Thanks to Blaze H., Daibissaram L., Dorville D., Ferga L., Garime Y., Jasawant-Ghiraou G., Paupy S., (students of the M2 Pratiques et Ingénierie des Didactiques Contextuelles (PIDC) – INSPE Guadeloupe – promo 2019) for discussions.

REFERENCES

Akker, J. J. H. van den (Ed.). (2006). *Educational design research*. Routledge.

Baker, M. (2003). Computer-Mediated Argumentative Interactions for the Co-Elaboration of Scientific Notions. In J. Andriessen, M. Baker, & D. Suthers (Eds.), *Arguing to Learn* (pp. 47–78). Springer Netherlands. https://doi.org/10.1007/978-94-017-0781-7_3

Bengtsson, M. (2016). How to plan and perform a qualitative study using content analysis. *NursingPlus Open*, *2*, 8–14. https://doi.org/10.1016/j.npls.2016.01.001

Bonk, C. J., & Cunningham, D. J. (1998). Searching for learner-centered, constructivist, and sociocultural components of collaborative educational learning tools. In *Electronic collaborators: Learner-centered technologies for literacy, apprenticeship, and discourse.* (pp. 25–50). Lawrence Erlbaum Associates Publishers.

Bourdeau, J. (2017). The DBR Methodology for the Study of Context in Learning. In *Modeling and Using Context* (Vol. 10257, pp. 541–553). Springer International Publishing. https://doi.org/10.1007/978-3-319-57837-8_44

Byram, M., Nichols, A., & Stevens, D. (Eds.). (2001). *Developing intercultural competence in practice*. Multilingual Matters, p.7.

Cariou, J.-Y. (2009). *La conception codisciplinaire de métaressources comme appui à l'évolution des connaissances des professeurs de sciences: Les connaissances qui guident un travail de préparation pour engager les élèves dans l'élaboration d'hypothèses ou de conjectures*. http://www.theses.fr/11882435X

Cross, T. L. (2012). *Cultural Competence Continuum*. *24*(Child and Youth Care Work), 83–85.

Cross, T. L., Dennis, K. W. , & Isaacs, M. R., & Dennis, K. W. (1989). Towards a culturally competent system of care. Vol. I: A monograph on effective services for minority children who are severely emotionally disturbed. *Washington, DC: CASSP Technical Assistance Center, Georgetown University Child Development Center.*

Dillenbourg, P. (1999). *What do you mean by collaborative learning?* 16.

Farokhi, M., & Hashemi, M. (2011). The Analysis of Children's Drawings: Social, Emotional, Physical, and Psychological aspects. *Procedia - Social and Behavioral Sciences*, *30*, 2219–2224. https://doi.org/10.1016/j.sbspro.2011.10.433

Forissier, T., Bourdeau, J., & Psyché, V. (2017). *Quand les contextes se comparent et se parlent* [Text]. https://www.contextesetdidactiques.com:443. https://www.contextesetdidactiques.com/243

Gauch, H. G. (2009). Science, Worldviews, and Education. *Science & Education*, *18*(6), 667–695. https://doi.org/10.1007/s11191-006-9059-1

Hall, E. T. (1989). *Beyond culture* (Anchor Books ed). Anchor Books, p.85.

Mak, Jason. (2014). *Diversity and Human Rights Consortium: What is Cultural Competency?*

Merlo-Leurette, S., & Forissier, T. (2009). *La contextualisation dans l'enseignement des sciences et techniques en Guadeloupe*. 9.

Marope M., Griffin P., & Gallagher C. (2017). Future Competences and the Future of Curriculum A Global Reference for Curricula Transformation. *INTERNATIONAL BUREAU OF EDUCATION*.

Overall, P. M. (2009). Cultural Competence: A Conceptual Framework for Library and Information Science Professionals. *The Library Quarterly*, *79*(2), 175–204. https://doi.org/10.1086/597080

Piaget, J. (1926). *La représentation du monde chez l'enfant*. 14.

Scarino, A., Liddicoat, A., Curriculum Corporation (Australia), Australia, & Department of Education, E., and Workplace Relations. (2009). *Teaching and learning languages: A guide*. Curriculum Corporation.

Sfard, A. (1998). On Two Metaphors for Learning and the Dangers of Choosing Just One. *Educational Researcher*, *27*(2), 4–13. https://doi.org/10.3102/0013189X027002004

Vygotski, L. S., & Sève, F. (1985). *Pensée et langage*. Messidor, Éd. Sociales, p.272-273.
Zakaria, N., & Cogburn, D. L. (2010). Context-dependent vs. content-dependent: An exploration of the cultural behavioural patterns of online intercultural communication using e-mail. *International Journal of Business and Systems Research*, *4*(3), 330. https://doi.org/10.1504/IJBSR.2010.032954

QUESTIONING STRATEGIES TO PROMOTE AND ASSESS, COGNITION METACOGNITION AND CONCEPTUAL UNDERSTANDING IN CHEMISTRY: AN ANALYSIS

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This study focuses on how various types, styles and sources of questions can be used to facilitate higher levels of cognition, metacognition and conceptual understanding in chemistry. This is achieved by analysing in-class questioning and inquiry based activities to determine how they influence a student's metacognitive awareness and approach to conceptional understanding in chemistry. The participants in the current study are two classes of 28 students who participated in an 8-week module of chemistry before deciding to take it as a subject of study for the last two years in upper secondary school. Participants in the study completed pre and post surveys on both their approach to learning chemistry and their metacognitive awareness. The data collected consisted of in-class audio recordings which were backed up for contextual reasons by visual recordings, and also the written work generated by students during inquiry based tasks. The questions and responses which occur during the lessons and evidence of any resulting cognition and metacognition on the part of the students were analysed during the data collection period. The relationship between the students' metacognitive levels and their approach to learning is analysed in the study, both before and after the data collection period. The range of questions posed by the teacher (also the research-practitioner) was analysed and categorised. In this pilot study, the need for a greater range of in-class questions was identified and also the need to be not bound by curriculum in terms of allowing students to develop their own ideas.

Keywords: questioning, cognitive development, metacognition

INTRODUCTION

Metacognition consists of both metacognitive knowledge - knowledge about cognitive processes as well as metacognitive skills – the cognitive processes that regulate and oversee learning (Flavell, 1979). While cognition is necessary to perform a task, metacognition is key to understanding how a task is performed (Schraw, 2001). Although metacognition can be interpreted simply as thinking about one's own thinking, metacognition is a complex construct central to theories of conceptual change (Rickey & Stacy, 2000).

The contribution of metacognition to scientific understanding has become a central area of research (Zohar & Barzilai, 2013). This is perhaps unsurprising, given that science is a quintessentially metacognitive activity: it continually questions itself, probing and testing the robustness of accumulated knowledge (Fleming, Dolan & Frith 2012). Teaching strategies that encourage metacognition and metaconceptual understanding should be fundamental in chemical education as they are the key to more durable and transferable learning and are needed to achieve mastery of the subject (Rickey and Stacey, 2000; Tsai, 2001). In keeping with this, metacognitive skills have been shown to have a significant impact on problem-solving success (Flavell, 1979).

Despite the importance of metacognition and metaconceptual understanding in chemical education, it is an area which is often neglected in teachers' practice (Thomas, 2012). It is crucial, of course, for chemical educators to understand metacognition in order to be able to teach using a metacognitive approach.

This study is particularly interested in the role of questioning in promoting metacognition. Elder and Paul (1998) argue that thinking is not driven by answers but by questions, and to think through or rethink anything, one must ask questions that stimulate thought. Most teachers are not themselves generators of questions and answers of their own, that is, they are not seriously engaged in thinking through or rethinking through their own subjects. Rather, they are purveyors of the questions and answers of others-usually those of a textbook (Elder & Paul, 1998). If teachers want to engage students in thinking through content they must stimulate their thinking with questions that lead them to further questions.

This study examines how teacher questions influence student awareness of their cognition (metacognitive knowledge) and regulation of their cognition (metacognitive skills) in a second level chemistry context.

Objectives

The three primary objectives of this study were (i) to develop teaching and learning strategies which increase higher levels of teacher questioning and student responses associated with metacognition in chemistry, (ii) to determine the students' metacognitive behaviours in response to teacher questioning and (iii) To evaluate the overall impact of metacognitive questioning on students' levels of metacognitive awareness.

METHODOLOGY

An interpretive methodology is used in this research project, as it is concernted with theory building rather than hypothesis testing. Interpretive methodology in an educational context involves classroom observation, interviewing of students and teachers, and the construction of case studies. Some quantitative data is also incorporated into this methodology.

Approach

A pre-pilot study was carried out, which identified relatively low level of metacognitive questioning by the teacher (Figure 1 below). A metacognitive teaching plan was developed, which involved adapting teaching and learning strategies focused on promoting metacognition (see below) for use with the chemistry classroom.

A pilot study was then carried out, which involved implementing the metacognitive teaching plan during an eight week introductory chemistry module. The participants were a group of 28 students aged 15-16 years in a suburban second level school in Dublin, Ireland.

The metacognitive teaching plan

The teaching and learning strategies adapted and included in the metacognitive teaching plan include:

- Explicit Instruction in metacognition. – to promote general awareness of the importance of metacognition in chemistry.
- Regulatory Checklist (RC) – to promote metacognitive skills (King 1991)
- Strategic Evaluation Matrix (SEM) – to promote metacognitive knowledge (Schraw, 1998) Metacognitive curriculum and guided inquiry experiments – to promote metacognitive skills (McGarry et al., 2015)
- Metacognitive Modelling – by students and the teacher to promote metacognitive knowledge and skills (Schraw, 1998)

Recording and analysis of questions, responses and behaviours

All lessons were recorded in order to be able to evaluate student behaviours and responses to questions. Teacher questions were categorised based on knowledge dimensions (Anderson et al., 2001). Metacognitive student behaviours resulting from teachers questions were categorised using Cambridgeshire Independent Learning (C.Ind.Le) framework (Whitebread et al., 2009).

Evaluating metacognitive awareness

The lesson recordings also allowed for an evaluation of teacher questioning and its impact on metacognitive behaviours. Student metacognitive awareness was determined pre and post pilot using the Metacognitive Awareness Inventory (MAI, adapted from Schraw and Dennison, 1994). The MAI is an instrument that measures students' metacognitive knowledge and skills, and also their component subcategories.

RESULTS

The results from this study are outlined below in

(i) Impact of the metacognitive teaching plan on teacher questioning

The inclusion of the use of teaching and learning strategies which explicitly addressed metacognition in the pilot study greatly increased the level of metacognitive questioning occurring during lessons relative to the pre pilot (Figure 1).

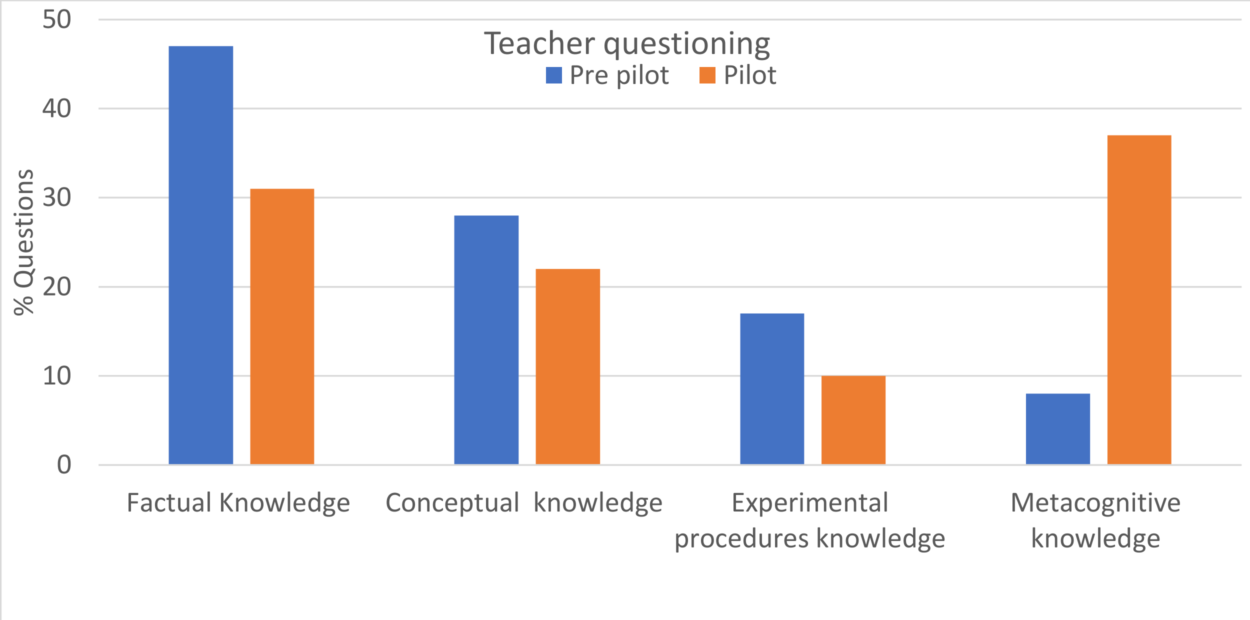

Figure 1 Impact of metacognitive teaching plan on teacher questioning

(ii) Metacognitive student behaviours resulting from teacher questions

The number of incidents of metacognitive student behaviours resulting from teacher questions is shown in Figure 2. It is evident that teacher questioning promoted metacognitive behaviours in the students, particularly the metacognitive skills of control and evaluation.

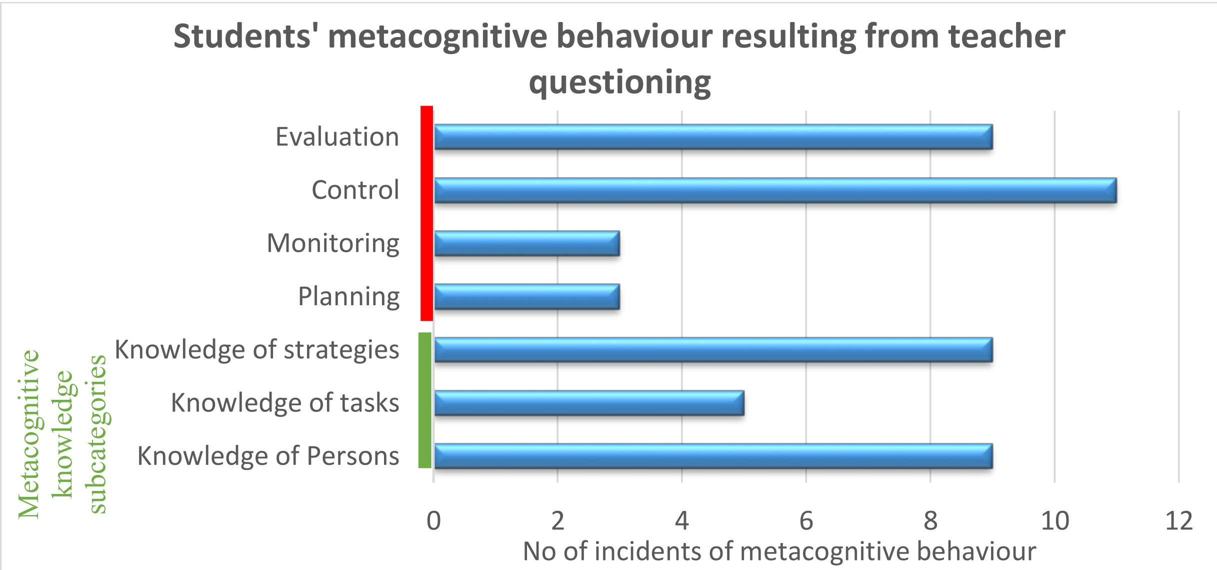

Figure 2 Students' metacognitive behaviour resulting from teacher questioning

(iii) Pre and post-test metacognitive awareness

The pre and post average student scores for metacognitive knowledge and metacognitive skills are shown in Figure 3, together with the scores for the component subcategories. The increase in metacognitive knowledge was primarily due to an increase in procedural knowledge. While the increase in metacognitive skills was primarily due to evaluation, comprehension monitoring and planning. Interestingly, debugging strategies (process of analysing and removing error) scored highly in both pre and post surveys.

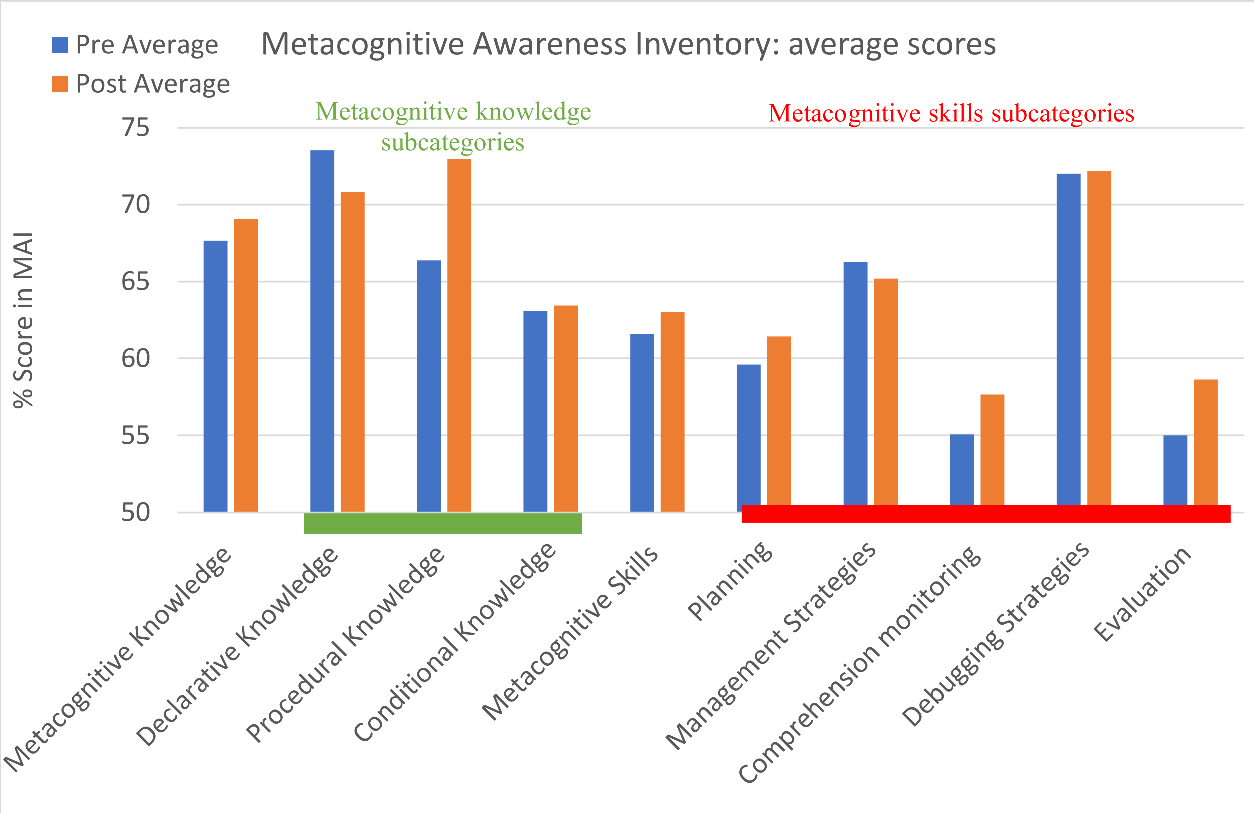

Figure 3 Average student scores: Metacognitive Awareness Inventory

DISCUSSION

The metacognitive teaching plan, which incorporated teaching and learning strategies which explicitly addressed metacognition, let to increased levels of metacognitive questioning by the teacher in chemistry lessons. In this regard, the metacognitive teaching plan was effective.

Students exhibited metacognitive behaviours as a result of teacher questioning, particularly in the metacognitive skills of evaluation and control. Evaluation relates to refers to appraising the outcomes and regulatory process of learning (Schraw., 2006). Control relates to beliefs held by learners, since internal control is effectively achieved when individuals take responsibility for critically assessing what they are doing during learning and why they are doing it (Tsai 2001). In terms of metacognitive knowledge, knowledge of strategies and persons were also frequently exhibited. Knowledge of strategies refers to knowledge about thinking, learning and problem-solving strategies that students might use in order to achieve goals, and knowledge of persons refers to refers to self-knowledge of the variables that influence the individual's cognitive activity, knowledge of the cognition of others and knowledge of the universals of people's cognition (Kuhn, 1999; Kuhn & Pearsall, 1998; Flavell et al., 2002). Implications

It is evident from the pre- and post-MAI surveys that there was a small increase in the average student scores on metacognitive knowledge and metacognitive skills. The increase in metacognitive knowledge is largely due to the increase in procedural knowledge. There was a small decrease in declarative knowledge. In terms of metacognitive skills, there was an increase in the average student score in each subcategory with the exception of management strategies.

One of most important outcomes of the pilot study was the refinement of the metacognitive teaching plan. The teaching and learning strategies which influenced metacognition within the introductory chemistry classroom will be developed and expanded upon. The challenge is now to embed these strategies in chemistry within a year long chemistry course while also determining their effect on student conceptual understanding in chemistry.

This will be the next stage of this research project which is examining (i) metacognitive approaches to teaching, learning and curriculum development in chemistry (ii) metaconceptual understanding and assessment in chemistry, and (iii) the relationship between metacognition and motivation in chemistry education

ACKNOWLEDGEMENT

We would like to thank all the students who took part in the study.

REFERENCES

Anderson, L. W. & Bloom, B. S., (2014). A taxonomy for learning, teaching, and assessing: A revision of Bloom's. Harlow: Pearson.

Elder, L., & Paul, R. (1998). The Role of Socratic Questioning in Thinking, Teaching, and Learning. The Clearing House, 71, 5, 297-301.

Flavell, J. H., Miller, P. H., & Miller, S. A. (2002). Cognitive development. Upper Saddle River, NJ: Prentice-Hall

Flavell, J. H. (1979). Metacognition and Cognitive Monitoring: A New Area of Cognitive-Developmental Inquiry. *American Psychologist*, 34, 10, 906-11.

Fleming, Stephen M., Dolan, Raymond J., & Frith, Christopher D. (n.d.). *Metacognition: computation, biology and function*. The Royal Society.

Garner, R., & Alexander, P. A. (1989). Metacognition: Answered and Unanswered Questions. *Educational Psychologist, 24,* 2, 143-158.

Jacobson, N. S. & Truax, P. (1991). Clinical significance: A statistical approach to defining change in psychotherapy research. *Journal of Consulting and Clinical Psychology, 59,* 12–19.

King, A. (1991). Effects of training in strategic questioning on children's problem-solving performance. *Journal of Educational Psychology, 83,* 3, 1991.

Kuhn, D. (1999). Metacognitive development. In L. Balter & C. S. Tamis-LeMonda (Eds.), Child psychology: A handbook of contemporary issues (pp. 259–286). Ann Arbor, MI: Psychology Press.

Kuhn, D., & Pearsall, S. (1998). Relations Between Metastrategic Knowledge and Strategic Performance. *Cognitive Development, 13,* 2, 227-248.

McGarry, B. J., Theobald, K., Lewis, P. A., & Coyer, F. (2015). Flexible learning design in curriculum delivery promotes student engagement and develops metacognitive learners: An integrated review. *Nurse Education Today, 35,* 9, 966-73.

Rickey, D., & Stacy, A. M. (2000). The Role of Metacognition in Learning Chemistry. *Journal of Chemical Education, 77,* 7, 915-20.

Schraw, ., & Dennison, G. (1994). Assessing Metacognitive Awareness. *Contemporary Educational Psychology, 19,* 4, 460-475.

Schraw, G. (1998). Promoting general metacognitive awareness. *Instructional Science : an International Journal of Learning and Cognition, 26,* 113-125

Thomas, G. P. (2012). Metacognition in Science Education: Past, Present and Future Considerations. 131-144.

Tsai, C.-C. (2001). A Review and Discussion of Epistemological Commitments, Metacognition, and Critical Thinking with Suggestions on Their Enhancement in Internet-Assisted Chemistry Classrooms. *Journal of Chemical Education, 78,* 970-974.

Whitebread, D., Coltman, P., Pasternak, D. P., Sangster, C., Grau, V., Bingham, S., Almeqdad, Q., ... Demetriou, D. (2009). The development of two observational tools for assessing metacognition and self-regulated learning in young children. *Metacognition and Learning, 4,* 1, 63-85

Zohar, A., & Barzilai, S. (2013). A review of research on metacognition in science education: current and future directions. *Studies in Science Education, 49,* 2, 121-169.

PART 2: STRAND 2

Learning Science: Cognitive, Affective, and Social Aspects

Co-editors: *Graca Carvalho, Vanessa Kind*

& Florence Le Hebel

CONTENTS

STRAND 2: INTRODUCTION

LEARNING SCIENCE: COGNITIVE, AFFECTIVE, AND SOCIAL ASPECTS

The number and quality of the proposals in this strand show the research's breadth focusing on cognitive, affective and social aspects. In this ESERA 2019 proceedings edition, 17 papers are included and can be grouped in four themes.

A first theme, bringing together 6 papers focus on the dimensions of motivation, interests, emotions and attitudes in science learning. Stiller and Wild investigate whether the provision of autonomy in combination with prompts during experimentation influences students' motivation and knowledge gain. They show that young students did not seem to be able to cope with the demands of a more open learning environment and discuss possible learning conditions to improve this. Cetin-Dindar reveals that students' constructing educational games, including science concepts, increase their motivation to learn science. Two papers explore the role of emotions in science learning: Contini and colleagues aim to deepen the role that the feeling of pleasure can play in science education experiences in which metaphors and narratives are used systematically. They argue that a strict connection exists between aesthetic pleasure and cognitive processes. Drawing on scientific literature, they claim that science-learning shows more relevant results when it is connected to aesthetic experiences. Watts presents concrete methods that can be used to increase student receptivity by reducing negative emotions and showing how these methods can support content learning in the science classroom. Castro and colleagues map three different dimensions about biodiversity values of secondary school student, "ecological", "symbolic and ethical" and "economic", showing a close relationship with those found in the scientific literature. Moreover, Chu and colleagues investigate students' engagement and participation in science classrooms. Their study indicates some factors that could be used by classrooms teachers to support students' preferred participation practices. In particular, preliminary findings suggest that science educators should think more critically about the role of non-verbal participatory practices for supporting learning and should conduct more classroom-situated research focusing on understanding students with non-verbal participation preferences.

A second theme deals with socio-cultural, gender issues and the diversity of students. Hönig and colleagues investigate how young people of different gender and cultural backgrounds living in Germany differ in their vocational orientation in the sciences. Their results show that not all students prefer the same sources in vocational orientation in science. It differs according to the gender and migration background and involves rethinking strategies to improve vocational orientation in science. In the same vein, Brinkmann and colleagues present and discuss the development and evaluation of tools for gender- and diversity-sensitive career orientation in chemistry. Kirstein and colleagues aim to examine students' individual activities and difficulties while working on collaborative hands-on inquiry learning tasks considering different topic areas in a heterogeneous chemistry classroom, as they consider it is crucial to be aware of possible obstacles and to know in which way they are related to students' individual prerequisites. Guttierrez and Blanchard investigate the experiences of families who took part in STEM activities in their homes and give insight into ways to bridge formal school STEM content standards into learning settings within student homes. Kjelsberg investigates what the lived experience of Bildung in university level education is. The results show that physics students today do have experience of going through a process of Bildung during their time at university. The most common experience is one of increased scepticism. His study also supports the notion of Bildung as a social process.

The contributions included in the third theme focus on language and reasoning. Marialva and colleagues use inquiry-based learning methodologies and experimentation as a tool to promote science and language integrated learning. In a word-level analysis of learners decoding with minimal comprehension English second language science text, Stott and Beelders show that these learners fixate longer on the scientific terms than the others did, and suggest that the degree of linguistic cognitive demand of scientific terms is not the primary factor determining the degree of difficulty they experience during reading. Sin and Chang show that students have different academic self-concepts of different topics of a subject such as a wave and mechanics in physics and ascribe the differences to the use of different reasoning styles in mechanics and wave.

Finally, the fourth theme gathers three contributions focusing on innovative projects. Smit and colleagues implement industry–science projects aiming to foster secondary school students' interest in science-based technology careers. Their results demonstrate that factory visits combined with embedded tasks are one way to overcome fixed self-concepts and allow the students to reconsider a career in the technology and engineering industry towards the end of secondary school. Osman and Hamdan provide secondary school students the opportunity to experience hands-on and minds-on project-based authentic interdisciplinary modules stemming from their interests and designed by seniors and graduate students. This innovative approach attempted to foster student conceptual understanding, increase their motivation towards learning science, and promote their growth as they prepare to take on post-secondary education. In their study, Forissier and colleagues show that contexts effects learning appears as an innovative method based on intercultural collaboration during comparison of the natural contexts of the students involved.

Graca Carvalho, Vanessa Kind & Florence Le Hebel

EXPERIMENTING WITH PROMPTS VS. RECIPE-STYLE EXPERIMENTING:

IMPACT ON MOTIVATION AND ACHIEVEMENT

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Experimentation is one of the most important scientific working methods in biology. However, on the one hand, students can perceive experimentation as very complex, especially when students were offered a high degree of autonomy. On the other hand, fully structured recipe-style inquiry processes seem to be inappropriate to promote the development of students' scientific reasoning skills. Consequently, to support experimentation optimally and foster an autonomous working practice a combination of instructional support and open inquiry is needed. Prompts provide a high degree of freedom and give instructional guidance by offering hints. Accordingly, prompts allow students to work on a task autonomously and with an appropriate degree of support. The research question in this study focusses on, whether the provision of autonomy in combination with support by prompts during experimentation influences motivation and knowledge gain. In the quasi-experimental study (N=151) students in grades 5 and 6 were randomly assigned to two treatment conditions: recipe-style experimentation and experimentation supported by prompt-cards. The results showed that the students of the 'prompt-group" reported significant lower values in basic need satisfaction (subscale 'competence' and 'autonomy') and in motivation (subscales 'perceived choice', 'perceived competence' and 'interest/enjoyment'). Likewise, the students did not benefit from prompts in the knowledge gain. Summarizing, for young students, experimenting with strong guidance seems to be more beneficial than using prompts. The fulfilment of the need for competence as well as the perceived competence was lower in the 'prompt-group' than in the 'full-structured group'. Thus, these students did not seem to be able to cope with the demands of a more open learning environment. Presumably, it is necessary to improve the students' competence, e.g. by gradually increasing the degree of autonomy in experimenting, in order to enable students to perceive themselves as competent.

Keywords: instructional strategies, motivation, science inquiry

INTRODUCTION

In the German biology curriculum, experimentation is considered to play an important role as a central method of the natural sciences (KMK, 2005). Experimentation is described as a problem-solving process, in which students need to generate questions and hypotheses, design and run experiments and evaluate data (Abd-El-Khalick et al., 2004). Students can perceive experimentation as very complex (Harlen, 1999), which can lead to high cognitive demands, especially when students are offered a high degree of autonomy. One way of avoiding excessive demands and guiding learners during experimentation is to use instructional support (Fretz et al., 2002). For science experiments in schools, recipe-style tasks are often applied. However, fully structured recipe-style inquiry processes seem to be inappropriate to promote the development of students' scientific reasoning skills (Sadeh & Zion, 2012), as these structuring elements often do not involve an understanding of the experimental process (Hofstein & Lunetta, 2004). In addition, experimenting in this way implies that students work through instructions and have no option to decide how to plan or analyse the experiment. This way of experimenting reduces the degree of freedom and thus the autonomy of the students. Consequently, to support experimentation optimally and foster an autonomous working practice, a combination of instructional support and open inquiry is needed (Mayer, 2004). Using prompts during experimentation is a possibility to provide a higher degree of freedom and give instructional guidance by offering hints and allowing students to work on a task autonomously (Ge & Land, 2003) and with an appropriate degree of support. Accordingly, tasks supported by prompts may more easily match students' skills and thus increase their perceived competence. Perceived autonomy and perceived competence are regarded as predictors for intrinsic motivation (Ryan & Deci, 2017).

Our research question focusses on whether the provision of autonomy in combination with support by prompts during experimentation influences students' motivation and knowledge gain in contrast to full-structured experiments.

THEORETICAL BACKGROUND

Motivation: Self-Determination Theory

Learning processes at school depend on motivational conditions. According to self-determination theory, a requirement for motivated action is that the three basic psychological needs for autonomy (the need of individuals to experience personal accountability and empowerment for their actions), competence (experiencing possibilities and backup in performing actions), and social relatedness (feelings of being connected and belonging to others) are satisfied (Deci & Ryan, 2000; Ryan & Deci, 2017). In the school context, the satisfaction of these basic psychological needs yields higher engagement with the learning objects and good performance (Niemic & Ryan, 2009; Reeve, 2015). Furthermore, it can be differentiated between various forms of motivation, intrinsic and extrinsic motivation (Ryan & Deci, 2000; Ryan & Deci, 2017). In terms of the learning process, intrinsic motivation means that learning proceeds as it is associated with a positive experience. An intrinsically motivated student learns for the sake of the subject. Extrinsically motivated learning is based on the desire for positive consequences or avoiding negative ones. An extrinsically motivated student does not learn for reasons of learning or because he is interested in the subject but because of an external reward, such as grades. The reasons for motivated behaviour can be arranged on a continuum of regulatory styles that ranges from the purely controlled form of regulation, the external regulated behaviour to the purely autonomous form of regulation, that underlies intrinsically motivated behaviour (Ryan & Deci, 2000; Ryan & Deci, 2017).

Experimentation

Scientific inquiry indicates the execution and understanding of scientific work and thought (NRC, 2000). Experimentation represents one method of scientific inquiry (Lederman, 2009; Mayer, 2007; Paul, Lederman, & Groß, 2016) and can be described as a problem-solving process (Abd-El-Khalick et al., 2004; Gott & Roberts, 2008; Klahr, 2000; Mayer, 2007). The steps in Klahr's (2000) Scientific Discovery as Dual Search model are related to the steps and phases of experimentation (Abd-El-Khalick et al., 2004; Mayer, 2007) (see also Stiller, Stockey, & Wilde, 2018; Figure 1).

In science lessons, experimentation is supposed to facilitate the understanding of a scientific inquiry process, and provide an understanding of scientific thought and work (Wirth et al. 2008). Prompts are one possibility to support this learning processes. They are defined as hints or questions in order to activate knowledge, strategies or skills (Wirth, 2009) and can be used in experimentation to structure students' thinking (Wichmann & Leutner, 2009).

HYPOTHESES

Students using prompts may perceive more choices than students experimenting in a recipe-style. Since students can choose prompts related to their difficulties with the experiment, their perceived competence can also be supported. From this, the following hypotheses can be derived:

> H1: Students who experiment with prompts for experimental support perceive themselves as more autonomous than students who experiment in a recipe-style.

> H2: Students who experiment with prompts for experimental support perceive themselves as more competent than students who experiment in a recipe-style.

Intrinsic motivation relies on the perception of autonomy (Reeve, 2015; Ryan & Deci, 2017) and competence (Ryan & Deci, 2017). Autonomy-supportive learning environments are beneficial in terms of intrinsic motivation, engagement, and learning (Reeve, 2015). Not satisfying the need for competence or autonomy results in lower performance and commitment (Miserandino, 1996). Learning environments that satisfy the basic psychological needs support intrinsic motivation and foster student engagement during learning activities as well as their learning performance (Niemiec & Ryan, 2009).

> H3: Students who experiment with prompts for experimental support are more intrinsically motivated than students who experiment in a recipe-style.

> H4: Students who experiment with prompts for experimental support learn more than students who experiment in a recipe-style.

METHOD

Sample and study design

In order to answer the question of whether support of experimentation by using prompt-cards is worthwhile for students in terms of motivation and knowledge gain, this study was conducted as a quasi-experimental intervention study with a pretest-posttest comparison group design (Figure 1). In the study, 151 students in grades 5 and 6 (11.28±0.69 years) from two German grammar schools participated. The classes were randomly assigned to two treatment conditions: ‘full-structured experimentation’ (n = 75) and ‘prompt-card group’ (n = 76). Both groups differed in instructional support during experimentation. In the “full-structured group”, a full-structured experimentation guide determined the procedure while the students of the ‘prompt-card group’ received a reduced protocol template and prompt-cards that they could use as support.
The study was embedded in a four-lessons-teaching unit dealing with the behaviour of isopods. Before and at the end of the intervention, the students completed a questionnaire concerning motivation and knowledge.

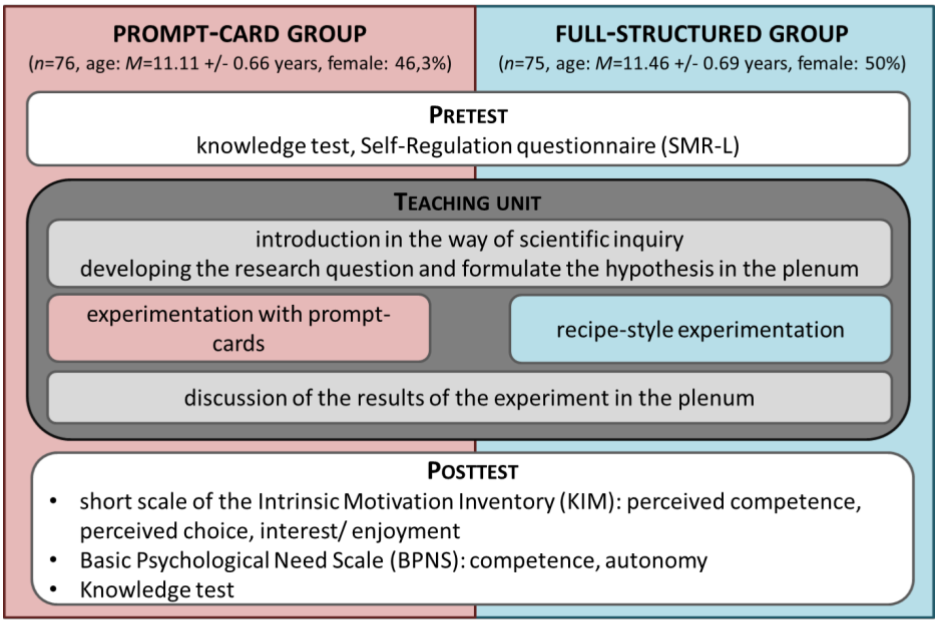

Figure 1. Study design.

Treatments and lessons

The teaching unit started with a short introduction into the way of scientific inquiry. In the following, the students carried out the experiment, recorded their observations and results, and interpreted the data (Figure 2).

Before experimentation, the research question and the hypotheses were developed in both groups in the plenum. Afterwards, the students plan and analyse the experiment in small groups of three to four students. This practical experimentation was divided into six steps for the students: 1. planning: experimental setup, 2. planning: experimental procedure, 3. analysing the observations: calculation of mean, 4. analysing the observations: description of the results, 5. discussion of the results: interpretation and 6. discussion of the results: conclusion. These steps are used to structure the experimentation process on the protocol template. At the end of the lesson, the students discussed the results in the plenum.

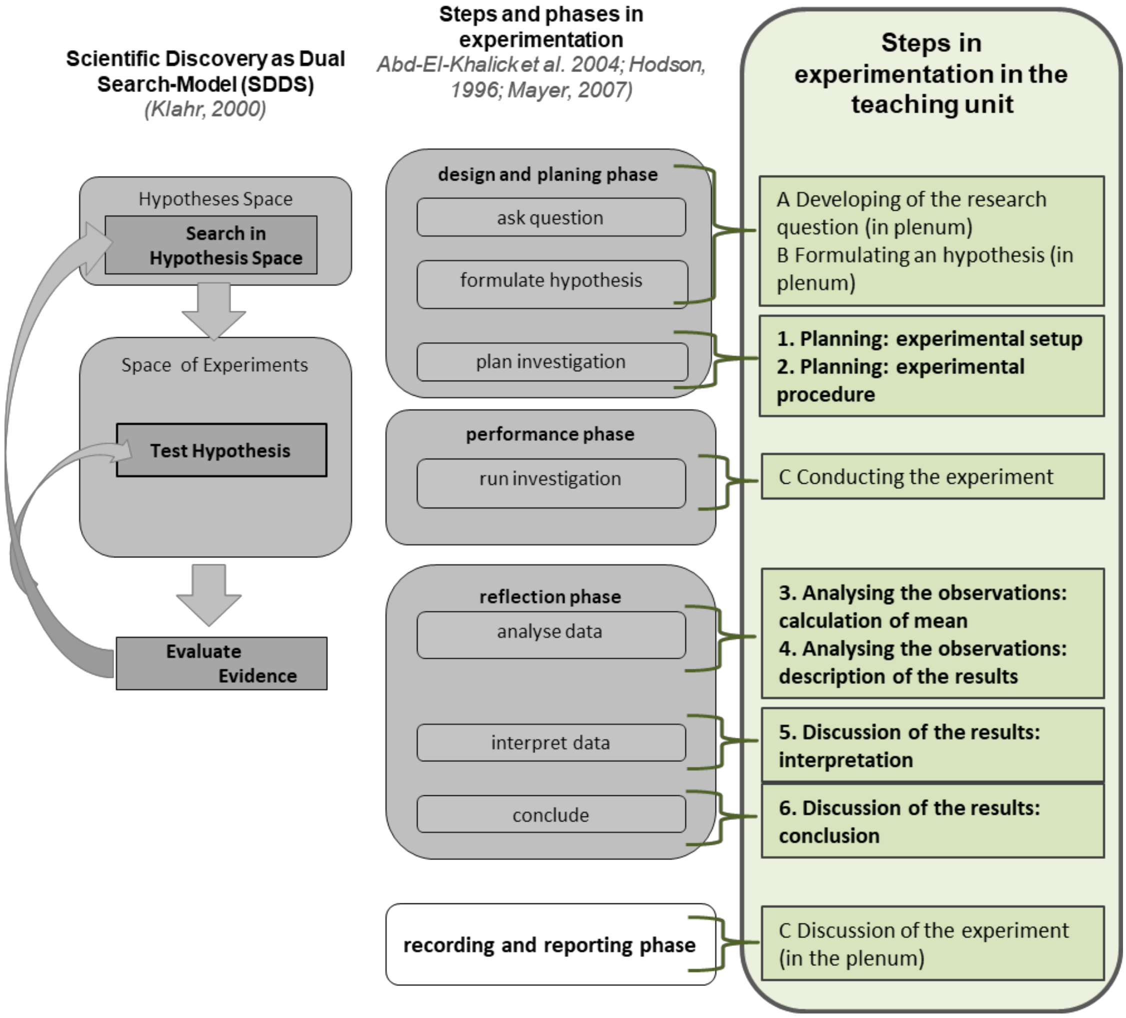

Figure 2. Overview of steps in experimentation in the teaching unit based on the SDDS model and the steps and phases of experimentation (see also Stiller, Stockey & Wilde, 2018). The experimental steps that were supported by prompt-cards in the prompt-card group are marked in bold.

Both groups differed in the planning and analysis of the experiment. The students of the 'full structured group' experimented in a recipe-style and received full-structured experimentation guides. In addition to structuring through the six steps of experimentation, the protocol template of the full-structured group also contained detailed instructions on how the students should perform these steps. Thus, the students in this group had no possibilities to decide anything in the experimental process for themselves. They had to follow the step-by-step instructions in the experimentation guide. The students in the prompt-card group investigated the same research question, but in contrast to the 'full structured group', they experimented independently. The protocol template of this group included merely the structuring by the six steps and at the appropriate places a hint which prompt-card can be used. The students received 14 prompt-cards that they could use as support to manage experimentation. For each step in the process of experimentation, a set of 2-3 cards was provided for the students. The cards of a set differ in their level of support, from a few general hints on the first card (a) to a concrete solution proposal on the last card (c). The general hints in card (a) provide support on a basic level and emphasize experimentation in general without specifically focusing on the lesson's experiment. Prompts are given in the form of questions such as *'Consider how you will conduct the experiment and how you will notice your observations: How's the experiment going? What do you have to pay attention for? What do you count and how often do you count?'*. At the end of the prompt-card followed the question of whether it helped the students and advised otherwise to use the next card for the experimental step. The second prompt-card (b) includes some specific questions that relate more to the experiment in this lesson and are no longer limited to experimentation in general, e.g. *'Consider the following aspects: How often and when do you want to count the isopods? How is an isopod on the centerline counted? What does the columns and the rows of your raw data table contain?'*. In the end, the question of whether the card helped was raised again, but this time, if not, the students had to contact the teacher to pick up the last card. The last prompt (c) card includes the same concrete solution proposal as the one in the full-structured experimentation guide in the other intervention group. These cards were only provided for the two steps of planning an experiment (experimental setup, experimental procedure), but not for analysing and interpreting the results. For these steps, the second card corresponds to the full-structured intervention guide.

Before starting with experimentation, the students were introduced to the use of the prompt-cards. Besides, the teachers emphasized that the use of the cards is helpful and that it is essential to use them if the students are stuck. Nevertheless, while experimenting, the students decided on their own which of the help cards they need and want to use.

Measuring instruments and statistical analysis

To get some information about students' general learning motivation in biology, an adapted version of the Self-Regulation Questionnaire (SRQ) from Thomas and Müller (2016) with the four subscales 'external', 'introjected', 'identified' and 'intrinsic' regulation was used in the pretest. To make statements about students' perceived degree of autonomy, the Relative Autonomy Index (RAI; min.: -12, max.: 12) was calculated with these four subscales (Vallerand & Ratelle, 2002). The more positive this value is, the more autonomous is the student regulated and the more negative it is, the more controlled he or she is.

After the lessons, an adapted and translated version of the subscales 'autonomy' (Cronbachs α = .70) and 'competence' (Cronbachs α = .71) from the Basic Psychological Need Scale (BPNS, Decy & Ryan, 2000) as well as the subscales 'perceived choice' (Cronbachs α = .65), 'perceived competence' (Cronbachs α = .80) and 'interest/enjoyment' (Cronbachs α = .86) of the short scale of motivation (KIM, Wilde, Bätz, Kovaleva & Urhahne, 2009) were applied in the posttest. The scales 'autonomy' and 'perceived choice' were evaluated in order to provide findings on perceived autonomy during teaching (hypothesis 1). 'Competence' and 'perceived competence' indicate the fulfilment of the need for competence (hypothesis 2). The subscale 'interest/enjoyment' is considered as a measure of intrinsic motivation (hypothesis 3). To measure the knowledge gain (hypothesis 4), a knowledge test including nine lessons related open-ended questions concerning the process of experimentation (inquiry knowledge) was used in the pre- and posttest (2 points per question, maximum 18 points).

Analyses of Variance (ANOVAs) were conducted to check whether both groups differed in the motivational scales and in the knowledge gain. To test hypotheses 1 to 3 one-factorial ANOVAs were carried out and for hypotheses 4 a mixed-ANOVA was applied.

RESULTS

The students of both groups differed significantly in the Relative Autonomy Index in the pretest (F(1; 148) = 3.96, p <.05, partial η^2 = .03). The RAI is higher in the 'full-structured group' (M = 5.19, SD = 3.71) than in the prompt-card group (M = 3.91, SD = 4.13). The 'full structured group' was significantly more autonomous regulated than the prompt-card group already at the beginning of the study.

The results of the motivational scales of the post-test, are presented in the following (Figure 3). At the end of the lessons, students of the prompt-card group showed significantly lower values in the subscale 'autonomy' of the BPNS ($M = 2.40$, $SD = 0.76$) ($F(1; 149) = 8.05$, $p < .01$, partial $\eta^2 = .05$) as well as in the subscale 'perceived choice' of the KIM ($M = 2.25$, $SD = 0.85$) ($F(1; 149) = 7.69$, $p < .01$, partial $\eta^2 = .05$) than students in the full structured group (BPNS: $M = 2.70$, $SD = 0.51$; KIM: $M = 2.61$, $SD = 0.75$). Consequently, the first hypothesis cannot be supported. Also, there were significant differences in the subscale 'competence' of the BPNS ($F(1; 149) = 16.59$, $p < .001$, partial $\eta^2 = .10$) and the subscale 'perceived competence' of the KIM ($F(1; 149) = 33.70$, $p < .001$, partial $\eta^2 = .14$) in favour of the full structured group (*full structured group*: BPNS: $M = 2.74$, $SD = 0.68$, KIM: $M = 2.61$, $SD = 0.75$; *prompt-card group*: BPNS: $M = 2.29$, $SD = 0.69$, KIM: $M = 2.25$, $SD = 0.85$). So, the second hypothesis cannot be confirmed, too. In addition, students of the full-structured group were intrinsically more motivated ($M = 3.10$, $SD = 0.84$) than students in the prompt-card group ($M = 2.65$, $SD = 1.05$) ('interest/enjoyment': $F(1; 149) = 8.38$, $p < .01$, partial $\eta^2 = .05$). Concluding, the third hypothesis also cannot be confirmed. In summary, the results concerning the motivational scales showed, contrary to expectations, a motivational benefit for the full-structured group.

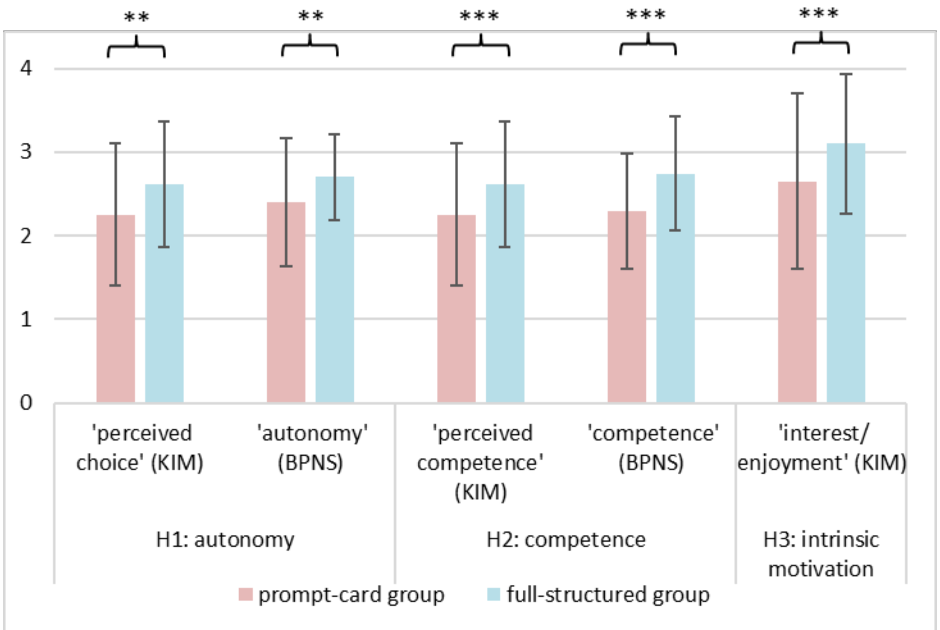

Figure 3. Results for the hypotheses 1 - 3. ** p < .01 ***p < .001

The results of the mixed-ANOVA showed a significant effect of the lessons concerning the knowledge gain ($F(1; 141) = 176.31$, $p < .001$, partial $\eta^2 = .56$), but no significant interaction effect ($F(1; 139) = .08$, p = ns, partial $\eta^2 = .00$). In conclusion, the prompt-card group did not learn more than the full-structured group. So, the last hypothesis could not be supported, too.

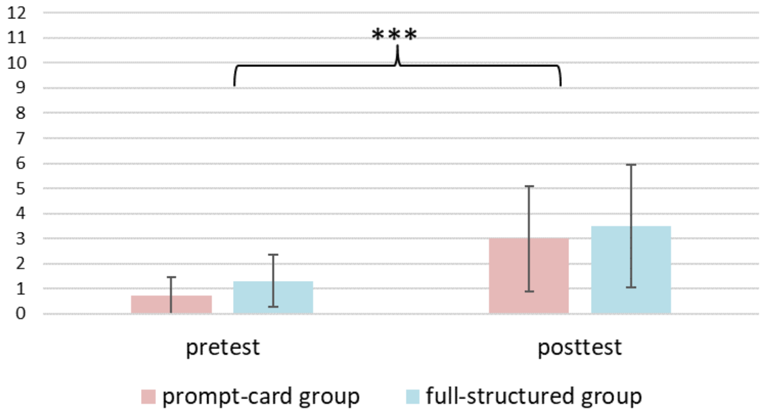

Figure 4. Results for the hypothesis 4. ***p < .001

Summarizing, the results of the ANOVAs for the comparison of the two groups showed that the students did not benefit from the guided experimentation in their basic need satisfaction, their motivation, and their knowledge gain.

DISCUSSION AND CONCLUSION

In this study, the hypotheses could not be supported. The students who were guided by prompts, when experimenting, didn't perceive themselves as more autonomous, more competent and were not more intrinsically motivated than students who experimented in a recipe-style. Besides, the students with prompts during experimenting did not learn more than the students experimenting in a recipe-style way. In conclusion, the results show that students do not benefit from prompt-cards regarding their motivation and knowledge gain. Accordingly, guiding with prompt-cards does not seem to be more suitable to support students of a lower level in experimentation.

Even if the findings from this study are limited by the differences in the motivational prerequisites of both groups, the results indicate that experimenting with strong guidance seems to be more beneficial than the provision of autonomy by using prompts. Although the learning environment with full-structured experimentation objectively offers fewer opportunities for experiencing autonomy, younger students seem to perceive it differently. Students can only use and appreciate the possibilities of an open learning environment if they feel competent enough to cope with the demands (Krapp, 2005). The fulfilment of the need for competence as well as the perceived competence were lower in the 'prompt-card group' than in the 'full-structured'-group. Thus, these students did not seem to be able to cope with the demands of a more open learning environment. For students with low competencies in self-regulation and problems to work focused on a task, open learning environments are not very useful (Dohn, 2013). Consequently, students' inquiry learning should be supported by e.g. scaffolds, which structuring the process of inquiry for the students (Dohn, 2013; Krajcik et al., 1998). The prompt-cards in this study do not seem to be sufficient to support the young students, perhaps because the young students perceived these prompt-cards as to complex. Presumably, especially if the students are young and with little or no experience in experimentation first, it is necessary to improve students' competence and provide more structure, e.g. by gradually increasing the degree of autonomy in experimenting in addition to the prompt cards, in order to enable the students to perceive themselves as competent. In consequence, it can be assumed that this also results in intrinsic motivational qualities and better learning.

However, the results of the study have some limitations. The students in both groups differ in their general learning motivation in biology. Following, it's possible that the full-structured group in this study showed higher values in the motivational scales after the intervention because of their more self-determined motivation in general. Additionally, the quasi-experimental study was conducted with a small sample size and with students of one school type. Furthermore, it might be possible that the prompt-cards were not used by the students to a large extent as it would have been appropriate. It is possible that students needed the prompt-cards, but they did not use them because they have the tendency to avoid help-seeking. In order to secure the findings, the study should be replicated on a larger scale with students of different school types and in different grades. Besides, further studies should take the actual use of the prompt-cards into account, for example by focusing on the conditions for using them or by giving the students the chance to get more familiar with the prompt-cards over a longer period. In addition, the use of regression analyses could be useful in order to gain further insights, e.g. how motivational preconditions mediate the effect of learning support through prompts.

To summarize, it seems that support with prompt-cards might not be sufficient for younger students with low experience in experimentation. However, experimenting in a recipe-style is not adequate to enhance the development of students' scientific inquiry skills (Sadeh & Zion, 2012). Consequently, further studies are needed to investigate how prompt-cards or other formats for younger students can be used successfully in order to promote motivation and learning. Actually, it seems that younger students do not only need support during experimentation, but they should also be supported during the use of support.

REFERENCES

Abd-El-Khalick, F., Boujaoude, S., Duschl, R., Lederman, N. G., Mamlok-Naaman, R., Hofstein, A., Niaz, M., Treagust, D., & Tuan, H. (2004). Inquiry in Science Education: International Perspectives. *Science Education, 88,* 397- 419.

Deci, E. L., & Ryan, R. M. (2000). The "What" and "Why" of Goal Pursuits: Human Needs and the Self-Determination of Behaviour. *Psychological Inquiry, 11*(4), 227-268.

Dohn (2013): Situational Interest in Engineering Design Activities. *International Journal of Science Education, 35*(12), 37-41.

Fretz, E. B., Wu, H. K., Zhang, B., Davis, E. A., Krajcik, J. S., & Soloway, E. (2002). An investigation of software scaffolds supporting modelling practices. *Research in Science Education, 32*(4), 567-589.

Ge, X., & Land, S. M. (2003). Scaffolding Students' Problem-Solving Processes in an Ill-Structured Task Using Question Prompts and Peer Interactions. *Educational technology research and development, 51*(1), 22-38.

Gott, R., & Roberts, R. (2008). Concepts of evidence and their role in open-ended practical investigations and scientific literacy; background to published papers. *The School of Education, Durham University, UK.*

Harlen, W. (1999). *Effective Teaching of Science. A Review of Research*. Edinburgh: Scottish Council for Research in Education.

Hofstein, A., & Lunetta, V. N. (2004). The Laboratory in Science Education: Foundations for the Twenty-First Century. *International Journal of Science Education, 88*(1), 28-54.

Klahr, D. (2000). *Exploring science. The cognition and development of discovery processes*. Cambridge: MIT Press.

KMK (2005). *Bildungsstandards im Fach Biologie für den mittleren Schulabschluss.* [Beschluss vom 16.12.2004] [Educational standards in biology for middle school graduation]. München: Luchterhand.

Krajcik, J., Blumenfeld, P. C., Marx, R. W., Bass, K. M., Fredricks, J., & Soloway, E. (1998). Inquiry in project-based science classrooms: Initial attempts by middle school students. *Journal of the Learning Sciences, 7*(3-4), 313-350.

Krapp, A. (2005). Basic needs and the development of interest and intrinsic motivational orientations. *Learning and Instruction, 15*(5), 381-395.

Lederman, J. S. (2009). Teaching scientific inquiry: Exploration, directed, guided, and opened-ended levels. *National geographic science: Best practices and research base*, 8-20.

Mayer, J. (2007). Erkenntnisgewinnung als wissenschaftliches Problemlösen [Inquiry as scientific problem-solving]. In D. Krüger & H. Vogt (Eds.): Theorien in der biologiedidaktischen Forschung. Ein Handbuch für Lehramtsstudenten und Doktoranden (pp. 177-196). Berlin/Heidelberg: Springer-Verlag.

Mayer, R. E. (2004). Should There Be a Three-Strikes Rule Against Pure Discovery Learning? *American Psychologist*, *59*(1), 14-19.

Miserandino, M. (1996). Children who do well in school: Individual differences in perceived competence and autonomy in above-average children. *Journal of educational psychology*, *88*(2), 203.

National Research Council [NRC] (2000). *Inquiry and the National Science Education Standards. A Guide for Teaching and Learning*. Washington: National Academies Press.

Niemiec, C. P., & Ryan, R.M. (2009). Autonomy, competence, and relatedness in the classroom. *Theory & Research in Education, 7*(2), 133-144.

Paul, J., Lederman, N. G., & Groß, J. (2016). Learning experimentation through science fairs. *International Journal of Science Education*, *38*(15), 2367-2387.

Reeve, J. (2015). *Understanding motivation and emotion* (6th ed.). Hoboken, New Jersey: Wiley.

Ryan, R. M., & Deci, E. L. (2000). Intrinsic and extrinsic motivations: Classic definitions and new directions. *Contemporary educational psychology, 25*(1), 54-67.

Ryan, R. M., & Deci, E. L. (2017). *Self-determination theory. Basic psychological needs in motivation, development, and wellness.* New York: Guilford Press.

Sadeh, I., & Zion, M. (2012). Which Type of Inquiry Project Do High School Biology Students Prefer: Open or Guided? *Research in Science Education*, *42*(5), 831-848.

Stiller, C., Stockey, A., & Wilde, M. (2018). Hands off, Minds on? – The Pros and Cons of Practical Experimentation? In Finlayson, O.E., McLoughlin, E., Erduran, S., & Childs, P. (Eds.), *Electronic Proceedings of the ESERA 2017 Conference. Research, Practice and Collaboration in Science Education*, part 2/strand 2 (Russell, T. & Graça, S. C.) (pp. 232-242). Dublin, Ireland: Dublin City University.

Thomas, A., & Müller, F. (2016). Entwicklung und Validierung der Skalen zur motivationalen Regulation beim Lernen [Development and validation of scales for motivational regulation in learning processes]. *Diagnostica, 62*, 74-84.

Vallerand, R. J., & Ratelle, C. F. (2002). Intrinsic and Extrinsic Motivation: A Hierarchical Model. In R. M. Ryan & E. L. Deci (Eds.), *Handbook of self-determination research* (pp. 37-64). Rochester, NY: University of Rochester Press.

Wichmann, A., & Leutner, D. (2009). Inquiry Learning. *Zeitschrift für Pädagogische Psychologie, 23*(2), 117-127.

Wilde, M., Bätz, K., Kovaleva, A., & Urhahne, D. (2009). Überprüfung einer Kurzskala intrinsischer Motivation (KIM). [Validation of a short-scale of intrinsic motivation] *Zeitschrift für Didaktik der Naturwissenschaften, 15,* 31–45.

Wirth, J. (2009). Promoting self-regulated learning through prompts. *Zeitschrift für Pädagogische Psychologie, 23*(2), 91-94.

Wirth, J., Thillmann, H., Künsting, J., Fischer, H. E., & Leutner, D. (2008). Das Schülerexperiment im naturwissenschaftlichen Unterricht. Bedingungen der Lernförderlichkeit einer verbreiteten Lehrmethode aus instruktionspsychologischer Sicht [The student experiment in science lessons. Conditions of learning promotion of a widespread teaching method from the point of view of instructional psychology]. *Zeitschrift für Pädagogik, 54*(3), 361-375.

THE EFFECT OF EDUCATIONAL GAMES ON STUDENT MOTIVATION IN SCIENCE

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For educators, the important goal is to figure out the way how students learn effectively and retain knowledge. Because of this goal constructivist teaching strategies are used for meaningful understanding. These strategies engage students to learning process and they experience by active participation, which also increase student motivation. Educational games, which create active learning environment, enable students to use their scientific conceptions, and create friendly classroom environment, are entertaining and increase engagement in classroom environment, hence could promote motivation in science learning. Considering this theory the purpose of the current study was to investigate whether there was a significant effect of educational games on student motivation and achievement in science education. Twenty-one elementary level students participated in the current study. The science teacher encouraged them to construct educational games related to curriculum subjects. The students constructed educational games and played the games afterwards altogether. The Wilcoxon Signed Rank Test was used to analyze the student motivation on two occasions, before and after the intervention. The difference between the two scores on the motivation was statistically significant. The results of this study revealed that constructing educational games by the students including science concepts increased their motivation to learn science. The instructional strategies that increase student motivation in science should be investigated in larger samples.

Keywords: Educational games, Motivation, Elementary level

INRODUCTION

For educators, the important goal is to figure out the way how students learn effectively and retain knowledge. Many studies in various branches of science reported that student-centered approaches are more effective in meaningful learning to be occurred and student understanding of scientific concepts are more enduring compared to traditional teacher-centered methods (such as Bektas, 2011; Calik, Ayas, & Coll, 2009; Uzuntiryaki, Çakır & Geban, 2001). While students construct the new knowledge, they are active through tasks through self-talk, inner speech, guided-participation, scaffolding, apprenticeships, and peer-interaction. Studies in science education (Zusho, Pintrich, & Coppalo, 2003; Singh, Granville, & Dika, 2002; Pintrich, Marx, & Boyle, 1993, Schunk, 1991) reveal that motivation positively affects students' performance in learning science. Educational games are entertaining and increase engagement in classroom environment, hence could promote motivation in science learning (Foster, 2008). Salen and Zimmerman's (2004) defined games a "system in which players engage in artificial conflict, defined by rules, that results in a quantifiable outcome" (p. 80). In line with this definition considering constructivist theory, educational games were used in this current study for emphasize learning, create active learning environment, enable students to use their scientific conceptions, and create friendly classroom environment. In addition to cognitive perspective of learning process, affective perspective of learning process should also be taken into account such as attitudinal or motivational process (Pintrich, Marx, & Boyle, 1993). Involving and participation in learning process give students motivation to learn, enjoyment, and satisfaction. Constructivist teaching strategies engage students to learning process and they experience by active participation, which increase student motivation (Britner & Pajares, 2006; Pintrich, 2003; Schunk & Pajares, 2002).

Therefore, in this current study, the purpose was to investigate whether there was a significant change on student motivation to learn science when students constructing and developing educational games.

METHOD

Four parts are presented in this method section, which are participants, instrument, design of the study and intervention.

Participants

Twenty-one seventh grade students took part into the study. Eleven female and ten male students were in the group. The previous (fall) semester GPA mean of the students was 73.48 (out of 100) (SD=14.30). The minimum GPA was 52 and maximum GPA was 98.

Instrument

The measuring tool used in the study was Motivated Strategies for Learning Questionnaire (MSLQ) and used to measure students' motivation in science learning (Pintrich, Smith, Garcia, & McKeachie, 1991), consisting of 44 items on a 7-point Likert-type scale, from 1 (not at all true of me) to 7 (very true of me). This questionnaire aims to measure students' motivational orientations and their use of different learning strategies. The translated and adapted version was used in this study (Sungur, 2004). The researcher tested the questionnaire and reasonable fit indices were found via Confirmatory Factor Analysis using LISREL. Besides the MSLQ items, the students were asked to complete their gender and their previous semester science grades.

Design of the Study

The one-group pretest-posttest design (Fraenkel & Wallen, 2003, p. 278) is used as a poor experimental design in this study (see Table 1 for research design details).

Table 1. Research Design.

Group	Pre-test	Intervention	Post-test
One-group	Pre-motivation scores	Constructing and developing educational games and playing	Post-motivation scores

Intervention

The science teacher followed the science curriculum during the study and continued to teach science in the traditional manner. The main difference during the intervention was the students constructed and developed educational games and playing the games afterwards altogether. In addition, the students were actively involved in the process and the teacher was a facilitator and guided them and give feedback during the process. After the teacher explained the scientific topics, the students constructed and developed their own educational games in groups (some students preferred to develop games indıvidually and some in groups) considering and including scientific concepts during the whole spring semester. Design and developing educational games are consisting of following stages: brainstorming stage, researching stage, designing stage, testing stage and re-designing stage. The teacher asked the following sample questions in each stage to the groups:

- *Brainstorming stage*: What game do you think to design? What do you think about the materials that can be used? Which objectives do you think to include to your game? etc.
- *Researching stage*: What sort of games do you like to play, card or board games? You can also adapt your favorite game or create your own game with your rules? What do you what to search? Which materials can be the best for this game? etc.
- *Designing stage*: Design your game and write the materials used. Do you think the number of questions are enough? Which material can you use for your game to be more durable? etc.
- *Testing stage*: What are your class mates' opinions about your game? Do you think your game is appropriate to the objectives? What can your classmates learn from this game? What can be done to improve your game?
- *Re-designing stage*: Based on your initial design and revisions made, redesign your game.

Figure 1. Sample Games.

During this process, the teacher encouraged the students to think about games they could developed related to objectives. The students were free to use any materials or designs (existing games or creating new games with rules). The main point was to develop games using recycled, obtained easily, and inexpensive materials. During the designing stage, the students searched internet and books for scientific content, related questions and design of the games. The next stage was constructing and testing the games, during this stage they tested the durability of the materials and the rules of the games. The last stage was fixing the games based on the peer's opinions and feedbacks from the previous stage (see sample games in Figure 1). The teacher encouraged the students during these stages and often checked the reliability and validity of the questions used in the educational games.

RESULTS

The first research question was whether there was a change in the scores on student motivation from Time 1 (initial-MSLQ) to Time 2 (pre-MSLQ). A Wilcoxon Signed Rank Test (Pallant, 2010) was conducted to compare the two different motivation scores on two different conditions. The Wilcoxon Signed Rank Test does not revealed a statistically significant increase on the student motivation to learn science after theoretical explanation of the subject, $z= -1.339$, $p=.181$. The median score on the student motivations just increased from initial-MSLQ (Md= 220) to pre-MSLQ (Md= 222), but this difference is not statistically significant.

The second research question was whether there was a change in the scores on students' motivation from Time 2 (pre-MSLQ) to Time 3 (post-MSLQ). The research question was to check whether there was a change in the scores in the student motivation to learn science from the beginning and end of the semester (Table 2). The Wilcoxon Signed Rank Test revealed a statistically significant increase in the student motivation to learn science after constructing and developing educational games, $z= -2.312$, $p<.05$, with a large effect size ($r=.50$) (Cohen, 1988). The median score on the student motivations increased from pre-motivation (Md= 222) to post-motivation (Md= 231). The Figure 2 shows the students' motivation change during the semester.

Table 2. Descriptive Statistics.

Time	N	Min.	Max.	Median	Mean	50% Trimmed Mean	Skewness	Kurtosis
Initial-MSLQ	21	115	270	220,00	216,95	219,524	-1,227	2,925
Pre-MSLQ	21	113	277	222,00	217,71	220,101	-1,136	2,805
Post-MSLQ	21	138	294	231,00	229,00	230,410	-,654	,402

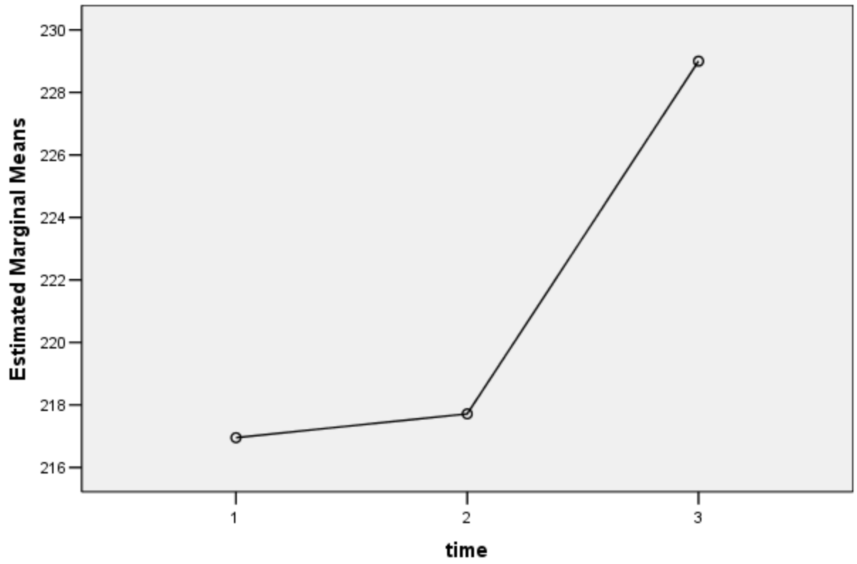

Figure 2. The Change of Students' Motivation Scores during the Semester.

DISCUSSION AND CONCLUSIONS

The results of this study revealed that constructing and developing educational games was effective on student motivation in science. As Brophy (1998) stated the students in the current study were focused on the developing and constructing educational games, they were more motivated in the process rather than being successful in the course. While developing the educational games, the teacher acted as a facilitator and the students were free to express their concerns during the process, the students interacted with each other, and the classroom environment were at the control of the students at the every stage. Ryan and Grolnick (1986) expressed that when students have more autonomy in class, they have higher self-worth and mastery motivation. Furthermore, the motivational theories promoted constructivist learning environment in science teaching and learning (Pintrich, Marx, & Boyle, 1993; Pintrich & Schunk, 2002); and, this study extends the effectiveness of constructivist learning environments on student motivation in science.

Student motivation can change from course to course; therefore, different educational and instructional technologies can be constructed considering student motivation to learn. Investigating the nature of student motivation can help teachers and instructors to understand student motivation within a given course since student motivation affect students learning and their course achievement. During the developing the educational games, the students re-considered the subjects they had learnt and in the future studies the conceptual effect of educational games could be also investigated. In addition, other instructional strategies that increase student motivation in science should be also investigated. Small sample size was the limitation of this study. To increase the generalization, the study should be replicated in various school types, grade levels, over a longer period of time, and environmental conditions.

REFERENCES

Bektas, O. (2011). *The effect of 5E learning cycle model on tenth grade students' understanding in the particulate nature of matter of matter, epistemological beliefs and view of nature of science*. Unpublished dissertation, Middle East Technical University, Ankara, Turkiye.

Britner, S. L., & Pajares, F. (2006). Sources of science self-efficacy beliefs of middle school students. *Journal of Research in Science Teaching, 43* (5), 485-499.

Brophy, J. (1998). *Motivating students to learn*. Boston: McGraw Hill.

Calik, M., Ayas, A., & Coll, R. (2009). Investigating the effectiveness of an analogy activity in improving students' conceptual change for solution chemistry concepts. *International Journal of Science and Mathematics Education*, 7(4), 651-676.

Cohen, J. W. (1988). *Statistical power analysis for the behavioral sciences* (2nd ed.). Hillsdale, NJ: Lawrence Erlbaum Associates.

Foster, A. (2008). Games and Motivation to Learn Science: Personal Identity, Applicability, Relevance and Meaningfulness. *Journal of Interactive Learning Research, 19*(4), 597-614.

Fraenkel, J. K, & Wallen, N. E. (2003). *How to design and evaluate research in education* (5th ed.). New York: McGraw-Hill, Inc.

Pallant, J. (2010). *SPSS Survival Manual: A step by step guide to data analysis using SPSS* (4th ed.). New York: McGraw Hill.

Pintrich, P. R., Marx, R. W., & Boyle, R. A. (1993). Beyond cold conceptual change: The role of motivational beliefs and classroom contextual factors in the process of conceptual change. *Review of Educational Research, 63*(2), 167-199.

Pintrich, P. R., Smith, D. A., Garcia, T., & McKeachie, W. J. (1991). *Motivated strategies for learning questionnaire*. Ann Arbor, MI: The University of Michigan, NCRIPTAL.

Pintrich, P. R., & Schunk, D. H. (2002). *Motivation in education: theory, research, and applications* (2nd ed.). Upper Saddle River, NJ: Pearson Education.

Salen, K., & Zimmerman, E. (2004). *Rules of play: Game design fundamentals*. Cambridge, MA: MIT Press.

Schunk, D. H. (1991). Self-efficacy and academic motivation. *Educational Psychologist, 26*, 207-231.

Schunk, D. H., & Pajares, F. (2002). The development of academic self-efficacy. In A. Wigfield, & J.S. Eccles (Eds.), *Development of achievement motivation* (pp. 16– 31). New York: Academic Press.

Uzuntiryaki, E., Çakır, H., & Geban, Ö. (2001). Kavram haritaları ve kavramsal değişim metinlerinin öğrencilerin "asit-bazlar" konusundaki kavram yanılgılarının giderilmesine etkisi. *Yeni Bin Yılın Basında Fen Bilimleri Eğitimi Sempozyumu, (7–8 Eylül 2001), Bildiriler Kitabı, 281–284, 2001* Maltepe Üniversitesi Eğitim Fakültesi, İstanbul.

Zusho, A., Pintrich, P. R., & Coppalo, B. (2003). Skill and will: The role of motivation and cognition in the learning of college chemistry. *International Journal of Science Education, 25*(9), 1081-1094.

STORIES ABOUT NATURE AS AESTHETIC EXPERIENCE IN SCIENCE EDUCATION

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In recent decades, constructivist and cognitivist research recognized the important role played by imagination in science education. In particular, the potential of imaginative approaches to attract students to the scientific contents has been highlighted, in addition to the importance of routinely engaging learners' imagination in everyday learning experiences. The function performed by emotions and, in particular, by the feeling of pleasure appears to be less investigated in scientific literature: it is still not clearly defined how it is possible to facilitate learning processes related to the scientific contents by making them more enjoyable.
A branch of research is exploring the possibility of using metaphors and narratives for this purpose: to mobilize the emotional and affective dimension, integrating it with the logical one. This contribution aims to deepen the role that the feeling of pleasure can play in science education experiences in which metaphors and narratives are used systematically.
There is an area in which the feeling of pleasure is intertwined in a paradigmatic way with the knowledge of peculiar elements: in the aesthetic experience, we consider an object (artistic or natural) to be beautiful to the extent that we perceive a feeling of pleasure aroused by it.
In this regard, the more pleasant stories about nature are to read, the more effective they are in terms of educational effectiveness.
Stories need to be not only clear, precise, explanatory; stories need in fact not only to be understood, but also aesthetically enjoyed.
By taking "The Winter Story" as example (Fuchs, 2011), the paper focuses on the characters that make stories enjoyable. The pleasure of the text is indeed an essential ingredient in the narrative understanding of natural phenomena: the presence of metaphors, personifications, of a "grammar of stories", meaning the elements that are involved in the cognitive value of the narration.

Keywords: Aesthetic Experience, Science Education, Evaluation.

AESTHETIC PLEASURE AND SCIENCE EDUCATION

Aesthetic experience, pleasure and beauty

The Aesthetic experience's foundational characteristics have been recently discussed in the scientific literature (Desideri, 2018, p.13), where it has been defined "an experience with the characteristics of a dense, memorable and joyful synthesis, an experience that comes from the fusion of perceiver and perceived previous to their distinction. It is an experience without a subject and without an object". Such definition finds strong roots in the philosophical tradition, as the meaning of *aesthetic experience* oscillates between three main different aspects: the feeling of something radically "close", immediately present; a sort of intuition, the possibility of grasping something indeterminate, yet essential; the experience of beauty, which generates a feeling of specific pleasure. A particularly relevant resonance with the latter element can be traced in Kant's analysis of the aesthetic experience, as he discussed the *feeling of the beautiful* expressed in the *judgment of taste* (Kant, 1952). The judgment of taste, in Kant, is defined as a reflection based on the "free agreement" between the object and the need for finality of the intellect, which arouses a feeling of delight. The object of the feeling of beauty appears to be "made for" the needs of the subject, and oriented to arouse aesthetic emotions and a sense of harmony. Kant established a connection between pleasure and beauty, specifically declined in two definitions proposed in his analytic of the beautiful. In the former, Kant affirms "the beautiful is that which, apart from a concept, pleases universally". In this case, the judgement of taste belongs to the subjective experience, which appears individual and non-objective. Nonetheless, it demands consent and sharing, as it implies the claim of a common validity, related to a common sense that all men share. Universality can therefore be conceived as subjective, since it refers to a common sentiment of the judging subjects that resides in them. For this very reason, it remains without proof. However, universality itself becomes the foundation of shared meanings: taste can be formed, educated, it can be an index of a cultural identity. In the second definition, Kant states "the beautiful is that which, apart from a concept, is cognized as object of a necessary delight". In this case, beauty is not an element determined by a concept, but an evidence perceived by the subject. However, in order to happen, the recognition of beauty needs to be connected with pleasure aroused by beauty itself. In other words, the feeling of beauty exists only if the object in question is considered as a source of pleasure. Considering the elements underlined, it is possible to claim that Kant's view suggests that the experience of beauty and pleasure can be considered as the oscillation between a sense of intimacy and, at the same time, a sense of distance from the object. As proposed by Givone (2003), we can call it an experience of "enchantment".

Intimacy and distance of the beautiful

Intimacy and distance are both relevant elements to be taken into account in the analysis of the role played by pleasure in the experience of beauty. Regarding *intimacy* we can affirm, following Kant (1952), that beauty is the object of a free and immediate feeling: the judgment on beauty is neither conditioned by other judgments on the object nor the result of a deductive argument. Instead, the beautiful appears to be experienced on the basis of the needs of the subject. For example, a beautiful natural landscape may seem to be formed in order to allow a subject to admire and appreciate it. Moreover, the regularity of a composition of shapes and lines, or the logic in the proportions of a portrait or a statue, can generate a feeling of correspondence with a subject's need for harmony. For Bergson (2001), the sense of beauty can be identified in the arousing of a peculiar psychic state in the subject, meaning the identification of a high degree of continuity with our own experiences. On the other hand, *distance* plays a relevant role in in the experience of beauty, given how it appears as something we cannot completely explain as a defined concept. It comprehends irreducible elements, almost showing an autonomous subjectivity. For example, in Leonardo's Mona Lisa we can recognize the technique of the composition, but the smile remains an ineffable and indeterminate aspect. Similarly, a beautiful musical composition that follows a regular trend draws attention on the details that determine its variations, or the pleasure in the sense of grace is generated by a movement that looks regular and free at once, as something that cannot be determined by a preceding calculation. Given these elements we can affirm that pleasure, in the experience of beauty, can be considered as the immediate contact with something intimate and, at the same time, a feeling fostered by the search for something, which cannot be immediately grasped.

Beauty, aesthetic pleasure and cognition

In order to understand the strict relation that connects beauty, pleasure and cognition, we can once again refer to Kant's understanding of the aesthetic pleasure. In his view, the aesthetic pleasure corresponds to the experience of beauty and, at the same time, the aesthetic pleasure maintains a strong connection with the "understanding". When he defines the aesthetic experience, Kant used in fact the expression ″free play″ between the cognitive power of imagination and understanding (1952). Drawing on this premise, it is possible to recognize a "free agreement" between the object and the intellect in the judgement of taste. Such judgment is in fact a-conceptual but, at the same time, it is not entirely independent from the intellect. In other words, imagination functions in a rule-governed way, but without being governed by any rule in particular (Ginsborg, 2019). This peculiarity explains the mediating role played by the judgement of taste between the sensible dimension and the conceptual one. The experience of beauty shows an "originating" aspect, as it lays the foundation for knowledge itself. It invites to renew acquired rules, to identify affinities between different contexts, to give shape to new aspects of reality, to desire and anticipate hidden configurations of the world.

THE KANTIAN RELATIONSHIP BETWEEN THE AESTHETIC PLEASURE AND THE COGNITIVE ACTIVITY OF JUDGING FINDS SUPPORT IN RYLE AND GALLIE'S DEFINITION OF PLEASURE (1954). IN THEIR VIEW, PLEASURE IS A PECULIAR STATE THAT OSCILLATES BETWEEN EMOTIONS AND COGNITIVE FACULTIES. IN THE SAME VEIN, LEVINSON AND MATRAVERS (2005) STATED THAT THE AESTHETIC PLEASURE REQUIRES THE ATTENTION OF THE SUBJECT FIRSTLY ON THE CONTENT OF THE OBJECT, SECONDLY ON ITS MEANING, AND FINALLY ON ITS FORM.

By referring to the distinction previously made between the categories of intimacy and discontinuity, we can state that the aesthetic experience establishes a special continuity between our faculties and, at the same time, it rises a clear discontinuity in the ordinary flow of experience.

Aesthetic pleasure and Science Education

The strict connection, or even partial correspondence, between aesthetic pleasure and cognitive processes entails relevant consequences not only for reflections related to the Aaesthetic field, but also for other ones, such as pedagogy (Contini, 2019; Manera, 2019) and Science Education. In regard with the former, Egan (1990) - drawing on Vygotsky's conception of imagination (Vygotsky, 2004) - has defined imagination as an ability that allows to think in terms of possibilities (Egan, 1990). As for the latter, Wickman (2006) has argued, drawing on empirical data, that the processes of understanding and learning scientific contents show more relevant results when is connected to aesthetic experiences. Jakobson and Wickman (2008), by analyzing the use made by primary school children of the category of pleasing/displeasing, have highlighted its relevant role in engaging children in learning science. Milne (2010) argued that a careful exploration of all the qualities inherent in sense experience helps to generate a sense of wonder and interest in science. Finally, Stapleton (2018), Caiman and Lundegård (2018) have provided evidences of the importance of the role played by imagination in learning scientific contents. Drawing on these studies, we can state that educators should put more efforts in providing aesthetic experiences when presenting scientific contents. As argued by Hadzigeorgiou (2016, p. 53), activities that include the use of narrative in science education enhance "the aesthetic experience of pleasure". Similarly, Egan (2019) underlined the narratives' potential to involve students in everyday classroom activities and attract them to the world of science. In regard with the most relevant elements that narratives need to present in order to be effective, some Authors (Altman, 2008; Klassen, 2009) have underlined the importance of including elements such as metaphors, narrative coherence, characterization, conflicts, problems' resolution, and elements challenging previous knowledge. With particular regard to metaphorical devices, an innovative line of research (Fuchs, Contini, Dumont, Landini and Corni, 2019) recently explored how metaphors give formal content to stories of forces of nature, and how - at the same time - stories inform about the meaning of the metaphors in narrative, arousing a feeling of pleasure. By analyzing the example of the Winter Story (stories of forces of nature), and how - at the same time - stories inform about the meaning of the metaphors in narrative, arousing a feeling of pleasure.

Fostering aesthetic pleasure in storytelling trough continuity and discontinuity

Drawing on the discussed ambivalence of the aesthetic experience in terms of intimacy-continuity and distance-discontinuity, we argue that certain narrative elements are particularly effective in order to promote aesthetic pleasure.

With regard to the sense of continuity, we refer an example where metaphors of personification are used, as often happens in science stories for children that present scientific contents. A first explanation lies in the fact that personification can foster empathy, even in the specific terms of an *embodied simulation* (Gallese & Fredberg, 2007). Secondly, we argue that metaphors establish two kinds of continuity. On the one hand, we find continuity among different concepts, because metaphors condense many information in a single semantic element. On the other, we experience the continuity of our faculties, since metaphors bind pleasure and learning by making the latter faster. Thirdly, in order to understand metaphors we need to activate our imagination, as they require to go beyond the objective similarities immediately recognized (Johnson, 1981).

Concerning the sense of discontinuity, a first explanatory example can be found in the narrative scheme of the reversal. In Aristoteles' *Poetics* (1962), the reversal schema constituted the basis of the cathartic experience and the condition of a complex narrative plot. In relevant twentieth-century studies on narratives it was considered as an essential element for the construction of a narrative (Bruner, 1992). More recently, (Passalacqua & Pinzola, 2016), narrative has been studied for its relevant communicative function. A second relevant element related to the importance of the sense of discontinuity can be traced in metaphor. The effect of discontinuity in metaphor is related to its cognitive power, since metaphors tend to organize experience in an innovative way, which cannot be anticipated and determined by any prepared concept. Thirdly, a link between metaphor, discontinuity and pleasure can be related to the fact that the process of metaphors' understanding can trigger a rewarding cognitive research for elements that were not previously determined (Forceville, 1996).

Narrative and personification of scientific facts: the example of the Winter Story

A relevant example of a narrative realized in order to present macroscopic physical science and, more specifically, the concepts of heat and cold can be found in the *Winter Story* (Fuchs, 2010), here summarized.

As the last of the warmth of late Fall left the plain surrounding Little Hollow, cold found its way into the area and spread out. [...] The cold of winter knew a good place where it could do its job of making everything and everybody cold [...] It could flow into the hollow where the town had been built. It could collect there and it knew it would not be driven out so easily by a little bit of wind [...] The people of Little Hollow [...] knew that the cold would find its way into their homes if they were not careful to close windows and doors. The cold could even sneak in through tiny cracks between walls and windows, so the people had learned to build their homes well to make it hard for cold to flow in. [...] At times when much cold had collected in their town, the fires in the furnaces had to work very hard to fight the cold. The people in their homes made sure that the heat produced by the furnaces would always balance the cold so that their homes felt comfortably warm.

From a first analysis, we can notice that through the conceptual metaphor of "cold as a fluid substance", we necessarily and ordinarily think of the cold (Fuchs, 2013, p. 16). Furthermore, the metaphors proposed in the story are the same that are used in the formal scientific description of such phenomena. The expressions "[...] the cold would find a way to enter their homes" and "[...] the people had learned to build their homes well to make it hard for cold to flow in", are at the same time used ordinarily and scientifically correct (Fuchs, 2006).

From a deeper analysis, we can notice that the metaphoric projections elicited by the story lead to a process of personification. The projection frames cold in terms of a force of Nature, meaning a *powerful agent*. In this personification, the cold performs actions, behaves like an agent who has the power to affect reality. If the cold is framed as an agent, we can conceive natural scenes in which it lives adventures and interacts with objects in the world. By acting as a force of nature, cold creates an event that takes place over time and changes things in the world. In this personification, the cold performs actions, behaves like an agent who has the power to affect reality. Acting as a force of nature, it therefore creates an event that takes place over time and changes things in the world. This is the kind of event we call a “story”. In our view, the supported ambivalence of aesthetic experience requires that personification makes the phenomenon "familiar", but for the “estrangement” effect, it must also be evident that we have the encounter between diverse meanings. For example, in this case, rather than saying "the cold gathered in one place", we could speak of a "cold army" as a "collective" agent, separated from the semantic domain of natural phenomena; in this way we could favor the already present sense of confrontation, battle, strategy, without losing scientific coherence. This could also distribute the personification on other "agents": for example, the wind in the phrase "It could accumulate there and knew that it would not be chased away so easily from a little wind as it could happen on the plain".

Beauty in narrative about Darwin’s evolution theory

It is possible to emphasize the importance of narrative’s aesthetic experience in learning processes that involve scientific concepts by referring to an example related to Darwin’s evolution theory.

In this case, the narrative strategy and the personification can help on the one hand to make the evolutionary logic intelligible and familiar, on the other to generate wonder. For example, the spontaneous instinct of bees could be focused in the construction of the perfect hexagons of their hives, as if they were conscious architects. In the evolutionary history of the whale, the unexpected majesty of the contemporary animal could be compared with the less pleasant and significant aspect of its ancestors.

The same ambivalence emerge in narrative schemes related with the evolution. They favor identification (sense of continuity) and, at the same time, exceed expectations (sense of discontinuity). For example, stories of marginalization and redemption, in which an apparent defect becomes an evolutionary resource.

Aesthetic pleasure in stories about evolution and natural selection

To synthetize the aforementioned aspects, we could conceive a narrative about the evolution of a whale, inspired by the book “When the wales walked” (Dixon, 2018). We know that in the skeleton of a whale it is possible to observe tiny hind limbs and pelvic bones disconnected from the rest of the skeleton. These bones demonstrate the connection of cetaceans with ancestors who lived on Earth. If a whale were to discover the existence of these “vestiges”, the story could become a journey aimed to investigate his own past. In such fictional time travel, the whale could meet its own ancestors, who could exhibit and speak about some of their determining features as members of a specie. This element can encourage identification as an aspect of continuity: for example, if the story is addressed to children, they could be stimulated to reflect on their roots and origins, especially in multicultural contexts. At the end of the journey, we could imagine that the whale "encountered" its own species and learned to look at their qualities from a different perspective (e.g., it could see some of its defects as resources), thus declining the aspect of surprise-discontinuity. Furthermore, the encounters with the ancestors taking place during the journey should favor two main elements. On the hand, the idea of continuity with the past (e.g., by highlighting the similarity of some distant ancestors' qualities). On the other hand, the awareness that there are ruptures and discontinuities (e.g., an odd feature that becomes an evolutionary advantage, setting the conditions for a renewal of the species).

The beauty of the phenomenon

We claim that closeness and difference can be thought of as immediately blended in the experience of a primary perception of the object. The primary perception conceived in the phenomenological approach is careful to all the qualities of sensory experience before the intervention of the cognitive filter. In fact, it includes conceptual schemes, and meanings already acquired. By referring to Merleau Ponty, Dahlin (2001) states that the *presence* of the subject when the object is constituted is the characteristic of a radical insight and the condition of a "profound, convincing and satisfying" learning. This perceptive experience appears as "nascent *logos* (intended meaning, order, knowledge)" and condition of objectivity itself.

Conclusive remarks

By referring to the Kantian tradition, we have argued that a strict connection exists between aesthetic pleasure and cognitive processes. Drawing on scientific literature, we have shown how science-learning shows more relevant results when is connected to aesthetic experiences. This connection entails relevant consequences for Science Education. Teachers and educators should in fact put more efforts in providing aesthetic experiences when presenting scientific contents. Our argument is that a viable way to enhance the aesthetic experience of pleasure in Science Education is the use of narrative. Through the analysis of aesthetic experiences' ambivalence, in terms of intimacy-continuity and distance-discontinuity, we argued that certain narrative elements such as metaphors of personification and the reversal scheme, are particularly effective in promoting aesthetic pleasure. To be effective, narratives need as well to possess elements such as coherence, characterization, conflicts, problems' resolution, and elements challenging previous knowledge. By analyzing the example of the "Winter Story", we have shown how metaphors give formal content to stories of forces of nature, and how such stories inform about the meaning of the metaphors in narrative, arousing a feeling of pleasure. Finally, by proposing various examples, we have argued that it is possible to emphasize the importance of narrative's aesthetic experiences in learning processes that involve concepts related to the evolution theory.

ACKNOWLEDGEMENT

Annamaria Contini, Professor of Aesthetics, Department of Education and Human Sciences, University of Modena and Reggio Emilia, wrote the paragraphs: Fostering aesthetic pleasure in storytelling trough continuity and discontinuity; Narrative and personification of scientific facts: the example of the Winter Story; The beauty of the phenomenon.

Alice Giuliani, Postdoc Fellow, Department of Education and Human Sciences, University of Modena and Reggio Emilia, wrote the paragraphs: Aesthetic experience, pleasure and beauty; Intimacy and distance of the beautiful; Beauty in narrative about Darwin's evolution theory; Aesthetic pleasure in stories about evolution and natural selection.

Lorenzo Manera, Postdoc Fellow, Department of Education and Human Sciences, University of Modena and Reggio Emilia, wrote the paragraphs: Beauty, aesthetic pleasure and cognition; Aesthetic pleasure and Science Education; Conclusive remarks.

REFERENCES

Altman, R. (2008). *A theory of narrative*. New York, NY: Columbia University Press.

Aristotle (1962). *Poetics* (I. Bywater Trans.). Oxford, UK: Oxford Press. (Original work published 4th century BC).

Bergson, H. (2001). Time and Free Will: an essay on the immediate data of consciousness. (F.L. Pogson & M.A. Mineola Trans.). New York, NY: Dover. (Original work published 1889).

Bruner, J. (1992). The narrative construction of reality. *Critical inquiry, 18*(1), 1-21. doi:10.1086/448619

Caiman, C., & Lundegård, I. (2018). Young children's imagination in science education and education for sustainability. *Cultural Studies of Science Education*, 13(3), 687-705.

Contini, A. (2019). Nelson Goodman and Project Zero: art, cognition, and education. *Studi di estetica*, 3(15), 149-170. doi: 10.7413/18258646077.

Dahlin, B. (2001). The Primacy of Cognition – or of Perception? A Phenomenological Critique of the Theoretical Bases of Science Education. *Science & Education,* 10, 453–475. doi: org/10.1023/A:1011252913.

Desideri, F. (2018). *Origine dell'estetico: dalle emozioni al giudizio*. Roma, IT: Carocci.

Dixon, D. (2018). *When the Whales Walked and Other Incredible Evolutionary Journeys*. London: Words and picture Editor.

Egan, K. (1990). *Romantic understanding: The development of rationality and imagination. Ages 8-15*. New York, NY: Routledge.

Egan, K. (2019). Honouring the role of narrative and metaphor in education. In M. Hanne & A. Kaal (Eds.), *Narrative and metaphor in education: Looking both ways* (21-31). New York, NY: Routledge.

Forceville, C. (1996). *Pictorial metaphor in advertising*. London: Routledge.

Freedberg, D., & Gallese, V. (2007). Motion, emotion and empathy in esthetic experience. *Trends in cognitive sciences*, 11(5), 197-203. doi: 10.1016/j.tics.2007.02.003.

Fuchs, H. U. (2007). From image schemas to dynamical models in fluids, electricity, heat, and motion. Examples, practical experience, and philosophy. In E. Van den Berg, T. Ellermeijer, and O. Slooten (Eds.), *Proceedings of the GIREP Conference* (2-64). Amsterdam: University of Amsterdam.

Fuchs, H. U. (2013). Costruire e utilizzare storie sulle forze della natura per la comprensione primaria della scienza. In F. Corni (Ed.), *Le scienze nella prima educazione* (11-33). Trento, IT: Edizioni Centro Studi Erickson.

Fuchs, H. U., Contini, A., Dumont, E., Landini, A., & Corni, F. (2018). How metaphor and narrative interact in stories of forces of nature. In M. Hanne & A. Kaal (Eds.), *Narrative and metaphor in education: Looking both ways* (91-104). New York, NY: Routledge.

Fuchs, H.U. (2010), Force Dynamic Gestalt, Metaphor, and Scientific Thought, In Corni, F. (Chair), *Innovazione nella didattica delle scienze nella scuola primaria: al crocevia fra discipline scientifiche e umanistiche*. Symposium conducted at the meeting of the University of Modena and Reggio Emilia, Italy.

Ginsborg, H. (2019). Kant's Aesthetics and Teleology. In The Stanford Encyclopedia of Philosophy. Retrieved from https://plato.stanford.edu/entries/kant-aesthetics/.

Givone, S. (2003). *Prima lezione di estetica*. Bari, IT: Laterza.

Hadzigeorgiou, Y. (2016). *Imaginative science education*. Cham, Switzerland: Springer International.

Jakobson, B., & Wickman, P. O. (2008). The roles of aesthetic experience in elementary school science. *Research in science education*, 38(1), 45-65. doi:10.100711165-007-9039-8.

Johnson, M. (1981). Introduction: Metaphor in the philosophical tradition. In M. Johnson (Ed.), *Philosophical perspectives on Metaphor* (3-47). Minneapolis: University of Minnesota Press.

Kant, I. (1952). *Critique of Judgment* (J.C. Meredith Trans.). Oxford: Oxford University Press. (Original work published 1790).

Klassen, S. (2009). The construction and analysis of a science story: A proposed methodology. *Science & Education*, 18(*3*), 401-423. doi: 10.1007/s11191-008-9141.

Manera, L. (2019). The aesthetic experience in the Reggio Emilia Approach. *Studi di estetica*, 3(15), 129-147. doi: 10.7413/18258646076.

Matravers, D., & Levinson, J. (2005). Aesthetic properties. In *Proceedings of the Aristotelian Society*: Vol. 79 (pp. 191-227).

Passalacqua, F., & Pianzola, F. (2016). Epistemological Problems in Narrative Theory: Objectvist vs. Constructvist Paradigm. In R. Baroni, & F. Revaz (Eds.), *Narrative Sequence in Contemporary Narratology* (195-217). Columbus: Ohio State University Press.

Ryle, G., & Gallie, W. B. (1954). Symposium: Pleasure. In *Proceedings of the Aristotelian Society*: Vol. 28 (pp. 135-164).

Stapleton, A. J. (2018). Imagery, intuition and imagination in quantum physics education. *Cultural Studies of Science Education*, 13(1), 227-233. Doi: 10.10071142201697428.

Vygotsky, L. S. (2004). Imagination and creativity in childhood. *Journal of Russian & East European Psychology*, 42(1), 7-97. doi:10.1080/10610405.2004.11059210

Wickman, P. O. (2006). *Aesthetic experience in science education: Learning and meaning-making as situated talk and action*. New York, NY: Routledge.

SUPPORTING CONCEPTUAL CHANGE - THE HOW AND WHY OF MINDFULNESS IN BIOLOGY EDUCATION

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Science learning and scientific literacy are dependent upon a student's ability to understand and process the concepts presented to them in the classroom. When students enter the classroom with pre-existing concepts, they often go through the process of conceptual change in order to integrate the newly presented material into their existing conceptual structures or to rework these structures. Yet, this natural learning process is sometimes hindered due to the emotional attachments to these pre-existing thought schemas. To increase the efficacy of educational interventions, this emotional aspect of learning needs to be recognized and addressed because these emotional states can otherwise lead to conceptual conservatism or even a boomerang effect. One possible means of addressing negative emotional states that arise in response to lessons that contradict with students' worldviews is the introduction of stress-reduction tools such as mindfulness, which has already proven to be effective in supporting an individual's ability to regulate their emotional responses and to access higher cognitive function. In fact, in this way, mindfulness can even be seen as analogous to intentional conceptual change and thus presents an integral means of supporting science learning. In this paper, I will briefly discuss the role of emotions in science learning and then present concrete methods that can be used to increase student receptivity through the reduction of negative emotions and how these methods can support content learning in the science classroom.

Keywords: Mindfulness, Learning, Emotion

Introduction

Research has shown that emotions are not only present in the science classroom but that they have a significant impact on learning outcomes (Alsop & Watts, 2003; Laukenmann et al., 2003; Pekrun & Stephens, 2012; Santos & Mortimer, 2003; Watts & Walsh, 1997; Zembylas, 2002, 2004, 2005). Learning about science can invoke a full-range of emotions from joy, wonder and surprise to anxiety, anger, fear and hopelessness (Sinatra, Broughton, & Lombardi, 2014), yet it has been shown that negative emotions, such as frustration or anger, may foster student resistance towards learning as they perceive the incoming scientific information as a threat (Gregoire, 2003; Linnenbrink & Pintrich, 2004) and this is particularly true when students ideas are challenged or in conflict with the scientific data presented in the classroom (Sinatra, Broughton, et al., 2014). There are a number of topics in the science classroom which could cause this type of conflict such as stem cell research, biological evolution and anthropogenic climate change (Griffith & Brem, 2004). Thus, understanding the role of emotions and addressing these emotional states in the context of science learning is important as there is a clear relationship between emotions and cognitive ability, in which positive emotional states are associated to an increase in cognitive functioning, while negative emotional states are associated with a narrowing of the cognitive functioning (Powietrzynska & Tobin, 2015). Most importantly, in terms of potential scientific literacy, findings have shown that emotions may support or impede conceptual change in science classrooms (Demastes-Southerland, Good, & Peebles, 1995; Duit, 1999; Duit & Treagust, 2003; Rhöneck, Grob, Schnaitmann, & Völker, 1999) as Sinatra et al. found that the processes of attitude change and conceptual modification are significantly impacted by student motivation and their emotional state and that the presentation of facts is not likely to be enough to cause students to relinquish their preconceptions in order to accept newly presented evidence (Sinatra, Kienhues, & Hofer, 2014; Sinatra & Seyranian, 2015).

How mindfulness supports science learning

Data on the effect of emotions on cognitive functions necessitates new teaching strategies that address and mitigate negative emotional states in order to support learning in the sciences. For this purpose, I propose the use of contemplative methods, specifically mindfulness practices, as a means of addressing extreme emotional states. Mindfulness practices have been well-integrated and successful in medical field for multiple decades and is finding increasing application in educational settings. Mindful practices can provide crucial support in addressing the emotional states in the classroom as it encourages the development of self-regulatory skills associated with the ability to be aware of emotions and consciously choose how to react to those emotions. Mindfulness in the classroom can thus be seen as a tool to monitor and ease emotional states so that cognitive functions remain intact (E. M. Watts, 2019).

From an educational perspective mindfulness offers teachers a means of addressing both the cognitive and affective dimensions of student experience in the classroom and "mindfulness training has been linked to a range of cognitive, social and psychological benefits to students and teachers" (Powietrzynska & Tobin, 2015, p. 2). As Tobin points out, this type of reflexivity is crucially important for individuals such as teachers and students as much of social life occurs without conscious awareness and such practices allow actors to better identify the way in which they are affected by their environment and how they affect other players in this environment and offers these actors a means by which they can rationally change aspects of their behaviour to benefit the collective group (2012). Most importantly when considering the positive effects that mindfulness can have in developing scientific literacy potential, it has been shown that mindfulness is in many ways analogous to intentional conceptual change as it reflects a voluntary state of mind that connects motivation, cognition and learning (Duit & Treagust, 2003; Salomon & Globerson, 1987).

Incorporating mindfulness into biology lessons

Mindfulness practices can be introduced into the science classroom in variety of forms and formats. Some school-wide programs involve in-depth training of all school personnel and the involvement of parents, while other interventions can occur at the classroom level through a simple introduction of specific practices from the teacher to a particular class. Powietrynska, Alexakos and Tobin offer an approach to mindfulness in the classroom through the use of heuristics, which encourages students to reflect upon their own thought processes, bodily sensations, emotions, etc. (2014). It is also possible to introduce mindfulness through simple isolated breathing exercises that also encourage students to use their breath as an anchor as they use their higher cognitive structures to observe limbic processes such as the arising of emotions, impulses and sensations.

Connecting mindfulness to classroom content

Although it is possible to introduce mindfulness into the classroom as a self-contained subject, it is also possible to introduce mindfulness in a way that it complements the content presented in the course curricula. Because of the biological effects and basis of mindfulness practices it is possible to introduce these in lessons that discuss anatomy and physiology, human health and even evolution (Table 1).

Table 1. Possible lessons where mindfulness could be incorporated into content.

Lessons Where Mindfulness Can Be Integrated into Science Content	
Anatomy and Physiology	▪ *Lessons on the brain and its anatomy* ▪ *Lessons on neuroplasticity* ▪ *Lessons on the nervous system, particularly about the nervous system(s)*
General Health	▪ *Stress and its effect on the body, in particular a look at the link between stress and certain diseases and ways to counteract stress*
Evolution	▪ *Evolution of stress-responses, threat-response etc.* ▪ *Evolution of various regions of the brain, in particular the difference between the neocortex and the limbic system*

Why mindfulness is useful in biology education

The efficacy of mindfulness in the promotion of increased well-being and decreased suffering has been shown through an extensive amount of studies (Gotink et al., 2015; Holzel et al., 2011; Ireland, 2014; Khoury, Sharma, Rush, & Fournier, 2015; Purser, Forbes, & Burke, 2016; Siegel, 2014; Tabak, Horan, & Green, 2015; Tang, Hölzel, & Posner, 2015; Taren, Creswell, & Gianaros, 2013; Zoogman, Goldberg, Hoyt, & Miller, 2015). The general use in education has also been studied and the results of these studies have highlighted not only on the personal effects for the practitioners but also on the overall improvement of classroom dynamics (Ergas, Hadar, Albelda, & Levit-Binnun, 2018; Felver & Jennings, 2016; Jennings & Greenberg, 2011; Kemeny et al., 2012; Kuyken et al., 2013; Mendelson et al., 2010; Napoli, Krech, & Holley, 2005; Powietrzyńska & Noble, 2018; Schonert-Reichl & Roeser, 2016; Sheinman & Hadar, 2016; Weare, 2012; Zajonc, 2016; Zenner, Herrnleben-Kurz, & Walach, 2014). More recently, studies have also began to examine the specific advantages that it offers for science learning (Powietrzynska & Tobin, 2015).

Supports conceptual change

Studies have shown that simply learning about evolution or climate change does not change an individual's stance on the issue. In other words, those who deny climate change, continue to do so regardless of the amount of factual data that is presented to them (E. Watts, 2019). This phenomenon of conceptual conservatism is rooted in the emotional nature of humans. Without addressing the emotional aspect of issues such as human origins or human|environment interactions, many educational interventions remain fruitless.

Mindfulness offers a means of addressing this emotional aspect and encourages practitioners to access the rational|logical thinking organs rather than basing reactions and judgements on limbic processes (Figure 1).

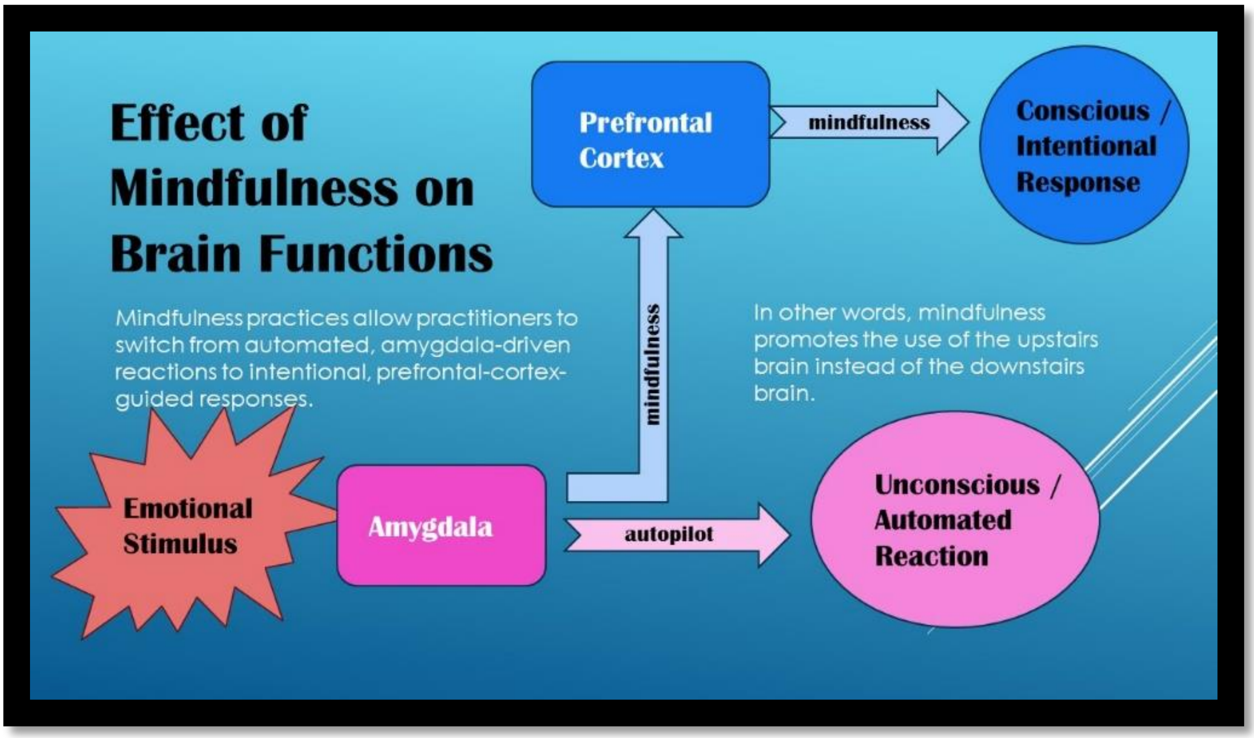

Figure 1. Effects of mindfulness on brain functions (E. M. Watts, 2019).

Makes classroom content more personal

In addition to ameliorating emotional states that can lead to conceptual conservatism, mindfulness practices can also make learning about biology more personal and thus more relevant and interesting. Learning about concepts such as the nervous system or about the circulation system or even the interplay between the parasympathetic system and sympathetic system are no longer abstract concepts that are limited to the pages of textbook but become concepts that students are able to understand and experiment with. These concepts become personal and thus more interesting as they learn how they can observe changes in these systems and even affect these systems through conscious choice. Likewise, learning about the change possible through mindfulness practices can awake a greater interest in the anatomy and physiology of the brain. The idea of neural plasticity becomes one of wonder and excitement once one realizes how this process can be actively guided. We are thereby able to help students better learn about scientific principles as they simultaneously learn about themselves. Moreover, we are awaking an interest in science and associating science learning with positive emotional states which in turn has effects on a student's future relationship to science and thus their overall scientific literacy potential.

Development of a Sample Lesson Plan

Based on these studies, I have begun to develop lesson plans that introduce students to mindfulness while also teaching core concepts of biology such as evolution and physiology

(Figure 2). The lesson plans are designed to be used consecutively as the information in one supports the content of the subsequent lesson.

The first lesson plan focuses on human evolution, particularly the evolution of the fight-or-flight modus. Here the emphasis is placed on understanding the advantages of 'stress' as a means of warning us about potential dangers, and also discusses the health problems associated with chronic stress in modern society as this ancient neurological system often 'overreacts' to stimuli in our current environment, e.g. deadlines. The second lesson plan takes a closer look at our anatomy and physiology, particularly in the differences between sympathetic and parasympathetic nervous systems and how these systems are involved in stress responses and how the balance between these systems can be influenced through conscious, mindful breathing exercises. The lesson was concluded by having the students engage in a five-minute mindful breathing activity.

Sample Lesson Plan for Teaching Mindfulness as Part of Biology Class on Evolution and Anatomy of the Nervous System
Class objectives: At the end of class students will be able to identify how stress reactions are related to evolution of the fight-flight-freeze system and the activation of the sympathetic nervous system. They should furthermore be able to identify the survival advantage that this system offered prehistoric humans and the disadvantages of the over activation of this system in modern society.
Connection to course goals: NGSS: HS-LS4-4 Biological Evolution: Unity and Diversity Builds upon: MS. Structure, Function, and Information Processing and 4-LS1-2 From Molecules to Organisms: Structures and Processes;
Anticipatory set: (*Goal*: Students should become acquainted with the idea of the physiological process of stress) • Open class discussion: When do you feel stressed? What physical attributes do you associate with feelings of stress?
Part 1: Evolution of Stress and the Effects on Our Modern Bodies and Minds
Introduction: (*Goal:* Students should begin to examine the evolutionary roots of stress) • Open class discussion: Is feeling stressed a pleasant feeling? Why or why not? Why have we evolved to feel stressed? • Student discussion: In small groups have students discuss the following questions: o What is stress? o What is the evolutionary advantage of stress? o How does the fight-flight-freeze system help animals survive in the wild? How did this system help primitive humans survive? o Does stress offer more advantages or disadvantages for modern man? *Optional expansion*: This time could be used to discuss the fight-flight-freeze system in greater detail.

Figure 2. Sample lesson plan.

While the direct learning goal for these lesson plans is to increase the students' understanding of the content knowledge by making the lessons more relatable and personal, the secondary goal is to introduce mindfulness within the context of understanding the effects of stress on the body. By understanding the potential to influence our own physiology through mindfulness activities in order to counter the harmful effects of stress students also become more generally aware of their ability to regulate negative emotional states, e.g. anxiety, anger, etc. This increased understanding of emotional regulation is one of the core reasons why mindfulness has the potential to improve classroom dynamics and thus lead to the development of more pro-social classrooms (Jennings & Greenberg, 2011; Kemeny et al., 2012).

Pre-service teachers' analysis of the lesson plan

To test the efficacy of these lesson plans and the willingness on the part of teachers to use such lesson plans in their classrooms, both lesson plans were presented to forty-five students currently enrolled in the biology education program at the Friedrich-Schiller University in Jena, Germany. Based on pre-post questionnaires, we found that the students were already aware of the importance of emotions in science classrooms with 6% of the students stating that emotions were *very important* and 76% reporting that they were *important* on the pre-questionnaire. They were also concerned about how negative emotions in the classroom could impair a teacher's ability to teach and a student's ability to learn.

After the conclusion of the trial of the lesson plans, the students were asked to rate the efficacy of the lesson plan. The results of the post-questionnaire showed that the majority of the students who participated found that the lesson plans had increased both their knowledge of the content material and increased their overall interest in mindfulness practices – with the majority of them stating that they would be interested in using mindfulness both in their personal and professional lives. In fact, the most frequent suggestion for improvement of the lesson was a call for an increased amount of time for mindfulness activities, rather than only five minutes at the conclusion of the lesson. The lesson plan will be updated according to this feedback and further testing is planned for the upcoming semester.

Conclusion

There is neurobiological evidence that emotional processes have a profound effect on learning, attention, memory, decision making and social functioning – all of which are crucial aspects of cognition that are relevant for learning in school settings (Immordino-Yang & Damasio, 2007; King, Ritchie, Sandhu, & Henderson, 2015), which means that it is necessary to develop new strategies to address emotions in the classroom in order to create the best learning conditions possible. Mindfulness presents a means of addressing these emotional processes in order to support learning while also increasing a sense of well-being in the classroom. The lesson plans developed for this purpose showed that biology content can be taught in combination with the basics of mindfulness and that students showed an increased understanding of content knowledge while also developing an increased interest in mindfulness practices.

Acknowledgements

My sincerest thanks to Clemens Hoffmann for his assistance in running the experiments with the pre-service teachers and to all of the pre-service teachers who participated in the analysis of the lesson plan.

REFERENCES

Alsop, S., & Watts, M. (2003). Science education and affect. International Journal of Science Education, 25(9), 1043 - 1047.

Demastes-Southerland, S., Good, R., & Peebles, P. (1995). Student's conceptual ecologies and the process of conceptual change in evolution. Science Education, 79, 637-666.

Duit, R. (1999). Conceptual change approaches in science education. In W. Schnotz, S. Vosniadou, & M. Carretero (Eds.), New perspectives on conceptual change (pp. 263-282). Kidlington, Oxford: Elsevier Science.

Duit, R., & Treagust, D. (2003). Conceptual change: a powerful framework for improving science teaching and learning. International Journal of Science Education, 25, 671-688.

Ergas, O., Hadar, L. L., Albelda, N., & Levit-Binnun, N. (2018). Contemplative Neuroscience as a Gateway to Mindfulness: Findings from an Educationally Framed Teacher Learning Program. Mindfulness. doi:10.1007/s12671-018-0913-4

Felver, J. C., & Jennings, P. A. (2016). Applications of mindfulnessbased interventions in school settings: an introduction. Mindfulness, 7(1), 1−4.

Gotink, R. A., Chu, P., Busschbach, J. J. V., Benson, H., Fricchione, G. L., & Hunink, M. G. M. (2015). Standardised mindfulness-based interventions in healthcare: an overview of systematic reviews and metaanalyses of RCTs. PLoS ONE, 10(4), e0124344.

Gregoire, M. (2003). Is It a Challenge or a Threat? A Dual-Process Model of Teachers' Cognition and Appraisal Processes During Conceptual Change. Educational Psychology Review, 15(2), 147-179. doi:10.1023/A:1023477131081

Griffith, J. A., & Brem, S. K. (2004). Teaching evolutionary biology: Pressures, stress, and coping. Journal of Research in Science Teaching, 41(8), 791–809.

Holzel, B. K., Carmody, J., Vangel, M., Congleton, C., Yerramsetti, S. M., Gard, T., & Lazar, S. W. (2011). Mindfulness practice leads to increases in regional brain gray matter density. Psychiatry Res, 191(1), 36-43. doi:10.1016/j.pscychresns.2010.08.006

Immordino-Yang, M., & Damasio, A. (2007). We feel, therefore we learn: The relevance of affective and social neuroscience to education. Mind, Brain and Education, 1(1), 3 - 10.

Ireland, T. (2014). What Does Mindfulness Meditation Do to Your Brain? Scientific America.

Jennings, P. A., & Greenberg, M. T. (2011). The Prosocial Classroom: Teacher Social and Emotional Competence in Relation to Student and Classroom Outcomes. Review of Educational Research, 79(1), 491-525. doi:10.3102/0034654308325693

Kemeny, M. E., Foltz, C., Cullen, M., Jennings, P., Gillath, O., Wallace, B. A., . . . Ekman, P. (2012). Contemplative/Emotion Training Reduces Negative Emotional Behavior and Promotes Prosocial Responses. Emotion, 12(2), 338 –350. doi:10.1037/a0026118.supp

Khoury, B., Sharma, M., Rush, S. E., & Fournier, C. (2015). Mindfulness-based Stress Reduction for Healthy Individuals: A Metaanalysis. Journal of Psychosomatic Research, 78(6), 519-528.

King, D., Ritchie, S., Sandhu, M., & Henderson, S. (2015). Emotionally Intense Science Activities. International Journal of Science Education, 37(12), 1886-1914. doi:10.1080/09500693.2015.1055850

Kuyken, W., Weare, K., Ukoumunne, O. C., Rachael Vicary, Motton, N., Burnett, R., . . . Huppert, F. (2013). Effectiveness of the Mindfulness in Schools Programme: Non-randomised Controlled Feasibility Study. The British Journal of Psychiatry, 203(2), 126-131.

Laukenmann, M., Bleicher, M., Fuß, S., Gläser-Zikuda, M., Mayring, P., & Phöneck, C. v. (2003). An investigation of the influence of emotional factors on learning in physics instruction. International Journal of Science Education, 25(4), 489-507.

Linnenbrink, E. A., & Pintrich, P. R. (2004). Role of affect in cognitive processing in academic contexts. In D. Y. Dai (Ed.), Motivation, Emotion, and Cognition: Integrative Perspectives on Intellectual Functioning and Development. (pp. 57-87). Mahwah, NJ: Lawrence Erlbaum Associates.

Mendelson, T., Greenberg, M. T., Dariotis, J. K., Gould, L. F., Rhoades, B. L., & Leaf, P. J. (2010). Feasibility and Preliminary Outcomes of a School-based Mindfulness Intervention for Urban Youth. Journal of Abnormal Child Psychology, 38(7), 985-994.

Napoli, M., Krech, P. R., & Holley, L. C. (2005). Mindfulness Training for Elementary School Students: The Attention Academy. Journal of Applied School Psychology, 21(1), 99-125.

Pekrun, R., & Stephens, E. J. (2012). Academic Emotions. In K. R. Harris, S. Graham, T. Urdan, S. Graham, J. M. Royer, & M. Zeidner (Eds.), Apa educational psychology handbook, vol 2: Individual differences and cultural and contextual factors (Vol. 2, pp. 3-31). Washington, DC: American Psychology Association.

Powietrzyńska, M., & Noble, L. (2018). Mindfulness – seeping through the cracks in the American context of teacher education. Learning: Research and Practice, 4(1), 66-77. doi:10.1080/23735082.2018.1428140

Powietrzynska, M., & Tobin, K. (2015). Mindfulness and Science Education. In R. Gunstone (Ed.), Encyclopedia of Science Education (pp. 1-7): Springer Netherlands.

Powietrzynska, M., Tobin, K., & Alexakos, K. (2014). Facing the grand challenges through heuristics and mindfulness. Cultural Studies of Science Education, 10, 65-81. doi:10.1007/s11422-014-9588-x

Purser, R. E., Forbes, D., & Burke, A. (Eds.). (2016). Handbook of Mindfulness: Culture, Context, and Social Engagement: Springer.

Rhöneck, C. v., Grob, K., Schnaitmann, G. W., & Völker, B. (1999). Learning in basic electricity: How do motivation, cognitive and classroom climate

factors influence achievement in physics? International Journal of Science Education, 20(5), 551-565.
Salomon, G., & Globerson, T. (1987). Skill may not be enough: The role of mindfulness in learning and transfer. International Journal of Education Research, 11, 623-637.
Santos, F. M. T. d., & Mortimer, E. F. (2003). How emotions shape the relationship between a chemistry teacher and her high school students. International Journal of Science Education, 25, 1095-1110.
Schonert-Reichl, K. A., & Roeser, R. W. (2016). Handbook of Mindfulness in Education: Springer.
Sheinman, N., & Hadar, L. L. (Eds.). (2016). Mindfulness in education as a whole school approach: Principles, insights and outcomes: Cambridge Scholars Publishing.
Siegel, R. D. (2014). The Science of Mindfulness: A Research-Based Path to Well-Being. Chantilly, Virginia: The Teaching Company.
Sinatra, G. M., Broughton, S. H., & Lombardi, D. (2014). Emotions in science education. In R. Pekrun & L. Linnenbrink-Garcia (Eds.), International Handbook of Emotions in Education (pp. 415-436). London: Routledge.
Sinatra, G. M., Kienhues, D., & Hofer, B. K. (2014). Addressing challenges to public understanding of science: Epistemic cognition, motivated reasoning, and conceptual change. Educational Psychologist, 49(2), 123-138.
Sinatra, G. M., & Seyranian, V. (2015). Warm change about hot topics: The role of motivation and emotion in attitude and conceptual change about controversial science topics. In L. Corno & E. M. Anderman (Eds.), Handbook of Educational Psychology (pp. 245-256): Routledge.
Tabak, N. T., Horan, W. P., & Green, M. F. (2015). Mindfulness in schizophrenia: Associations with self-reported motivation, emotion regulation, dysfunctional attitudes, and negative symptoms. Schizophr Res, 168(1-2), 537-542. doi:10.1016/j.schres.2015.07.030
Tang, Y.-Y., Hölzel, B. K., & Posner, M. I. (2015). The neuroscience of mindfulness meditation. Nature Reviews Neuroscience, 16, 213. doi:10.1038/nrn3916
Taren, A. A., Creswell, J. D., & Gianaros, P. J. (2013). Dispositional Mindfulness Co-Varies with Smaller Amygdala and Caudate Volumes in Community Adults. PLoS ONE, 8(5), e64574. doi:10.1371/journal.pone.0064574
Tobin, K. (2012). Sociocultural perspectives on science education. In B. J. Fraser, C. J. McRobbie, & K. G. Tobin (Eds.), Second international handbook of science education (pp. 3 -17). Dordrecht: Springer.
Watts, E. (2019). Teaching Climate Science to Increase Understanding and Receptivity. The American Biology Teacher, 81(5).

Watts, E. M. (2019). Neanderthals in the Classroom. Boca Raton, FL.: Taylor & Francis.

Watts, M., & Walsh, A. (1997). Affecting primary science: a case from the early years. Early Childhood and Care, 129, 51-61.

Weare, K. (2012). Evidence for the Impact of Mindfulness on Children and Young People.

Zajonc, A. (2016). Contemplation in Education Handbook of Mindfulness in Education (pp. 17-28). New York: Springer.

Zembylas, M. (2002). Constructing genealogies of teachers' emotions in science teaching. Journal of Research in Science Teaching, 39, 79-103.

Zembylas, M. (2004). Young children's emotional practices while engaged in long-term science investigations. Journal of Research in Science Education, 41, 213-238.

Zembylas, M. (2005). Three Perspectives on Linking the Cognitive and the Emtional in Science Learning: Conceptual Change, Socio-Constructivism and Poststructuralism. Studies in Science Education, 41, 91-116.

Zenner, C., Herrnleben-Kurz, S., & Walach, H. (2014). Mindfulness-based Interventions in Schools - A Systematic Review and Meta-analysis. Frontiers in Psychology, 5, 603.

Zoogman, S., Goldberg, S. B., Hoyt, W. T., & Miller, L. (2015). Mindfulness Interventions with Youth: A Meta-analysis. Mindfulness, 6(2), 290-302.

BIODIVERSITY VALUES OF SECONDARY SCHOOL STUDENTS

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Biodiversity is an important and complex concept that involves three hierarchical levels, comprising from genes to ecosystems in an integrated manner with biological evolution as a structure main axis. The values of biodiversity emerge in conflicts between different social interests related to the use and preservation of environment. This study aimed to investigate biodiversity values of secondary school students. Thus, we created and validated a 5-point Likert scale questionnaire about biodiversity values. Then it was applied to 73 secondary school students. The factorial analysis of data allowed us to map three different dimensions about biodiversity values of students: "ecological", "symbolic and ethical" and "economic". These values showed a close relationship with those found in the scientific literature. The differences found among them are due to particularities of the micro social context. Thus, biodiversity plays a central role in biology curriculum and the comprehension of these values provides a wide vision about the human interference on environment and a critical perspective of biodiversity. It is important to clarify in science teaching the values of complex concepts in order to help teachers to understand students and improve pedagogical material.

Keywords: values in science education, biodiversity, secondary school

INTRODUCTION

Biodiversity is a main concept to understand biology and which includes three hierarchical levels (or dimensions), comprising from genes to ecosystems (Wilson, 1997; Lévêque & Mounolou, 2004). This concept has been occupied human mind since the beginning of humanity. Nowadays, there are complex scientific classification systems for all this biological diversity. For Lévêque (1999), biodiversity is not only a catalogue of genes, species or environments. This concept goes beyond of a fragmented approach of the three dimensions and must be seen as a dynamic/interactive set of those different levels of biological hierarchy. In this sense, biological evolution works as a main axis of biodiversity:

> "According to current theories of evolution, it is due to the existence of genetic diversity within species that they can adapt to changes in the environment. It always marked Earth's history. Conversely, the genetic diversity of species evolves over time, in response to these changes in environment, as well as due to mutations. The same occurs with plant and animal communities, which constitute ecosystems and responds by means of qualitative and quantitative changes to fluctuations in the environment in which they live. This dynamic of biological systems and ecological conditions, to which they are confronted, explains that species evolve and diversify and that ecosystems host more or less rich floras and faunas" (Lévêque, 1999, p. 18).

The biodiversity values emerge from a conflict between different social interests related to the use and preservation of environment. In this sense, the values make up the reasons why people are interested in that. Unlike the biological definition of the concept, experts in social sciences have been using the values of biodiversity in different manners. (Wiegleb, 2002). For Lévêque and Mounolou (2004), the biodiversity values occupy three dimensions: I) Economic: values related to the supply of raw materials for human development, in relation to industry, medicines, agricultural production, biotechnology and tourism; II) Ecological: values aimed to maintain life on the planet; III) Ethics and patrimony: values focused on the moral duty to protect all other forms of life. In this work we create a fourth dimension of values, "symbolic and ethical", which is related to the well-being of the humans in relation to nature.

Science education plays an important role in this context. By understanding the concept of biodiversity and its values, students can rethink the use of environmental resources and perceive more critically at how our society organizes itself. The decision-making power of students is strengthened, helping to build a reflective education on environmental issues. However, to understand biodiversity it is necessary for teachers to develop activities that go beyond simply memorizing the concept. It is important that teachers know which values their students have linked to biodiversity. Without access to these values, any activity prepared for teaching biodiversity is decontextualized and meaningless. In this scenario, the present study aimed to characterise the biodiversity values of secondary school students.

METHOD

The work was conducted in three phases. The first involved the creation and validation of a 5-point Likert scale questionnaire about biodiversity values. We did a bibliographical research about biodiversity values in literature. Then, we categorized the values in three dimensions and formulated 27 questions (9 questions for each value). Science teachers, graduate students in science education and academic professors analysed the questions in the process of validation. They judge the contend and form of the questions, verifying if the questionnaire had conceptual errors or were ambiguous. The second phase was the application of the questionnaire in October 2017. Then, in the third phase we analysed the data generated.

The work had a qualitative feature, once it involves the description and categorization of the biodiversity values of chosen students. In addition, the research had also a quantitative feature, once statistical tools were used to obtain the data. The research presented here can be considered a mixed methodological approach (Morais & Neves, 2007).

Participants

The participants of this research were 73 elementary students (between 12 and 14 years old) from a public school at a city in the interior of Brazil. They come from middle and lower economic class families and have little access to cultural assets such as museums or libraries. Their school did not have a science or computer laboratory. However, the science curriculum of this school was very sophisticated. The science teachers of this school based-on the curriculum on science literacy and inquiry-based learning. Therefore, students have classes that strongly stimulates scientific thinking in a constructivist approach.

Questionnaire

Each question proposed a different situation for the respondent to position himself. The scale ranging from 1 to 5 showed the degree of importance and consequently the decision made by the respondent on the proposed situations. Some examples of questions about each value:

Q1 Economic value

In my opinion, one of the main reasons for us to approve extracting plants from an environment is the production of new medicines.

Q8 Ecological value

In my opinion, the main reasons for approving biodiversity conservation is to maintain genetic variability within each species.

Q24 Ethics and patrimony value

In my opinion, one of the main reasons for approving the preservation of a forest is the presence of native people living there.

Validation and Statistical analysis

The first step of validation was the evaluation of the questionnaire by experts consisting of professors and researchers with Biological Sciences background. This validation step allowed removing ambiguous questions, the improvement in vocabulary and the greater precision of the assertions. After application, the internal structure of the questionnaire was validated through exploratory factorial analysis. The assumptions about the suitability of data were tested using the Kaiser-Meyer-Olklin (KMO) and Bartlett tests (Malhotra, 2001; Hair Jr et al, 2009). The factors were extracted according to the main components method and the number of factors was extracted according to Scree test (Cattell, 1966). After extraction, the factors were retained and rotated by the Varimax orthogonal rotation method (Tabachnick & Fidell, 2007). All statistical analyzes were performed in RStudio software version 0.99.902 with the packages "psych", "GPArotation" and "nFactors".

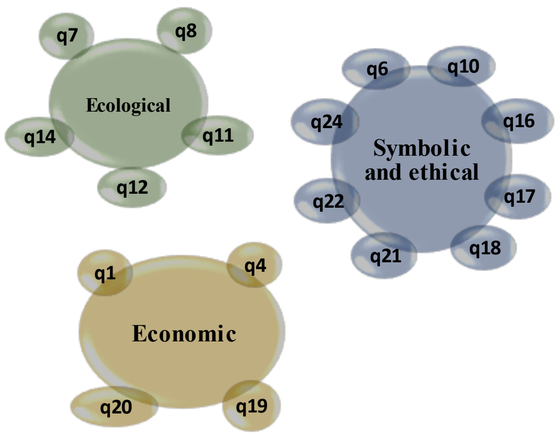
RESULTS

Table 1 presents the factor loads of each question. The loads indicate which variables (questions) were more related to each factor. The symbol "/" represents questions with factor loads whose values were less than 0,10. According to the scree test, it was obtained 3 factors. The next step was the grouping of questions that were more related to each other (figure 1) according to the factorial loads. The first factor was called *Symbolic and ethical* and covered questions 6, 10, 16, 17, 18, 21, 22 and 24. The second factor was called *Economic* and involved questions 1, 4, 19 and 20. Finlay, the last factor was called *Ecological* and grouped questions 7, 8, 11, 12 and 14. The denomination of each factor was given according to the baseline of theoretical reference, the content of the questions and the way in which they interrelate within each factor. Overall and Individual MSA (KMO) must be higher than 0.50. The analyses showed an Overall MSA=0.64 and the individual KMO for each question also showed positive results. Bartlett´s test p-value must be less than 0.05. The analysis showed a p-value= 0.05. Although p-value score of Bartlett´s test was at the limit, the consistency of the other data supported the continuity of the analyses.

Table 1. The factorial loads of questionnaire´s factorial solution.

Factorial solution			
Content of question	**Factor 1**	**Factor 2**	**Factor 3**
q1 - Plants for medicine	\	0.46	\
q4 - Mining	\	0.42	0.12
q6 - Ecotourism	0.5	\	\
q7 - Species extinction	\	\	0.41
q8 - Genetic variability	-0.1	0.4	0.5
q10 - Soil protection	0.43	-0.14	0.2
q11 - River protection	0.14	\	0.55
q12 - Climate regulation	0.18	-0.11	0.38
q14 - Divine nature	0.1	-0.11	0.66
q16 - Welfare	0.35	-0.17	0.35
q17 - Beauty of landscape	0.68	-0.21	0.2
q18 - Good memories	0.63	0.24	\
q19 - Fear or disgust	\	0.52	-0.14
q20 -Living beings that cause problems	-0.14	0.56	\
q21 - Knowledge on biodiversity	0.45	0.11	0.35
q22 - Future generations	0.51	\	\
q24 - Presence of indians	0.43	-0.19	0.29

Figure 1. Categories of biodiversity values generated with data of factorial analysis.



DISCUSSION AND CONCLUSION

The biodiversity values of secondary students found in this work corresponds to the values characterised by Lévêque, Mounolou (2004) and Wiegleb (2002). Factorial solution reveals that students tend to respond (agreeing or disagreeing) those questions that belongs to each factor, according to the factorial loads of each question. So, students evaluated and perceived biodiversity in three dimensions: (i) ecological, (ii) symbolic and ethical, and (iii) economic.

In the ecological dimension, questions treated about the maintenance of biodiversity in order to avoid extinction of species (q7), to maintain genetic variability (q8), to protect rivers (q11) and to regulate climate (q12). All the questions grouped by the factorial loads have strict relation with ecological aspects. It shows inner content coherence of students.

The symbolic and ethical dimension were related to a group of questions about the biodiversity preservation for ecotourism (q6), the protection of the soil (q10), well-being and the beauty of nature (q16 and q17), the memories that this landscape brings (q18), the knowledge (q21), the maintenance of natural resources (22) and the presence of indigenous (q24). This dimension was wider than the previous one and presents aspects of an ethical stance in society. The framework that supports this dimension was subjective, since it relates to the well-being, the memories and the beauty provided by nature. The question about protection of the soil (q10) was initially created to analyse the ecological dimension. However, when students answered this question, it has grouped with questions about the symbolic and ethical dimension. One hypothesis to explain this situation involves the relation of this students with the soil. Most of the students come from rural areas. They need to protect the soil for future generations and to farm, otherwise their families will not have jobs or food.

The last dimension was economic. It involved questions related to the use of biodiversity for mineral exploration and economic development (q4). This dimension showed an anthropocentric view of biodiversity that places nature at the service of human wills (q1, q19 and q20).

Therefore, we concluded that the questionnaire applied and the statistical validation of data contributed to the characterisation of how students relate and articulate reasons to evaluate biodiversity. This is important for science teaching, once it helps the teacher to understand the conceptions of their students and consequently to prepare more efficient pedagogical materials that promotes students' perception of biodiversity from a critical perspective. The next phase of this research is the individual characterization of the students in a cluster analyses, involving the 3 factors. This next step is important to we understand more precisely the characteristics of this group of students about the biodiversity values.

REFERENCES

Cattell, R.B. (1966). The scree test for the number of factors. *Multivariate Behavioral Research*, 1(2), 245-276.

Hair Jr., J.F., Black, W.C., Babin, B.J., Anderson, R.E., & Tatham, R.L. (2009). *Análise multivariada de dados*. Porto Alegre: Bookman.

Lévêque, C. (1999). Biodiversity, Bauru: EDUSC.

Lévêque, C., & Mounolou, J.C. (2004). Biodiversity, London: John Wily and Sons Ltd.
Malhotra, N.K. (2001). Pesquisa de marketing: uma orientação aplicada. Porto Alegre: Bookman.
Morais, A. M.; Neves, I. P. A. (2007). A teoria de Basil Bernstein. Alguns aspectos fundamentais. *Revista Praxis Educativa*, 2(2), 115-130.
Tabachnick, B.G., & Fidell, L.S. (2007). Using multivariate analysis. Needham: Allyn & Bacon.
Wiegleb, G. (2002). The value of biodiversity. Environmental values, submitted.
Wilson, E.O. (1997). Biodiversity II: understanding and protecting our biological resources. Washington: Joseph Henri Press.

ACKNOWLEDGEMENT

This research was supported by the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior – Brasil (CAPES) – finance cod 001, and by the Graduate Program on Comparative Biology (Faculty of Philosophy, Sciences and Letters – University of São Paulo).

FACTORS ASSOCIATED WITH STUDENTS' ENGAGEMENT AND PARTICIPATION IN YEAR 11 AND YEAR 12 SCIENCE CLASSROOMS

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This study investigated factors associated with students' participatory style in Years 11/12 science classrooms. Students' preferences for verbal or non-verbal engagement and participation practices and what makes some students more verbal while others remain more silent was examined. To measure factors of interest, we developed the Engagement and Participation in Classroom-Science (EPIC-S) questionnaire, consisting of inquiry into four clusters: Expectations, Attitudes, Interaction, and Practices, and which was validated using Rasch Analysis (RA) and Confirmatory Factor Analysis (CFA). A total of 557 students in Australia, Indonesia, South Korea and Taiwan participated. Findings indicated verbal and non-verbal practices were strongly correlated (r=0.6). Factors associated with verbal and non-verbal practices were expectations for classroom engagement and participation practices, peer support, and interest in science. Teacher openness was found to be associated only with students' non-verbal practices and gender was a significant variable for non-verbal practices. While student country was not found to be associated with engagement and participation practices, upon calculating the standard error of the mean (SE) to predict trends among populations in each country using sample mean values, there were differences in verbal and non-verbal engagement and participation practices.

Keywords: Participation and engagement, verbal and non-verbal practices, secondary science classroom

INTRODUCTION

Studies of science education tend to focus on verbal engagement as participation in science classrooms, such as how frequently students ask or answer teachers' questions (Preznel et al, 2012). Students who remain silent may be misinterpreted as being passive and disengaged during science (Chien et al., 2018; Kang, Chu, Martin, 2018) and are consequently described as being "passive" or "non-engaged." However, such participation is too narrowly defined and does not fit well with participatory norms in different contexts as other studies have shown engagement and participation practices to differ in different countries (see Song, 2013). Comparison of engagement and participation preferences from students in different educational contexts has potential to reveal differences in individuals and groups of students that are important for educators to consider. The conceptual framework in this study provided below (See Figure 1).

RESEARCH QUESTIONS

This study was conducted to identify factors associated with students' engagement and participation practices in Year 11 and 12 science classrooms. The specific research questions are: 1) What predictors are associated with students' verbal participation and non-verbal participation practices? 2) How do variables like gender and academic achievement impact on students' participation practices?

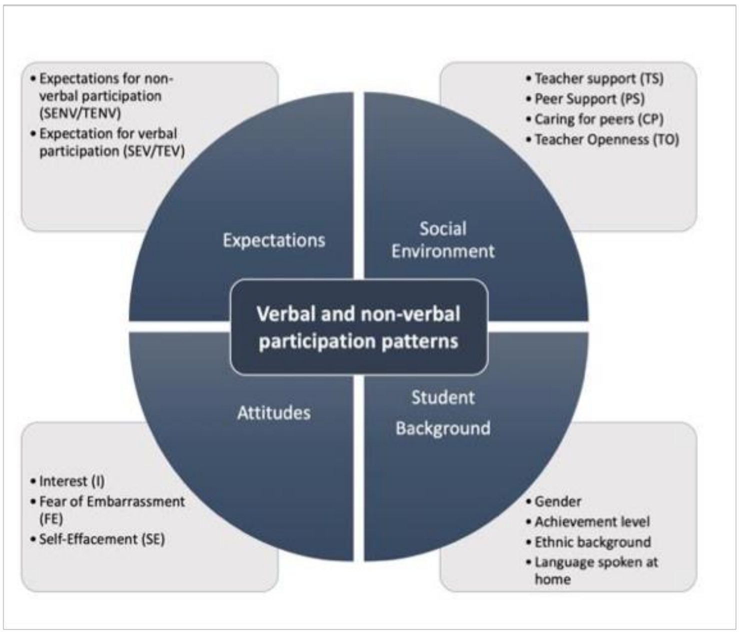

Figure 1. Conceptual framework of this EPIC study

RESEARCH METHOD AND DESIGN

Data Collection

This quantitative survey aimed to predict students' preferred engagement and participation practices in science classrooms. Initial data collection was recently completed, but ongoing data collection is underway to address unequal sample sizes in each country. Thus, data reported here is preliminary. A total of 552 students from four different countries – South Korea, Taiwan, Indonesia, and Australia – participated in this study (see Figure 2). These countries represent a range of achievement data on international science assessments (e.g. TIMSS and PISA), from top groups to middle to well below average. In addition, these countries represent a range of cultural diversity in the classroom from mono- to multi- cultural societies.

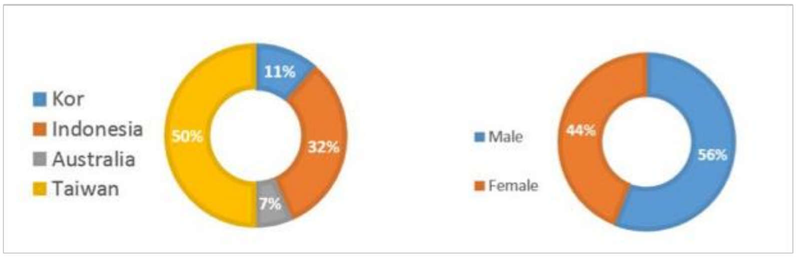

Figure 2. Percentage of participants from Korea, Taiwan, Indonesia, and Australia

Questionnaire and data preparation

Item validation from previous *EPIC-S* studies (Ahn, Chu, Martin, Chien, & Chang, 2016; Chien, Jen, Martin, Chu, & Chang, 2017; 2018) were used. Rasch modelling was used for person and item reliability. In addition, Cronbach's alpha reliability was also calculated.

In Table 1, items in each scale are in acceptable fit. The infit and outfit have the mean square values within the range of 0.7–1.3, and z scores for the infit and outfit have a magnitude less than 2 (i.e. |zinfit| ≤ 2 and |zoutfit| ≤ 2). Scales of 8 show moderate person reliability (0.50 - 0.65) and 5 scales (TEV, FE, TO, RT and CP) show low person reliability (0.24 –0.40). Most scales show high/moderate item difficulty (0.57–0.99), except for the VP scale (0.40). Even though the reliabilities of some scales are moderate/low, items in each scale are within the values range for good fit between the Rasch model and students' responses. To improve the scale reliability in our follow-up study, additional items in each scale will be developed, and more samples, including a wide range of students' tested abilities, will be collected. Cronbach's alpha reliability was also calculated, with results that indicated the items in the scales were well designed to measure accurately the scale developers' focal points of interest. All scales except the CP scale showed reasonably high Cronbach's alpha reliability (> 0.75). The CP scale (a =0.53) was excluded.

Data analysis

After data preparation, 12 scale scores (except for the CP scale) were analysed using multiple-regression analysis to identify predictors associated with the two dependent variables: verbal participation and non-verbal participation. All independent variables that showed as equal/above the 0.4 Pearson correlation coefficient were included in a multiple regression analysis. ANOVA was conducted to investigate the influence of demographic variables and students' study preferences, such as gender and study hours. Due to unequal sample sizes by country, we calculated the standard error of the mean to predict sample population trends for each EPIC-S scale in each country.

Table 1. Scales, Rasch measurement model information, and Cronbach's alpha reliability calculation (N=552)

Scale Names (number of items)		Mean (MNSQ)		Reliabilities		*a*
		infit	outfit	Person	Item	
Expectations	Student Expectations: Non-verbal: SENV (4)	0.99	0.96	0.60	0.96	0.80
	Student Expectations: Verbal (SEV:3)	0.99	0.90	0.63	0.73	0.83
	Teacher Expectations: Non-verbal (TENV: 4)	0.98	0.94	0.50	0.97	0.86
	Teacher Expectations: Verbal (TEV: 3)	0.99	0.86	0.32	0.59	0.86
Participation practice	Non-verbal participation (NVP: 4)	0.98	0.95	0.55	0.96	0.80
	Verbal participation (VP: 3)	0.99	0.86	0.65	0.40	0.85
Attitudes	Interest (I: 5)	0.98	0.99	0.63	0.85	0.80
	Fear of embarrassment (FE: 3)	0.99	0.88	0.24	0.57	0.92
	Self-effacement (SE: 4)	0.99	1.00	0.51	0.88	0.75
Inter-relationship	Peer support (PS: 5)	0.98	1.03	0.66	0.99	0.80
	Teacher openness (TO: 3)	1.00	1.01	0.27	0.95	0.80
	Relationship with teacher (RT: 3)	0.97	0.85	0.47	0.94	0.85
	Care for peer (CP: 3) –deleted scale	**0.99**	**0.99**	**0.29**	**0.98**	**0.53**

Reliabilities: the reliability of distinctions among items and persons respectively, *a* : Cronbach's alpha reliability

FINDINGS

Predictors

When examining Year 11 and 12 students' participatory practices in the science classroom, students' expectations was the largest contributor to both verbal (SEV, beta=.38) and non-verbal practices (SENV, beta=.29). Non-verbal engagement and participation was the second

Country	0.15 A>I/K>T	0.10 A/I>K/T	0.06 T>K/I/A	**0.13** **K>A/I>T**	**0.16** **A/I>T/K**	0.05 A>K/I/T	0.05 T>K>I/A	0.08 I/A/K>T	0.10 A/K>T/I	0.30 A/K/I>T

CONCLUSION and IMPLICATIONS

The study indicates factors that could be helpful in predicting students' classroom engagement and participatory practices. Some factors could be used by classroom teachers to support students' preferred participation practices. For example, the relationship with teachers (RT) is the unique factor in this study influencing students who prefer to engage in non-verbal participation practices. Students from Korea and Taiwan displayed high non-verbal / low-verbal participation practices, but these countries demonstrate high levels of achievement on international assessments (OECD, 2016), suggesting non-verbal science classrooms do not limit learning opportunities. Likewise, Australian and Indonesian students who demonstrate preferences for verbal engagement show lower achievement on the same assessments. Students may show different patterns due to cultural expectations about how to engage in school and learning. Instrument revision and more balanced samples are required, but preliminary findings suggest science educators should think more critically about the role of non-verbal participatory practices for supporting learning and should conduct more classroom-situated research focusing on understanding students with non-verbal participation preferences. Findings will be used for further EPIC-S item revision, to shape interview questions and develop classroom observation protocols.

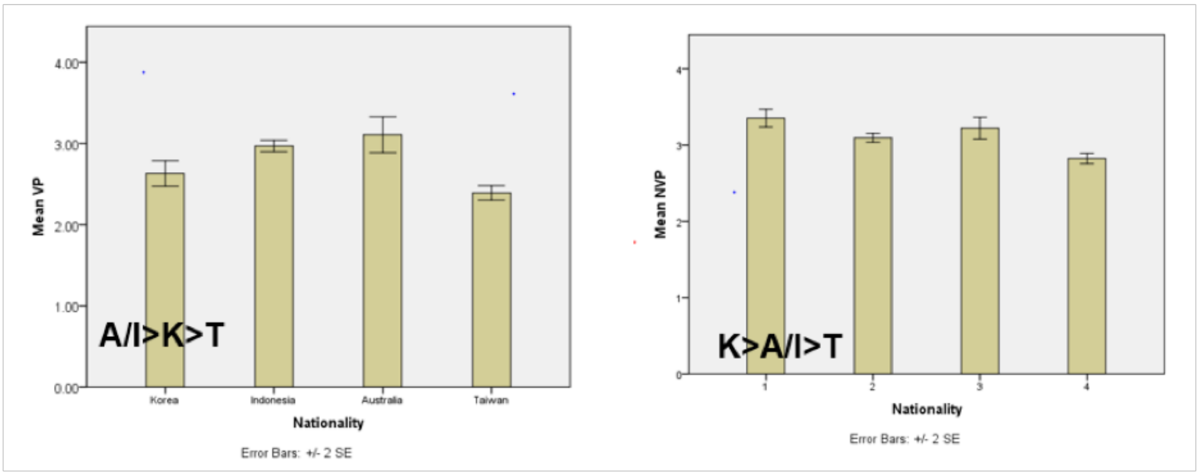

Figure 3. Contury comaprison usinf the standard error of the mean

ACKNOWLEDGEMENT

We wish to extend our thanks and remembrance to our colleague Dr. Yu-Ta Chien (Taiwan) who was a core member of our research group. Dr. Chien passed away in October 2018.

REFERENCES

Ahn, W., Chu, H. E., Martin, S. N., Chien, Y. T., Jen, C. H., & Chang, C. Y. (2016). Development of an instrument to examine Engagement and Participation in Classroom-Science (EPIC-S). *East-Asian Association for Science Education (EASE)*. Tokyo, Japan

Chien, Y. T., Jen, C. H., Martin, S. N., Chu, H. E., & Chang, C. Y. (2017). Investigating what factors may affect student attitudes toward clicker usage in science classrooms: An exploratory study. *National Association for Research in Science Teaching (NARST)*. San Antonio.

Chien, Y. T., Jen, C. H., Martin, S. N., Chu, H. E., & Chang, C. Y. (2018). Factors Contributing to Student Participation in Science Classroom: A Survey Study. *National Association for Research in Science Teaching (NARST)*. Atlanta, USA.

Jacobson, N. S. & Truax, P. (1991). Clinical significance: A statistical approach to defining change in psychotherapy research. *Journal of Consulting and Clinical Psychology, 59*, 12–19.

Kang, D. Y., Chu, H.-E., & Martin, S. (2018). Exploring Korean high school students' perceptions about participation and engagement in school science using EPIC-S questionnaire. *East-Asian Association for Science Education (EASE)*. Taiwan.

OECD. (2016). PISA 2015 results (Volume I): *Excellence and equity in education.* Paris: OECD Publishing.

Preznel, M., Seidel, T., & Kobarg, M. (2012). Science teaching and learning: An international comparative perspective. In B. J. Fraser, K. G Tobin, & R. Campbell (Eds.), *Second international handbook of science education* (pp. 667–678). Dordrecht: Springer.

Song, J. (2013). The disparity between achievement and engagement in students' science learning: A case of East-Asian regions. In D. Corrigan, R. Gunstone, & A. Jones (Eds.), *Valuing assessment in science education: Pedagogy, curriculum, and policy* (pp. 285–306). Dordrecht: Springer.

CULTURE AND GENDER DIFFERENCES IN VOCATIONAL ORIENTATION IN SCIENCE

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Women and some minorities tend to be underrepresented in science (OECD, 2009). The present research investigates the science aspirations of young people with different gender and cultural backgrounds living in Germany. Further, it tries to establish what kinds of vocational orientation measures in science would appeal to female students with a migration background. The investigation is based on two separate studies: (i) secondary school students (N = 450) were asked about their science aspirations and their preferences in vocational orientation, and (ii) university students (N = 342) were asked to evaluate their vocational orientation in a retrospective view. Study (i) shows that secondary school students in Germany do not differ significantly in their science aspirations when gender and cultural background are taken into consideration. However, they do differ in their preferences in vocational orientation regarding science. The girls with a migration background tend to rely on more institutionalised, professional sources. They wish for more contacts with universities and teacher feedback. In contrast, the boys without a migration background prefer more informal sources such as YouTube videos in vocational orientation. Study (ii) shows that more professional, individual feedback was wished for by university students. The research provides the ground for the design of target group specific measures in vocational orientation in science.

Keywords: cultural diversity in school, gender issues, vocational education

THEORETICAL BACKGROUND

For understanding career choices, two different perspectives can be adopted: a sociological or a psychological lens (van Tuijl & van der Molen, 2016). When taking a psychological perspective, career choices can be explained by variables such as career aspirations or personality traits, for example strengths and weaknesses, extroversion or introversion (e.g. RIASEC (Holland, 1997), expectancy-value model (Eccles & Wang, 2016)). These analyses look at the individuals' dispositions and preferences. When taking a sociological perspective, career choices can be explained by variables belonging to a person's sociocultural environment, such as gender, class and race (e.g. Bourdieusian theory (Bourdieu, 1972) as used by Archer et al. (2015)). In this type of analysis, trends in the society are focused on and the perspective is, therefore, broadened in order to capture context variables that impact individual choices.

In the present study, the main focus is on the influence of gender and cultural background on career choices because women and men of different cultural backgrounds are not equally represented in science (OECD, 2009). Regarding the influence of gender and cultural background on career choices, some important findings have been documented. Female students with a working-class background struggle to develop concrete science aspirations, while this is easier for male, middle-class students (Archer et al., 2010). For example, boys are more likely to choose science subjects (Henderson et al., 2018; OECD, 2009; Riegle-Crumb, Moore, & Ramos-Wada, 2011) and to work in science (Bøe, Henriksen, Lyons, & Schreiner, 2011; OECD, 2008). Boys tend to prefer areas dominated by men such as physics and engineering (Sikora & Pokropek, 2012). Students' cultural background has an impact as well. Students from ethnic minorities choose scientific careers less frequently (Archer et al., 2012b, 2012a; Archer, DeWitt, & Willis, 2014; Carlone, Webb, Archer, & Taylor, 2015) resulting in unequal representation of the gender and culture groups in science. It can thus be assumed that women with a migration background face a double disadvantage in this sector of the job market because being female and belonging to an ethnic minority means that they belong to both groups which are underrepresented in the field of science.

Vocational orientation could play a key role for achieving more equal representation of all gender and cultural groups in science. It serves to both inform students about the range of occupations that are available and to analyse the young peoples' competencies and interests in order to find a good match. Vocational orientation can come in many forms, with a broad range of activities. To date, it is not known which activities are preferred by the different groups of students. We, therefore, do not know how to reach the groups that are currently under-represented in science with appropriate vocational orientation measures that are adapted to their needs.

Some non-culture-specific insights about the effects of vocational orientation measures have been made. Research has shown that activities taking place in school have positive effects on vocational orientation regarding science (Reinhold, Holzberger, & Seidel, 2018). This is especially true for compulsory practical work experiences and well-organised contacts with the local economy. However, not all school interventions have positive effects. Some even discourage students from science careers (Reinhold et al., 2018). Outside school, work experiences and contacts with universities are important factors for choosing a university course in science, with university visits being more important for girls (Robertson, 2000). In the social domain, family members have a greater influence on science course choices than friends. Especially the mother's advice plays an important role in young women's vocational orientation (Esch & Grosche, 2011). Also, more informal sources of information, such as online video platforms as well as TV series with science characters are gaining in importance in vocational orientation (Hoffner et al., 2006).

RESEARCH QUESTIONS

Although we do have knowledge about the effects of some measures employed in vocational orientation in general, we still lack an understanding of the preferences of boys and girls with different cultural backgrounds. The present research, therefore, provides insights into the preferences of young people with different gender and cultural backgrounds for vocational orientation in science. This is investigated from a psychological and a sociological perspective.

In the first part of the study, we investigated how secondary school students of different gender and cultural backgrounds differ in their vocational orientation in sciences. We wanted to know:

(Q1) How do male and female secondary school students with and without a migration background differ in their vocational orientation regarding science?

(Q1a) How do they differ in science aspirations?

(Q1b) How do they differ in their need for more information on jobs in science?

(Q1c) What sources of information do they use in their vocational orientation regarding science?

(Q1d) What sources of information would they like to use more in their vocational orientation regarding science?

In the second part of the study, we were interested in the retrospective view of current university students of science and non-science subjects on their vocational orientation. We wanted to know:

(Q2) How did university students of science and non-science subjects differ in their vocational orientation?

(Q2a) How do the students differ in their reasons for studying their subjects?

(Q2b) What sources of information did they use in their vocational orientation?

(Q2c) What sources of information would they have liked to use more in their vocational orientation?

METHODS

Secondary school students

For the first study, we collected data of 450 secondary school students between 13-19 years (*M* = 15.3) from 8 German schools using a paper-based questionnaire. About 45.8 % (206 students) of the students were female, 49.6 % (223 students) had a migration background, while the target group of girls with a migration background made up for 20.9 % (94 students) of the sample. The analyses were conducted using R (R Core Team, 2017) using the packages car (Fox & Weisberg, 2011), lavaan (Rosseel, 2012), psych (Revelle, 2017), and stats (Lüdecke, 2018).

We measured their science aspirations (DeWitt et al., 2011, translated), their need for information on science jobs (Driesel-Lange & Hany, 2005; Spitzer, 2017, slightly modified), and the sources the students had used and would like to use more in vocational orientation in science (Driesel-Lange & Hany, 2005).

University students

For the second study, we collected data of 342 students between 18-53 years (*M* = 23) from 4 German universities using an online survey. 58.2 % (299 students) were enrolled in at least one science subject, 86.0 % (294 students) were female and 16.4 % (56 students) had a migration background. The analyses were conducted using R (R Core Team, 2017) with the packages car

(Fox & Weisberg, 2011), gmodels (Warnes, Bolker, Lumley, & Johnson, 2018), lavaan (Rosseel, 2012), psych (Revelle, 2017), and stats (Lüdecke, 2018).

We investigated the students' reasons for their choice for a science or a non-science subject (Ellenberger & Ludwig-Mayerhofer, 2005; Hachmeister, Harde, & Langer, 2007, modified). Also, we asked them about the sources they had used in vocational orientation and those they would have liked to use more, just as in the study with secondary school students (Driesel-Lange & Hany, 2005).

RESULTS

Secondary school students

The reliabilities of the scales were good with values for Cronbach's α of .87 for science aspirations (DeWitt et al., 2011, translated, 4 items) and .74 for the need for information scale (Driesel-Lange & Hany, 2005; Spitzer, 2017, slightly modified, 5 items). Confirmatory factor analyses showed acceptable fit (Hu & Bentler, 1999) for the science aspirations scale ($df = 2$; CFI = .964; TLI = .892; SRMR = .029; RMSEA = .193; 90 % CI_{RMSEA} .140, .251). From the need for information scale, we excluded one linguistically difficult item and obtained very good model fit (CFI = .993; TLI = .978; RMSEA = .052; 90 %; CI_{RMSEA} .000, .121; SRMR = .020; Cronbach's $\alpha = .69$).

Two-way ANOVAs showed that the secondary school students do not differ significantly in their science aspirations (gender $F(1, 428) = 0.010$, $p = .919$; cultural background $F(1, 428) = 0.146$, $p = .703$; interaction $F(1, 428) = 0.986$, $p = .321$), and need for information (gender $F(1, 423) = 1.565$, $p = .212$; cultural background $F(1, 423) = 0.004$, $p = .950$; interaction $F(1, 423) = 0.317$, $p = .574$) when gender and cultural background are taken into consideration. In contrast, the students differed in their preferences for vocational orientation measures regarding science. Girls without a migration background ($M = 4.73$) used more sources than the boys ($M = 3.61$), while the inverse was true among the students with a migration background ($M_{girls} = 3.84 < M_{boys} = 4.13$). The interaction effect was significant, $F(1, 438) = 5.870$, $p = .016$.

The students also preferred different types of sources. Multiple logistic regressions showed significant effects for gender: the odds for using online videos were higher for boys than for girls ($b = 0.7$; $SE = 0.19$; $p < .000$). The odds were higher for girls for talking to a female family member ($b = 0.57$; $SE = 0.21$; $p = .007$), for attending a career fair ($b = 0.56$; $SE = 0.22$; $p = .011$) and for wishing for open days at university ($b = 0.71$; $SE = 0.32$; $p = .027$). For students with a migration background, the odds were lower for consulting a male family member ($b = -0.52$; $SE = 0.21$; $p = .012$) and wishing for online videos in vocational orientation in science ($b = -0.74$; $SE = 0.36$; $p = .038$) while the odds were higher for wishing for teacher advice ($b = 0.96$; $SE = 0.36$; $p = .008$) and for university visits ($b = 1.38$; $SE = 0.42$; $p < .001$). These sources were particularly interesting for girls with a migration background: 17 % wished for teacher advice and 16 % for open days at university. It seems like girls with a migration background tend to rely on more institutionalised, professional sources.

University students

The reliabilities of the 5 subscales of the reasons for course choices scale were good with values for Cronbach's α ranging between .70 and .83. Confirmatory factor analysis showed good model fit (Hu & Bentler, 1999) for the model of the reasons for course choices scale when it was assumed that 5 subscales exist (df = 80; CFI = .935; TLI = .915; SRMR = .053; RMSEA = .174; 90 % CI_{RMSEA} .063, .085).

The data showed that the non-science students scored higher on all subscales regarding the reasons for their course choices. The two groups seemed to differ in the overall strength of reasons or in response behaviour, rather than in the types of reasons. We, therefore, assume that the response patterns did not differ in quality but rather in intensity.

However, regarding the sources the science and non-science students had used in vocational orientation, we found significant differences. Significantly more science students had consulted a teacher ($\chi^2(1) = 6.50$; $p = .011$; $OR = 1.76$; $CI_{95\,\%}$ 1.11, 2.81), gone to fairs ($\chi^2(1) = 22.82$; $p < .000$; $OR = 4.40$; $CI_{95\,\%}$ 2.26, 9.16), and participated in Girls'/Boys' Days ($\chi^2(1) = 12.15$; $p < .000$; $OR = 3.44$; $CI_{95\,\%}$ 1.62, 8.00). A smaller number of science than non-science students had used homepages ($\chi^2(1) = 5.74$; $p = .017$; $OR = 0.59$; $CI_{95\,\%}$ 0.37, 0.93), consulted friends ($\chi^2(1) = 8.98$; $p = .003$; $OR = 0.52$; $CI_{95\,\%}$ 0.32, 0.82), female family members ($\chi^2(1) = 18.14$; $p < .000$; $OR = 0.39$; $CI_{95\,\%}$ 0.24, 0.62), and completed a work placement ($\chi^2(1) = 39.38$; $p < .000$; $OR = 0.24$; $CI_{95\,\%}$ 0.15, 0.39). Significantly more science students would have wished for more orientation via homepages ($\chi^2(1) = 4.22$; $p = .040$; $OR = 7.17$; $CI_{95\,\%}$ 0.98, 5.20), company tours ($\chi^2(1) = 7.63$; $p = .006$; OR=3.17; $CI_{95\,\%}$ 1.30, 8.87), and work placements ($\chi^2(1) = 4.83$; $p = .028$; $OR = 1.99$; $CI_{95\,\%}$ 1.03, 4.00). A smaller number of science students wished for more orientation through teachers ($\chi^2(1) = 5.70$; $p = .017$; $OR = -0.49$; $CI_{95\,\%}$ 0.26, 0.92) and fairs ($\chi^2(1) = 4.73$; $p = .030$; OR = 0.50; $CI_{95\,\%}$ 0.25, 0.99). In summary, we assume that more professional, individual feedback was wished for in a retrospective view of university students.

DISCUSSION AND CONCLUSION

The study shows that not all students prefer the same sources in vocational orientation in science. Boys without a migration background seem to like online videos in vocational orientation in science more than girls. This could be due to the range of videos that are currently available on social media. For instance, many YouTube channels present a 'nerdy' science identity which appeals more to boys than to girls (Archer et al., 2013). In contrast, for girls, the range of science channels that would allow for identification with a female science identity is much smaller. To improve vocational orientation in science for girls with a migration background, one strategy could be to diversify the range of YouTube channels covering science and to present a variety of science identities, including girls with a migration background working in science to enhance their presence as role models on social media. First attempts have been made in the project Diversity Sensitive Support (DiSenSu; www.disensu.de) in which short film portraits of girls with a migration background working in science were shot and published on Instagram. These girls reported very impressively on their personal experiences in their scientific careers.

For girls with a migration background, face-to-face conversations with family members or experts such as teachers or career counsellors are interesting. Also, they wish for more university visits. Therefore, another idea would be to make young women with a migration background available for the target group at career fairs as role models and counsellors. Also, regular science workshops at universities for selected girls could be helpful. Teachers could suggest especially shy girls with a migration background to participate in these workshops. In addition, individual feedback from experts and interventions taking place at university could be a key to successful vocational orientation for women with a migration background.

Based on this study, we designed an intervention for vocational orientation in science with which we aim to reach young women with a migration background to support them in their way into careers in science. In the project DiSenSu, we designed an intervention based on face-to-face coaching conducted by female university students who are currently enrolled in a science subject. The university students provide a professional yet personal feedback and could function as potential role models for young women. The coaching takes place in public space to build connections with science outside school. Here, the young women's parents could potentially be reached as well. We assume that the professional feedback of female university students, as well as the interweaving of science with the young women's lives outside school, could appeal especially to young women with a migration background.

ACKNOWLEDGEMENT

This research was funded by the Federal Ministry of Education and Research as part of the project "Diversity Sensitive Support: vocational orientation in STEM for female adolescents with migration background in cooperation with parents (DiSenSu)". Funding reference numbers 01FP1725 and 01FP1726.

REFERENCES

Archer, L., Dawson, E., DeWitt, J., Seakins, A., & Wong, B. (2015). "Science capital": A conceptual, methodological, and empirical argument for extending bourdieusian notions of capital beyond the arts. *Journal of Research in Science Teaching*, *52*(7), 922–948. DOI: 10.1002/tea.21227

Archer, L., DeWitt, J., Osborne, J., Dillon, J., Willis, B., & Wong, B. (2010). "Doing" science versus "being" a scientist: Examining 10/11-year-old schoolchildren's constructions of science through the lens of identity. *Science Education*, *94*(4), 617–639. DOI: 10.1002/sce.20399

Archer, L., DeWitt, J., Osborne, J., Dillon, J., Willis, B., & Wong, B. (2012a). "Balancing acts''': Elementary school girls' negotiations of femininity, achievement, and science." *Science Education*, *96*(6), 967–989. DOI: 10.1002/sce.21031

Archer, L., DeWitt, J., Osborne, J., Dillon, J., Willis, B., & Wong, B. (2012b). Science aspirations, capital, and family habitus: How families shape children's engagement and identification with science. *American Educational Research Journal*, *49*(5), 881–908. DOI: 10.3102/0002831211433290

Archer, L., DeWitt, J., Osborne, J., Dillon, J., Willis, B., & Wong, B. (2013). 'Not girly, not sexy, not glamorous': Primary school girls' and parents' constructions of science aspirations. *Pedagogy, Culture & Society*, *21*(1), 171–194. DOI: 10.1080/14681366.2012.748676

Archer, L., DeWitt, J., & Willis, B. (2014). Adolescent boys' science aspirations: Masculinity, capital, and power. *Journal of Research in Science Teaching*, *51*(1), 1–30. DOI: 10.1002/tea.21122

Bøe, M. V., Henriksen, E. K., Lyons, T., & Schreiner, C. (2011). Participation in science and technology: Young people's achievement-related choices in late-modern societies. *Studies in Science Education*, *47*(1), 37–72. DOI: 10.1080/03057267.2011.549621

Bourdieu, P. (1972). *Esquisse d'une théorie de la pratique: Précédé de trois études d'ethnologie kabyle*. Geneva: Droz.

Carlone, H. B., Webb, A. W., Archer, L., & Taylor, M. (2015). What kind of boy does science? A critical perspective on the science trajectories of four scientifically talented boys. *Science Education*, *99*(3), 438–464. DOI: 10.1002/sce.21155

DeWitt, J., Archer, L., Osborne, J., Dillon, J., Willis, B., & Wong, B. (2011). High aspirations but low progression: The science aspirations-careers paradox amongst minority ethnic students. *International Journal of Science and Mathematics Education*, *9*(2), 243–271. DOI: 10.1007/s10763-010-9245-0

Driesel-Lange, K., & Hany, E. (2005). Berufsorientierung am Ende des Gymnasiums: Die Qual der Wahl. In B. Kracke & E. Hany (Eds.), *Schriften zur Berufsorientierung*. Erfurt: Universität Erfurt.

Eccles, J. S., & Wang, M.-T. (2016). What motivates females and males to pursue careers in mathematics and science? *International Journal of Behavioral Development*, *40*(2), 100–106. DOI: 10.1177/0165025415616201

Ellenberger, L., & Ludwig-Mayerhofer, W. (2005). *Studieren in Siegen 2005 Ergebnisse der Befragung der Studienanfängerkohorte im BA Social Science des Wintersemesters 2004/2005*. Retrieved from http://www.fb1.uni-siegen.de/soziolog/personen/ludwigmayerhofer/studbefragung.html

Esch, M., & Grosche, J. (2011). Fiktionale Fernsehprogramme im Berufsfindungsprozess. Ausgewählte Ergebnisse einer bundesweiten Befragung von Jugendlichen. In Bundesministerium für Bildung und Forschung (Ed.), *MINT und Chancengleichheit in fiktionalen Fernsehformaten*. Bonn/Berlin: Bundesministerium für Bildung und Forschung.

Fox, J., & Weisberg, S. (2011). *An {R} companion to applied regression* (Second Edition). Thousand Oaks, CA: Sage. Retrieved from http://socserv.socsci.mcmaster.ca/jfox/Books/Companion

Hachmeister, C.-D., Harde, M. E., & Langer, M. F. (2007). *Einflussfaktoren der Studienentscheidung: Eine empirische Studie von CHE und Einstieg*. Gütersloh: CHE.

Henderson, M., Sullivan, A., Anders, J., & Moulton, V. (2018). Social class, gender and ethnic differences in subjects taken at age 14. *The Curriculum Journal*, *29*(3), 298–318. DOI: 10.1080/09585176.2017.1406810

Hoffner, C. A., Levine, K. J., Sullivan, Q. E., Crowell, D., Pedrick, L., & Berndt, P. (2006). TV characters at work: Television's Role in the occupational aspirations of economically disadvantaged youths. *Journal of Career Development*, *33*(1), 3–18. DOI: 10.1177/0894845305282768

Holland, J. L. (1997). *Making vocational choices: A theory of vocational personalities and work environments* (3rd ed). Odessa, FL: Psychological Assessment Resources.

Hu, L., & Bentler, P. M. (1999). Cutoff criteria for fit indexes in covariance structure analysis: Conventional criteria versus new alternatives. *Structural Equation Modeling: A Multidisciplinary Journal*, *6*(1), 1–55. DOI: 10.1080/10705519909540118

Lüdecke, D. (2018). *sjstats: Statistical functions for regression models. R package version 0.14.3*. Retrieved from https://CRAN.R-project.org/package=sjstats

OECD (Ed.). (2008). *Encouraging student interest in science and technology studies*. Paris: OECD.

OECD. (2009). Chart A4.6 Tertiary graduates in science-related fields among 25-34 year-olds in employment, by gender (2009). DOI: 10.1787/888932460192

R Core Team. (2017). *R: A language and environment for statistical computing. R version 3.4.2*. Vienna: R Foundation for Statistical Computing. Retrieved from https://www.R-project.org/

Reinhold, S., Holzberger, D., & Seidel, T. (2018). Encouraging a career in science: A research review of secondary schools' effects on students' STEM orientation. *Studies in Science Education*, *54*(1), 69–103. DOI: 10.1080/03057267.2018.1442900

Revelle, W. (2017). *psych: Procedures for psychological, psychometric, and personality research. R package version 1.7.8*. Evanston, IL. Retrieved from https://CRAN.R-project.org/package=psych

Riegle-Crumb, C., Moore, C., & Ramos-Wada, A. (2011). Who wants to have a career in science or math?: Exploring adolescents' future aspirations by gender and race/ethnicity. *Science Education*, *95*(3), 458–476. DOI: 10.1002/sce.20431

Robertson, I. J. (2000). Influences on choice of course made by university year 1 bioscience students: A case study. *International Journal of Science Education*, *22*(11), 1201–1218. DOI: 10.1080/09500690050166751

Rosseel, Y. (2012). lavaan: An R Package for Structural Equation Modeling. *Journal of Statistical Software*, *48*(2), 1–36.

Sikora, J., & Pokropek, A. (2012). Gender segregation of adolescent science career plans in 50 countries. *Science Education*, *96*(2), 234–264. DOI: 10.1002/sce.20479

Spitzer, P. (2017). *Untersuchungen zur Berufsorientierung als Baustein eines relevanten Chemieunterrichts im Vergleich zwischen Mittel- und Oberstufe sowie Darstellung des Chem-Trucking-Projekts als daraus abgeleitete Interventionsmaßnahme für den Chemieunterricht*. Universität Siegen, Siegen.

van Tuijl, C., & van der Molen, J. H. W. (2016). Study choice and career development in STEM fields: An overview and integration of the research. *International Journal of Technology and Design Education*, *26*(2), 159–183. DOI: 10.1007/s10798-015-9308-1

Warnes, G. R., Bolker, B., Lumley, T., & Johnson, R. C. (2018). *gmodels: Various R programming tools for model fitting. R package version 2.18.1.* Retrieved from https://CRAN.R-project.org/package=gmodels

DEVELOPMENT AND EVALUATION OF TOOLS FOR GENDER- AND DIVERSITY-SENSITIVE CAREER ORIENTATION IN CHEMISTRY

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Various studies show, that the interest in choosing a scientific career path seems low. This is especially true in chemistry among female students with migration background. The project DiSenSu focuses on this group of students. With the help of a digital vocational orientation program, with different tools, a comic and an interview, students will get a first glance into their competences for a STEM-profession. This vocational orientation program will be presented and discussed in detail. For the evaluation of the tool, a Mixed-Methods approach was used. The quantitative study is based on a computer-aided test of the digital tools. In a pre-study, for example, the levels of difficulty of the tasks related to the spatial visualization ability were tested. The qualitative study is based on the focus group research method for creating a suitable gender-sensitive comic. The outcome of the focus group research led to a full-scale modification of the original comic.

Keywords: Vocational Education, Gender Issues, Cultural Diversity in School

INTRODUCTION

The PISA-Study in 2015 for Germany shows a gender difference in students` interest for science at the age of 15 (Schiepe-Tiska, Simm & Schmidtner, 2016). Furthermore, there is a significant lower self-efficacy expectation among female students than among male students (Schiepe-Tiska et al., 2016). Further focusing on Germany, according to the *MINT-Nachwuchsbarometer*, a nationwide trend report with data of the situation of young talents in STEM domains, chemistry is a study program with a remarkably low growth rate for women, unlike other study programs with a traditionally low proportion of women such as physics and (electrical) engineering (Acatech/Körber-Stiftung, 2017). Many people consider chemistry being abstract, complicated and dominated by men. This stereotypical view influences young people of both genders but especially girls and may even prevent them from choosing a chemistry-related career (Cheryan, Ziegler, Montoya & Jiang, 2017; Wang & Degol, 2017; Prechtl, 2018). For women with a migration background, this difference is even more drastic. Several studies show that being female and having a migration background can be a "double disadvantage" in terms of career (Färber, Arslan, Köhnen & Parlar, 2008). The range of vocational choices of this group is compared to females without a migration background narrower with a clear focus on following four, less well paid, jobs: dental assistant, medical assistant, retail sales woman and hairdresser. Their participation in study programs for high paid professions like chemistry is also lower (Färber et al., 2008).

DESCRIPTION OF THE PROJECT & RESEARCH QUESTIONS

To close this gender gap and to promote chemistry careers among female students specially with migration background, the intention of the project DiSenSu (Diversity Sensitive Support; www.disensu.de) is the implementation of innovative gender- and diversity-sensitive digital vocational oriented events in schools and other educational organisations (Markic et al., 2018). Furthermore, the idea of Science in Public is followed as well. While other vocational orientation approaches focus on interests, in our project typical skills, competences and capabilities for a chemistry career (e.g. spatial ability, haptic skills) as well as students` self-efficacy are considered. Additionally, students read and analyse a comic focusing on female prototypes with a migration background in the laboratory. Female coaches with a background in chemistry assist the students during their work with the tools. After that, individual reflection of the results and personal coaching is offered. Figure 1 presents the foci and tools of the whole program, which takes, all in all, a full hour.

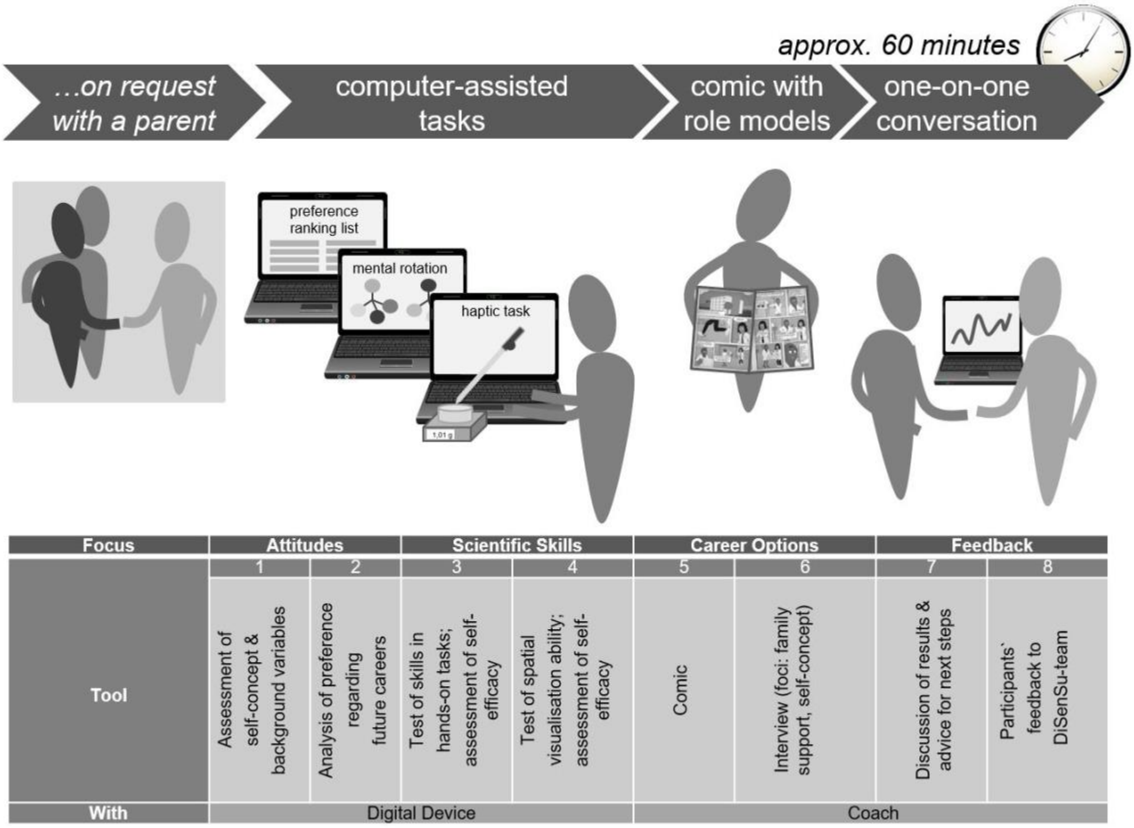

Figure 1. Short overview of the vocational orientation program

In the first phase of the project, the digital tool and the single phases will be tested. Following research questions have to be answered: Which potentials and limits arise for the gender-/diversity-sensitive tools with regard to the quality of the measures? How do the subject-related self-concepts, self-efficacy expectations and ideas of prototypes in science relate to the tasks offered? To answer the research questions a Mixed-Methods approach is used (Teddlie & Tashakkori, 2006). The main quantitative study is currently in progress.

Hereby established scales and completely new conceived designs are used. In this article we present two selected sub-studies.

QUANTITATIVE PRE-STUDY – TOOL 4: TEST OF SPATIAL VISUALIZATION ABILITY

Method

The mental rotation of molecules was chosen as a task to identify a competence typical for a chemistry profession in these girls (Prechtl, 2016). The most adequate tasks were identified in this pre-study. Therefor the difficulty of nine tasks were examined by two different student groups: 30 school students in the age of 13 to 16 years (M = 13.63 yr., SD = 0.84 yr.; 17 girls and 13 boys) and 29 undergraduates in the age of 19 to 32 years (M = 24.31 yr., SD = 3.00 yr.; 13 women and 16 men). They rated the tasks according to five different levels – from level 1, equals easy to level 5, equals hard. The results of this assessment of the two groups were compared with each other using the Mann-Whitney-U-test and the results within the groups were analysed with the Wilcoxon-Test. Aside from that, it was examined whether the levels of the tasks were assessed differently depending on previously being answered correctly or incorrectly.

Results

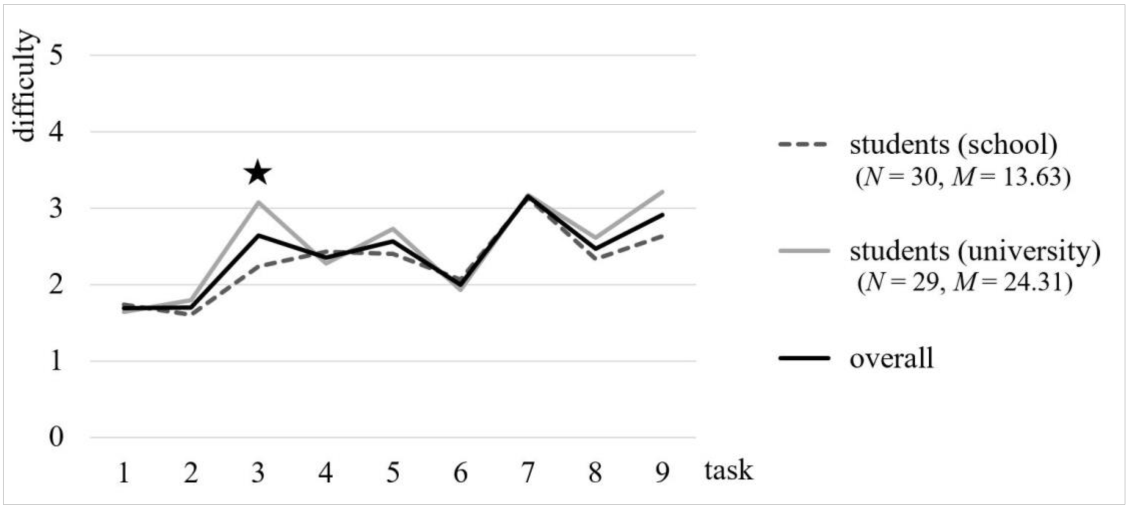

Figure 2. Average values of the degree of difficulty of nine tasks of mental rotation of molecules, completed by two different groups of students

Both groups, school and university students, identified the level of difficulty in the same way, the exception is task 3 as can be seen in figure 2. School students (M = 2.23, SD = 1.01) rated task 3 significantly easier than university students (M = 3.07, SD = 1.25; U = 271.00, p = .01). Task 3 was excluded. Looking at the results of the ranking of the different tasks depending on having solved the task correctly or incorrectly beforehand, there is a difference between university and school students. The university students ranked the level of difficulty of the tasks independently of being answered correctly or incorrectly, whereas the school students ranked the tasks 1, 2, 4 and 7 significantly lower after solving them correctly.

Table 1. Comparison of the perceived difficulty of the tasks of mental rotation of a molecule using the Wilcoxon-Test

Task	1	2	3	4	5	6	7	8	9
1		-0.22	-5.04***	-4.12***	-4.56***	-2.55*	-5.43***	-4.29***	-5.61***
2			-5.07***	-3.93***	-4.25***	-2.43*	-5.61***	-4.14***	-5.41***
3				-1.65	-0.38	-3.50***	-2.40*	-0.76	-1.54
4					-1.23	-2.40*	-4.01***	-0.91	-3.58***
5						-3.74***	-2.85**	-0.67	-1.71
6							-5.12***	-2.87**	-5.10***
7								-3.55***	-1.29
8									-2.93**
9									

Note: Shown are z-values of the Wilcoxon-test and their significance * = p < .05, ** = p < .01, *** = p < .001

The Wilcoxon-test was used to show differences between the tasks' perceived difficulties. The results are shown in table 1. Tasks 1 and 2 were ranked similar difficult but lower then all others. Tasks 4, 5 and 8 were ranked similar difficult and different to all others. Tasks 7 and 9 were ranked similar difficult and higher then all others. These findings showed, that the tasks could be arranged into the categories easy, medium and hard. In that way the series of tasks in the DiSenSu coaching tool was optimized. Taking all these results in consideration three tasks with different level of difficulty and with similar ranking after being answered correctly or incorrectly were identified.

QUALITATIVE STUDY – TOOL 5: COMIC

Background and theory

Within the context of the gender and diversity sensitive vocational orientation the female students get a comic with role models in STEM in which persuasive messages are embedded (Prechtl & Spitzer, 2019). The messages transport a connection between competence and diversity. They shall encourage girls to self-confidently measure their performance and consider a vocation in STEM accordingly. The project is accompanied by a research, which focuses on the question, whether story line and depiction style of the comic are suitable to motivate female students to work in a STEM field.

The chosen media format is a comic, so image sequences are used for presenting role models, who deal with attribution styles and positive self-efficacy. It is shown by studies of Ziegler & Schober (2001) or Perry & Penner (1990) that the effect of such modeling techniques is remarkable. Both groups have used short videos in which people address desired attribution patterns. The students who had seen the video had an improvement in school grades and participation at educational processes.

Method

The qualitative DiSenSu-study analyses two comics, which were created successively. To investigate the research question, the first comic was discussed with the method of group discussions in two focus groups (s. Bogner, Littig & Menz, 2014; Loos Schäfer, 2001). The participants of these focus groups differed from each other. Focus group 1 consisted of experts for diversity and focus group 2 consisted of experts for chemistry. To evaluate the group discussions, the interviews were transcribed. Then they were prepared and analysed with MAXQDA. Afterwards those transcripts were analysed comparatively. Based on the findings of the first study a second comic was created. While (re)designing the comic, the concepts to increase self-efficacy were integrated. Following this, the second comic was evaluated accordingly in the same way. Hereafter both results were compared and lead to the following conclusion.

Results of the discussions on the first comic

The analysis of the first comic produced following findings. Figure 3 presents the shares of the various topics of the overall conversation.

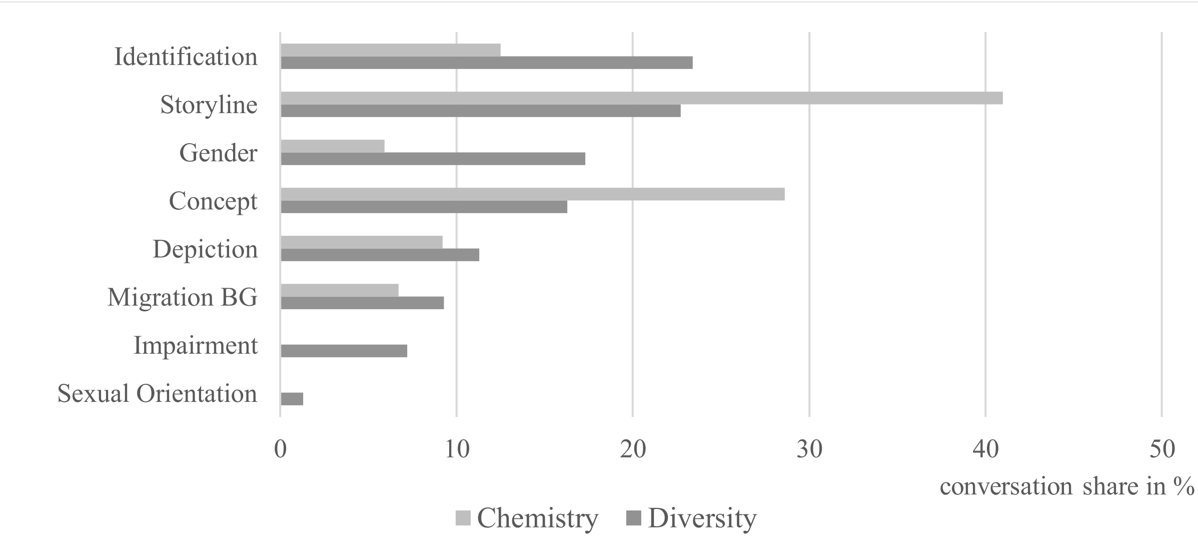

Figure 3. Percentage of conversation share of the various topics discussed by the experts for chemistry and experts for diversity about the first comic

The diversity experts talked about the ability of the female students with migration background to identify themselves with the protagonists of the comic. At 23.4 percent, this topic accounted for a large part of the overall discussion. All following percentage values refer to percentage of the total discussion time. Also the storyline (22.7 %), gender (17.3 %) and concept of the story (16.3 %) were discussed a lot. Besides the depiction of gender and laboratory (11.3 %), the migration background of the protagonists (9.3 %) and the option of depicting mental or physical impairment (7.2 %) were discussed. The option of depicting sexual orientation (1.3 %) was addressed briefly. The chemistry experts focussed on the comics' storyline (41.0 %) and its concept (28.6 %). Further they discussed the ability of the female students with migration background to identify themselves with the protagonists of the comic (12.5 %), the depiction of gender and laboratory (9.2 %), the migration background (6.7 %), and gender (5.9 %). The comic was complimented for illustrating females with a migration background in STEM field. But it was also criticised a lot. According to the participants of the discussion, the story line had a lot of flaws. The message was presented kind of awkwardly and the topics, gender and migration background, appeared enforced. The depiction of the protagonists and the laboratory was also criticised a lot. Laboratory coats were missing, the laboratory was in a “dangerous” state, the female bodies were depicted very “Barbie” like. Furthermore, most remarkable in this context is, that both groups mentioned that it seemed unrealistic to see only two females in the laboratory. It was said, that another man was missing to appear more realistic. Also interesting is, that skin colour was linked to competence. With the least competent person having a light skin tone and the most competent having a dark skin tone in this comic, it contradicts common prejudices.

Statements of the experts for diversity and for chemistry about the first comic, translated from German into English:

- *“Well, the more realistic the depiction is, the more I identify myself. (...) But I would (...) not really be able to identify myself with this doll-like person.”*
- *“For me, of course, it takes a little getting used to, so unrealistic, a bit artificial. Um, if there were other people, maybe a man in between would make the thing, that also not so umm unrealistic.”*
- “*By the way, I also noticed that different skin colours are used there. The darker the skin colour, the greater the expertise.”*
- *“The brighter, the more clueless at this moment. But um, um, I could do it a little bit contrary to what you normally see, because it's often the other way round from a feeling point of view.”*

Results of the discussions on the second comic

The diversity experts particularly discussed the depiction of the laboratory and characters (35.3 %), the comics’ storyline (33.8 %) and its concept (24.8 %). The migration background (3.7 %), the ability for identification (3.2 %) and gender (1.2 %) were discussed quite shortly. The chemistry experts focussed on the depiction of the laboratory and characters (34.9 %) and the comics’ storyline (33.1 %). The comics’ concept (8.7 %), the migration background of the protagonists (8.3 %) and gender (6.0 %) were discussed shorter. Figure 4 presents the shares of the various topics of the entire conversation.

The appearance of the protagonists, the depiction of competent females with character and the positive presentation of people with migration background were for example highly praised. The worker in a headscarf, as another example, was perceived as empathetic and therefore sympathetic. It was no longer mentioned as a problem, that there were only females in the workplace due to a small text passage, which said they are part of a larger team without using gender. Now the focal point of attention were the illustrations of processes and operations. It seemed that they were not shown detailed enough. Another concern was whether the comic was too difficult to comprehend for school students.

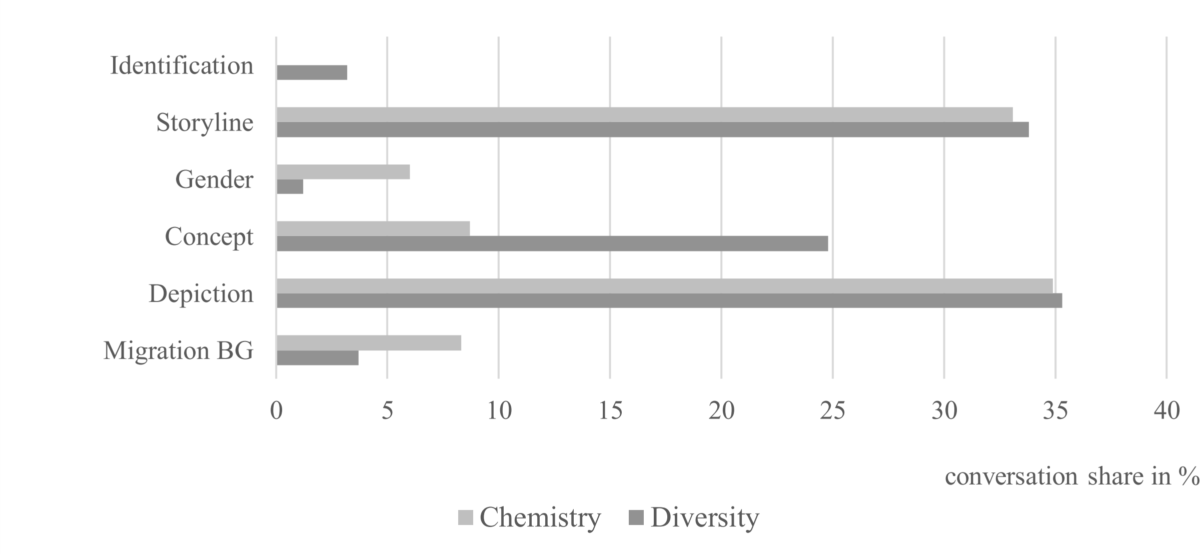

Figure 4. Percentage of conversation share of the various topics discussed by the experts for chemistry and experts for diversity about the second comic

Statements of the experts for diversity and for chemistry about the second comic, translated from German into English:

- *“What I liked on the first - um here at the first picture: "part of a research group". It takes the whole thing with this female/male and who is in this group now - and why are there only two of them now - takes it completely away.”*
- *“I wanted to address that, um - apart from the presentation - I really like the fact that the researcher with the headscarf appears so self-evidently. So there is no question at all whether she is competent or not. But that one is there - that one is the researcher - that one leads the way - that one has the knowledge - so and um that comes across so subtly. So there isn't a big-big barrel opened now - hello I'm the researcher. I know about everything' - but, um, it just comes across in the dialogue. I think, uh, it's very well done. The umm - there's no doubt about it - the one with the headscarf, if she knows that' - no - no - the one knows that. And Leyla can also teach them that.“*
- *“I think it's cool with the centrifuge. I think it's beautifully presented, only what I notice when we talk about correctness. A centrifuge would never be open. Never ever. And um, I don't know how to represent that now, so you - maybe a box. Because the problem is, it's a mega blatant security thing. Um that's definitely um um that wouldn't exist just because of all the friction and stuff.”*

Comparison of the two comics and conclusion

In all discussions, the focus laid on the comics’ storyline and concept. In comparison to the discussions about the first comic, which emphasis was on identification, the discussions about the second comic centred on the way of depiction.

According to this analysis there are certain quality criteria to consider while creating supplementary material which addresses young females with migration background who shall be encouraged to a STEM vocation. First of all, the level of study line and language has to be adequate for students. An accurate depiction of processes and operations in this context is important. In concern of the depiction of migration background, it is useful to present them positively. In the depiction of females, it is important to use quite realistic body types although it is a comic. For both, depiction of migration background and females, it is crucial not to use stereotypes but a variation in appearance. Competent professionals should be shown in an authentic context. In conclusion, taking the described recommendation for creating corresponding supplementary material into account, comics are able to encourage female students to consider a vocation in a STEM field.

SUMMARY AND OUTLOOK

With the first described sub-study three tasks of mental rotation of molecules could be selected specifically with just the right level of difficulty to test the spatial visualisation ability of the female students, i. e. an important competence for a job in the chemistry field. Furthermore, as a result of the main qualitative study, a totally new designed comic was created and evaluated to enrich the vocational orientation coaching to motivate young female students to not only think about a career in the chemistry field, but also to be able to see themselves actively in such a chemistry profession (s. https://www.disensu.de/comics/). The next big step in the project DiSenSu is the quantitative analysis of all recorded coaching data.

It should also be mentioned that this vocational orientation program is very well perceived by school students, parents and teachers. Feedback given directly after the coaching or in writing later, points out how helpful and special the vocational orientation coaching is. The students praise the duration of one hour, enjoy reading the comic, which was designed especially for them, see the different tasks as very helpful and mention how much they learn about the diversity of career opportunities within STEM and what job descriptions in this field actually look like. They leave the program motivated and encouraged.

ACKNOWLEDGEMENT

The project "DiversitySensitiveSupport: STEM vocational orientation for female adolescents with a migration background in daughter-parent dyads (DiSenSu)" is funded by the German Federal Ministry of Education and Research under the funding codes 01FP1725 and 01FP1726.

REFERENCES

Acatech/Körber-Stiftung (2017). *MINT-Nachwuchsbarometer 2017. Fokusthema: Bildung in der digitalen Transformation*. Hamburg: acatech/Körber-Stiftung.

Bogner, A., Littig, B. & Menz, W. (2014). *Interviews mit Experten. Eine praxisorientierte Einführung.* Wiesbaden: Springer VS.

Cheryan, S., Ziegler, S.A., Montoya, A.K. & Jiang, L. (2017). Why are some STEM fields more gender balanced than others? *Psychological Bulletin, 143 (1)*, 1-35.

Färber, C., Arslan, N., Köhnen, M. & Parlar, R. (2008). *Migration, Geschlecht und Arbeit. Probleme und Potenziale von Migrantinnen auf dem Arbeitsmarkt*. Opladen: Budrich.

Loos, P. & Schäfer, B. (2001). *Das Gruppendiskussionsverfahren. Theoretische Grundlagen und empirische Anwendung.* Opladen: Leske + Budrich.

Markic, S., Prechtl, M., Hönig, M., Küsel, J., Rüschenpöhler, L. & Stubbe, U. (2018). DiSenSu. Diversity Sensitive Support for Girls with Migration Background for **STEM** Careers. In I. Eilks, S. Markic & B. Ralle (Eds.), *Building bridges across disciplines* (pp. 251-218). Aachen: Shaker.

Perry, R.P. & Penner, K.S. (1990). Enhancing academic achievement in college students through attributional retraining and instruction. *Journal of Educational Psychology*, *82 (2)*, 262-271.

Prechtl, M. (2016). Moleküle mental konstruieren. Förderung räumlicher Fähigkeiten im Chemieunterricht. *Unterricht Chemie,* 27 *(151)*, 24-34.

Prechtl, M. (2018). Über die Herausforderung einer individualisierten und gendersensiblen Berufsorientierung für Schülerinnen in Chemie. In K. Groß & A. Schumacher (Eds.). *Einblicke in die chemiedidaktische Forschung zu den Schwerpunkten individuelle Förderung und naturwissenschaftliches Arbeiten. Festschrift für Prof. Dr. Ch. S. Reiners* (pp. 87-110). Universitäts- und Stadtbibliothek. ISBN 978-3-946275-03-9. Retrieved January, 15 2020 from http://kups.ub.uni-koeln.de/8268/

Prechtl, M. & Spitzer, P. (2019). Innovative Role-Model-Konzepte und außerschulische Lernarrangements für eine gendersensible Berufsorientierung im Fach Chemie. In E. Schlemmer & M. Binder (Hrsg.), ***MINT** oder **CARE**? Berufs- und Studienfachwahl von Frauen und Eckpunkte einer gendersensiblen Berufsorientierung* (pp. 151-166). Weinheim: Beltz/Juventa.

Prechtl, M. & Stubbe, U. (2019). Gender-/Diversitysensible Berufsorientierung mit DiSenSu. In C. Maurer (Hrsg.), *Naturwissenschaftliche Bildung als Grundlage für berufliche und gesellschaftliche Teilhabe* (pp 644-647). GDCP. Regensburg: Universität Regensburg.

Schiepe-Tiska, A., Simm, I. & Schmidtner, S. (2016). Motivationale Orientierungen, Selbstbilder und Berufserwartungen in den Naturwissenschaften in PISA 2015. In K. Reiss et al. (Eds.), *PISA 2015. Eine Studie zwischen Kontinuität und Innovation* (pp. 99-132). Münster: Waxmann.

Teddlie, C. & Tashakkori. A. (2006). A general typology of research designs featuring mixed methods. *Research in the Schools, 13 (1),* 12-28.

Wang, M.-T. & Degol, J.L. (2017). Gender gap in science, technology, engineering, and mathematics (STEM): current knowledge, implications for practice, policy, and future directions. *Educ. Psychol. Rev.*, *29 (1)*, 119-140.

Ziegler, A. & Schober, B. (2001). *Theoretische Grundlagen und praktische Anwendung von Reattributionstrainings.* Regensburg: Roderer.

DIVERSE STUDENTS, DIVERSE INQUIRY? HANDS-ON INQUIRY LEARNING IN HETEROGENEOUS CHEMISTRY CLASSROOMS

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Hands-on inquiry-learning tasks provide many opportunities for chemistry learning in heterogeneous groups. Commonly, students with various cognitive and affective preconditions work autonomously on those tasks and face individual difficulties and challenges. To be aware of possible obstacles and to know in which way they are related to students' individual prerequisites is crucial to create appropriate learning settings which take students' individual prerequisites into account. Against this background, the purpose of this study is to examine students' individual activities and difficulties while working on collaborative hands-on inquiry learning tasks considering different topic areas. In a qualitative study with 16-year-old students from different school types in Germany we used test data and video data from small-groups working on tasks on different topics. The results show that inquiry activities are quite individual as no correlation between a small-group' composition and activities during the inquiry-process could be found. Concurrently, high achieving small-groups show more activities that are necessary to gain knowledge from the inquiry learning task.

Keywords: Inquiry-oriented Learning, Differentiation, Video Analysis

PURPOSE OF THE STUDY

Inquiry learning in science education has become a widely used approach in recent years. A proven approach for inquiry learning in context of chemistry education is using collaborative hands-on inquiry learning tasks (Walpuski et al., 2008). Since students differ with regard to their competences in science (OECD, 2016) hands-on inquiry learning tasks have to be adjusted to students' individual prerequisites. Therefore, different individual prerequisites are important just as the way they are composed in small-groups. However, studies about the interaction of both students' individual prerequisites and effects of composing them in small-groups in context of hands-on inquiry learning in chemistry are still missing. As most of the studies focus on test data, there are barely qualitative insights about students' learning process. Therefore, the aim of our study is to gain insights into the use of hands-on inquiry learning tasks in heterogeneous chemistry classrooms across different topics. For this purpose, we analyse small-groups' individual ways of dealing with various hands-on inquiry learning tasks and investigate the correlation between small-groups' composition and inquiry activities and emerging difficulties in context of hands-on inquiry learning tasks.

THEORETICAL FRAMEWORK

Scientific Literacy as a part of education is an important learning outcome for every student in our modern society. There is international agreement that chemistry education as part of science education has to focus on educational aims, which are necessary to develop a general understanding of important scientific ideas and concepts as well as typical scientific practices and knowledge about science itself (AAAS, 1990; in Germany: KMK, 2004). By conducting experiments within inquiry learning tasks, students not only gain knowledge about chemical ideas, but also knowledge about science practices and the nature of science (Lederman et al., 2013). As doing so, students' prerequisites play an important role and affect their achievement (e.g. van Riesen et al., 2018). Prior content knowledge (van Riesen et al., 2018) and procedural knowledge (e.g. Stender et al., 2018; Ben-David & Zohar, 2009) have proven to be particularly relevant for successful inquiry learning in science education. Although students use similar activities when processing inquiry learning tasks low prior knowledge seems to determine a rather ineffective process structure (Mulder et al., 2010). Moreover, there are some insights about difficulties students have when working on hands-on inquiry learning tasks for single topics (e.g. Kechel, 2016). Overall, it seems that both, structure of inquiry activities the students use to structure the process and occurring difficulties have to be considered in investigations that focus on students' individual success while learning in a hands-on inquiry setting. For collaborative hands-on inquiry learning tasks the learning groups' composition also has to be considered for individual learning achievement (Lou et al., 2000). For example, general educational research has already stated out that low performing students profit most from heterogeneous small-groups whereas higher performing students tend to profit most from homogeneous small-groups (e.g. Lou et al., 2000).

DESIGN OF THE STUDY

In this study test data and video data of 16-year-old students from different school types in Germany processing hands-on inquiry tasks on different topics ('batteries', 'ocean acidification' and 'mineral water') has been analysed. Each topic involves the processing of two learning tasks that build on each other. Students' content knowledge has been assessed one week before and directly after the intervention by using multiple-choice single-select items. These tests consist of items relating to the contents of the learning tasks and items relating to general core ideas in chemistry (Celik & Walpuski, 2018). The items to general core ideas are used as anchor items. The parameters of the anchor items are fixed during scaling so that the tests can be related to each other. Additionally, we used established tests to assess students' cognitive abilities (Heller & Perleth, 2000) and procedural inquiry knowledge (Mannel, 2011) as control variables. In total, 146 students participated in our study working together in small-groups of four students. Furthermore, we selected 25 of these small-groups and videotaped their working processes. Test data have been analysed with unidimensional-IRT-models in R by using Test-Analysis-Modules (TAM) (Robitzsch, Kiefer, & Wu, 2019). Person parameters have been estimated by using WLE based on item parameters from MML-approach. Video data have been analysed using qualitative content analysis (Mayring, 2009) to identify different inquiry activities during the working process. For this purpose, a coding manual has been developed from our current video data, taking into account results from previous studies. Coding itself has been done timebased (10-second-intervals). 25 % of the video data considering different topics and small-group compositions have been analysed by two independent raters to determine the quality of the manual.

RESULTS

Although all items used in this study show sufficient item-fit statistics for the Rasch model, the reliabilities are only acceptable for tests regarding 'cognitive abilities' and 'procedural inquiry knowledge'. The reliabilities for the prior knowledge tests are quite low (Table 1). However, high correlations between all test scales ($r_P \geq .608$) justify the use of the prior knowledge data for further analyses.

Table 1 reliabilities of test scales

	chemical content knowledge			**inquiry knowledge**	**cognitive abilities**
	'batteries'	**'ocean acidification'**	**'mineral water'**		
reliability (Pre)	.606	.552	.595	.689	.726
reliability (Post)	.645	.666	.674	-	-
wMNSQ-values	0.72 - 1.84	0.65 - 2.91	0.69 - 1.46	0.87 - 1.16	0.83 - 1.10
t-values	-1.99 - 1.92	-3.00 - 2.86	-3.00 - 1.83	-1.23 - 1.82	-1.30 - 1.40
r_{it} (M(SD))	0.29 (0.18)	0.23 (0.24)	0.28 (0.21)	0.48 (0.09)	0.38 (0.11)

Overall, a significant increase in learning can be observed for all experimental tasks (subject 'batteries': $t(36) = 6.39$, $p < .001$, $d = 1.02$; subject 'ocean acidification': $t(53) = 5.97$, $p < .001$, $d = 1.01$; subject 'mineral water': $t(54) = 13.63$, $p < .001$, $d = 1.92$). Since only average tendencies can be derived from this consideration, the individual learning success was considered in a further step absolute (absolute difference between the abilities at both measuring points) and residual (deviation from the regressed learning increase depending on the abilities at the first measuring point). Of the 146 pupils, 76 learners fell short of expectations and 20 could not improve at all.

In addition to the performance data, the work phases of 23 small groups (93 pupils) were videographed. These learning process data were evaluated as part of a qualitative content analysis (Mayring, 2015). The coding manual is designed to cover all topics and comprises 7 main categories ('students work with the card material', 'students plan an experiment', 'students formulate hypotheses', 'students conduct an experiment', 'students make observations', 'students draw conclusions' and 'students work off-topic') with 16 codes (e.g.

‘students read the task’). The coding was time-based in 10-second intervals with a view to the experimental activities of the small group. In concrete terms, task-specific indicators (directly observable student actions and statements) of superordinate and task-independent activities (phases of experimentation) were coded. The observer agreement for this procedure varies according to the small group ($0.43 < \kappa_{Cohen} < 0.72$) and can be interpreted as acceptable to good (Wirtz & Caspar, 2002). An objective and thus reliable description of the experimental activities does not seem to be equally possible for every small group. For the further analyses, the frequencies of occurrence of the higher-level activities were standardized over the duration of the processing. With regard to heterogeneity within a small group (absolute difference between the most efficient and the least efficient learner), significant correlations can only be found with regard to specialist knowledge. Thus activities for planning ($r = .469$; $p = .024$) and evaluation ($r = .691$; $p = .000$) increase with increasing heterogeneity in a small group, while experimental activities ($r = -.358$; $p = .093$) and observation ($r = -.470$; $p = .024$) become less important for the group process. The performance level of the small group is not taken into account in this context, since heterogeneous small groups with an average high performance level have others than heterogeneous small groups with an average low performance level.

Within the framework of a communicative validation (exchange between the codes via inseparable categories or indicators) after completion of the coding, it was found that the experimental activities of individual pupils within a small group cannot always be clearly assigned to the overarching objective of cooperative task processing. In addition, especially in very heterogeneous small groups, individual pupils seem to dominate the working process.

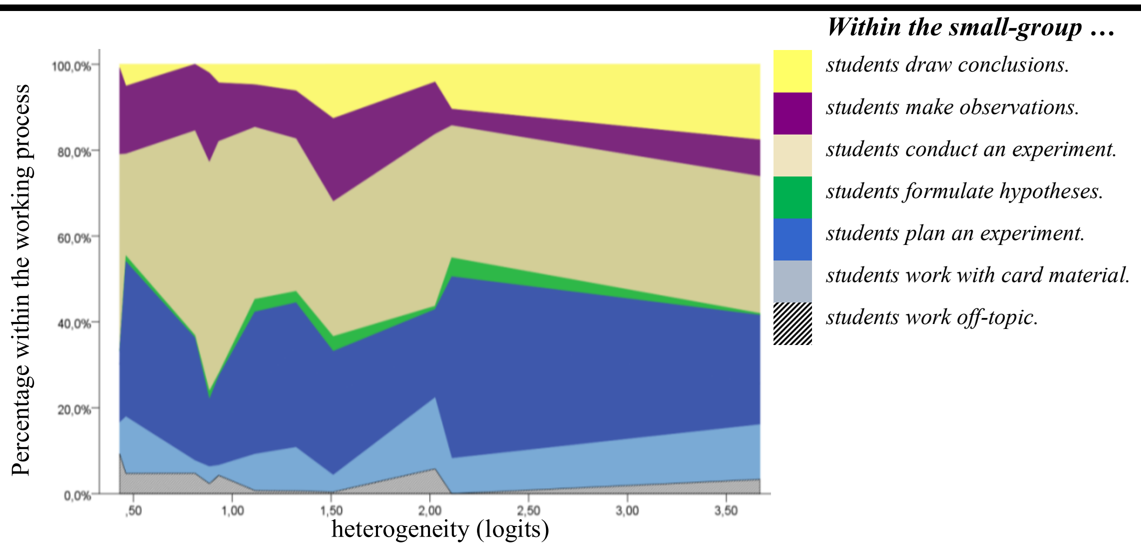

Figure 1 Group-specific activities within the working process

Therefore, in a second approach, the experimental activities at the individual student level were coded. In the course of further analyses, the comprehensive coding manual was revised. For this purpose, the topic-specific characteristics of the codes were worked out from the video material. Additional categories (e.g. ‘students document their results’) were added. Finally, the work phase of each learning task was analysed with the help of specific coding manuals (see Table 1).

Table 1 Characteristics of the coding manuals for the analysis of individual activities

	'batteries'		**'ocean acidification'**		**'mineral water'**	
	task 1	task 2	task 1	task 2	task 1	task 2
categories	8	8	8	8	8	8
codes	57	63	51	71	57	70

In all cases, this method provides significantly better observer agreement ($0.74 < \kappa_{Cohen} < 0.89$), which lies within an ideal range ($\kappa_{Cohen} > 0.70$) for qualitative class observation (Wirtz & Caspar, 2002; Frick & Semmel, 1978). For an initial analysis, the individual activities of twelve students from three different small groups were examined in more detail. In order to analyse the individual participation in the group process, κ_{Fleiss} was determined as the measure of agreement between the individual activities of the pupils. This shows that with increasing heterogeneity within a small group, participation in the group process becomes increasingly individual and different (see Table 2).

Table 2 Group-specific agreement of individual participation

	small group 1	small group 2	small group 3
Average level of performance (logits)	-0.433	-0.236	-0.149
heterogeneity (logits)	0.094	0.386	0.811
κ_{Fleiss}	0.658	0.412	0.362

DISCUSSION AND OUTLOOK

Overall, the results show that an individual-oriented analysis of experimental phases in cooperative settings is much more accurate than at the level of the small group. At the same time, such an approach allows deeper insights into the individual learning process within the framework of cooperative work. These can provide a central basis for the design of individualised and adaptive learning opportunities. The topic-specific coding also suggests that the content of the learning tasks also has an influence on the individual learning processes of the pupils. Due to the small data base, the analyses only provide indications of possible correlations. To what extent the topic on which the experimental task is based has an influence on the processing cannot be answered on the basis of the previous results either. Furthermore, the process data also indicate individual difficulties and mistakes, which seem to have a significant influence on the success of small-group work. In previous research, there have been numerous findings on difficulties and mistakes in experimentation, but these are often limited to specific topics. In addition, the occurrence of difficulties and mistakes has not been related to the learning conditions of students yet. It can be assumed that both individual participation and difficulties and mistakes have an influence on students' learning success.

Therefore, in a final study with 179 16-year-old students we will examine the relationship between individual learning prerequisites, individual processing strategies and difficulties. Analogues to our first study we used tests to assess students' individual prerequisites in first step. Therefore, we optimised those tests with insufficient tests statistics by improving existing items and creating new items. Furthermore, video data from 125 students working in 32 small groups are analysed. The results from the process analyses will be correlated with students' individual prerequisites. These findings can then be used to individualise learning processes during experimentation.

REFERENCES

American Association for the Advancement of Science (AAAS). (1990). The Nature of Science. [May 17th 2016]. http://www.project2061.org/publications/sfaa/online/chap1.htm

Ben-David, A., & Zohar, A. (2009). Contribution of Meta-strategic knowledge to scientific inquiry learning. International Journal of Science Education.

Kechel, J.-H. (2016). Schülerschwierigkeiten beim eigenständigen Experimentieren. Eine qualitative Studie am Beispiel einer Experimentieraufgabe zum Hooke'schen Gesetz [Students‘ difficulties during autonomous experimentation. A qualitative study on a hands-on task for the topic Hook´s law]. Berlin: Logos.

Lederman, N.G., Lederman, J.S., & Antink, A. (2013). Nature of science and scientific inquiry as contexts for the learning of science and achievement of scientific literacy. International Journal of Education in Mathematics, Science and Technology, 1(3), 138-147

Lou, Y., Abrami, P. C., Spence, J. (2000). Effects of Within-Class Grouping on Student Achievement: An Exploratory Model. Journal of Educational Research, 94, 101-112.

Mannel, S. (2011). Assessing scientific inquiry-Development an evaluation of a test for the low-performing stage. Berlin: Logos Verlag.

Mayring, P. (2000). Qualitative Content Analysis [28 paragraphs]. Forum Qualitative Sozialforschung / Forum: Qualitative Social Research, 1(2), Art. 20, http://nbn-resolving.de/urn:nbn:de:0114-fqs0002204.

Mulder, Y. G., Lazonder, A. W., & de Jong, T. (2010). Finding out how they find out: an empirical analysis of inquiry learners‘ need for support. International Journal of Science Education.

OECD (2016). PISA 2015 Results (Volume I). Excellence and Equity in Education, PISA, OECD Publishing, Paris. http://dx.doi.org/10.1787/9789264266490-en

Ständige Konferenz der Kultusminister (KMK). (2004). Bildungsstandards im Fach Chemie für den Mittleren Schulabschluss. [Educational Standards for Chemistry at Middle School Level]. München: Wolters Kluwer.

Stender, A., Schwichow, M., Zimmerman, C., & Härtig, H. (2018). Making inquiry-based science learning visible: the influence of CVS and cognitive skills on content knowledge learning in guided inquiry.

Van Riesen, S., Gijlers, H., Anjewierden, A., & de Jong, T. (2018). The influence of prior knowledge on experiment design guidance in a science inquiry context. International Journal of Science Education.

Walpuski, M., Wahser, I., & Sumfleth, E. (2008). Improvement of Inquiry-Learning Using Collaborative Tasks. In: B. Ralle & I. Eilks (Eds.): Promoting Successful Science Education – The Worth of Science Education Research (pp. 197-201). Shaker, Aachen.

LEADING FAMILIES TO STEM WITH EXTRA SCHOOL LEARNING

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This mixed methods study investigates the experiences of families who took part in STEM Career Club: Home Edition (SCCHE). Forty-four families at three rural, high poverty middle schools in the Southeastern US participated in SCCHE, receiving all materials necessary to complete up to 4 STEM activities in their homes. Parents generally perceived they had less understanding of STEM content than did their children, pre-activity; however, parents consistently answered more than 50% of content questions correctly on the post-activity survey. Parents and their children described developing or re-learning skills and content knowledge, and they most often noted enjoyment while participating in STEM activities with their families in this extra school learning experience. This study gives insight into ways to bridge formal school STEM content standards into learning settings within student homes to increase content knowledge, enhance home-school partnerships, and provide evidence-based applications for future extra school learning implementations.

Keywords: Parental Involvement, STEM Education, Informal Learning

INTRODUCTION

There has been a decline in the extent to which parents have been involved in their children's educations (Jeynes, 2012). A variety of reasons contribute to this trend: the increase of parents (particularly mothers) in the workforce, the fast-paced nature of society, increasing work hours, and the perceived reduction in the role of family in society (Jeynes, 2006; 2010; 2012; Mapp, Johnson, Strickland, & Meza, 2008). The majority of research on parental involvement is situated in preschool and primary grades contexts, and findings indicate that parental involvement is inversely related to their child's age (Hill, 2015). Hill asserts that it is easier to recruit parents of elementary school students to action, and parents often view their children's adolescent years (middle and high school) as a time for students to explore their identities and figure out who they want to become. Thus, parental roles change to include less involvement in school and academics as they attempt "to prepare them [children] for adult roles and experiences" (Hill, 2015, p. 43). The child's developmental level may dictate the degree to which they are interested in parental involvement; as adolescents mature, they often show more independence and less interest in certain forms of overt parental involvement (Bhargava & Witherspoon, 2015).

Parental involvement with schools during the middle school years is significantly associated with students' academic self-efficacy, academic aspirations, perceptions of academic potential, self-expectations, parental expectations, and teacher expectations (Seitsinger, Felner, Brand, & Burns, 2008).Thus, there is a need to provide opportunities for parents to remain involved in middle school to assist their children in content knowledge gains and planning for post-secondary education and careers (Epstein, 1986; Blanchard, Gutierrez, Hoyle, Painter, & Ragan, 2018). This study investigates the experiences of middle school students and their families who participated in an intervention intended to involve parents [guardians] with their middle-school children in engaging at-home STEM activities.

Theoretical Framework

Epstein (1986) identified six types of parental involvement that enhance student success in school: 1) involvement in basic obligations at home (i.e. securing school supplies, providing a quiet place to work while at home); 2) two-way communication between school and home (e.g., parent teacher conferences and more recently email or text communication); 3) volunteering at school (e.g., class parties, helping in the school cafeteria or library); 4) assisting students to complete at-home learning activities (ranges from high to low involvement and can be categorized into one of five categories); 5) involvement in school level decisions and advocacy (e.g., PTA or PTSO); and, 6) collaboration with community organizations. Epstein (1986) categorized 12 different types of at-home parental involvement activities into five categories: 1) reading books, 2) discussions between parent and child, 3) participation in informal activities (such as games using household materials), 4) implementation of contracts between parents, children, and teacher, and 5) tutoring and teaching the child skills and drills. Most at-home parental involvement programs are multidimensional and include between 3 and 4 of the above main types of involvement (Mattingly, Prislin, McKenzie, Rodriguez, & Kayzar, 2002).

Research Questions

The current research with the *STEM Career Club: Home Edition (SCCHE)* was designed as a vehicle to help parents work with their children in an extra school learning environment to complete up to 4 at-home STEM learning activities meeting Epstein's five categories. The research questions examined in this study are:

1) What are the characteristics of the families who participated in the SCCHE project? To what degree did families participate in the SCCHE project?

2) What content knowledge did participants (parents and children) demonstrate following SCCHE activities?

3) What were family members' perceptions of the SCCHE extra school learning experience?

METHOD

This funded research study (Blanchard & Gutierrez, 2016) builds off of a larger study (Blanchard et al., 2014; Gutierrez, 2016) and investigates the experiences of families who participated in at-home STEM activities using a mixed methods design (Creswell, 2013).

Context/Participants

Thirty-one families participated in this study, of the original forty-four families who initially consented (Total participants: N = 84: Parents/Guardians: n = 30, Children: n = 54). The participants were associated with established after-school STEM Career Clubs in 3 rural, high-poverty (>70% free-and-reduced lunch) middle schools in the southeastern US, as part of a

NSF-funded project (Blanchard et al., 2014). The STEM Career Club student membership for the participating schools was predominantly African American (55%), followed by White (22.5%) and Hispanic (8.1%). Large percentages of students in the four districts *failed* the end-of-grade mathematics (70.9%) and science (36.1%) tests.

STEM Career Club: Home Edition

Forty-four families initially consented to participate in this extra school learning environment, *STEM Career Club: Home Edition*. These families received all the materials required to complete a STEM activity in their homes, one activity at a time. When families returned the data associated with one activity (they kept all the STEM supplies), they were provided with the next activity until they completed a possible maximum of 4 activities throughout the school year. Included in each of the *Home Edition* kits were STEM materials (e.g., Circuit Scribe kit, Meccano robot, Germ Glo and *Achoo! The most interesting book you'll ever read about germs*, Steve Spangler's *Larry's Lab*); snacks, instructions for the activities, information about activity related careers and local post-secondary opportunities.

Data Sources & Analysis

In addition to the *STEM Career Club: Home Edition* materials, families also received pre-& post-activity questions. Each family member completed a pre-activity perceptions of knowledge survey and were asked to report on their affective perceptions and concerns prior to beginning the activity. Following the activity, all family members responded to 4-5 activity-specific content-related questions, and explained any changes in STEM understanding and their affective perceptions through short answer prompts.

Content knowledge questions were answered once families concluded the activities in their homes. These questions were multiple choice and included material that was specifically addressed within the at-home activities, such as: " You may program movement of your Micronoid by rotating its head back and forth in a unique pattern of your choosing through _____ programming. (a) Block-based, (b) Push-button, *(c) Learned Intelligent Movement*, (d) Text-based, and (e) None of the Above." Items were scored and the overall percentage correct for each participant, per activity, was calculated and reported through descriptive statistics.

Short-answer questions assessed family members' affective perceptions of the activity (" How did you feel about participating in today's STEM activity with your family at home?"), what participants learned ("What did you learn from completing today's STEM activity with your family at home?"), what was different than expected, and how STEM conceptual understanding was altered following the activity (" Did anything about the activity surprise you?" "Were there STEM concepts that you didn't know that you now have a better understanding of?"). Responses from each family member were then categorized into Epstein's five categories of at-home parental involvement activities.

RESULTS

RQ1: Characteristics of Families Participating in SCCHE and Degrees of Participation

Out of the 44 families who received materials for activity one, thirty-one families participated and returned data; 30 parents and 54 children participated in at least one *Home Edition* activity. Participants (parents & children) were mostly female (69%); only 30.8% of parent participants were male. Additionally, Caucasian participants comprised 46%, followed by African American (35%). Approximately 23% of parent participants held a high school diploma or less, with the majority of participants having either some technical or 4-year college experience (30.8%), a college degree (30.8%), or graduate degree (15.4%). The average age for participating students was approximately 12 years old and in either 6th or 7th grade. Return rates for data for SCCHE:

- *Activity 1 (Circuit Scribe):* 44 families received materials & 72.5% returned data;
- *Activity 2 (Meccano Switch Robot):* 29 families received materials & 79.3% returned data;
- *Activity 3 (Germ Glo & Achoo book):* 23 families received materials & 73.9% returned data; and
- *Activity 4 (Larry's Lab-A Steve Spangler Lab on super absorbent polymers):* 17 families received materials & 64.7% returned data.

The average return rate for data from participating families was 72.6% following each of the four activities.

RQ2: STEM Content Knowledge Demonstrated by Participants following SCCHE Activities

Parents generally perceived they had less understanding of STEM content than did their children, pre-activity. However, as shown in Table 1, parents consistently answered more than 50% of content questions correctly on the post-activity survey (≈ 47-91% of the time). Children (C) and Parents (P) were least successful in the area of electricity and circuitry (C:17.6%; P: 47.6%), and most successful with robots (C: 82.2%; P: 90.5%) and germs (C: 80.8%; P: 91.6%).

Table 1: ***SCCHE Activities, Participation Numbers, Participant Knowledge Perceptions, and Content Question Accuracy***

Activity	Parent (P)/ Child (C)	*n*	Perceptions of Content Knowledge Pre-Activity *(1 = Almost Nothing - 5 = Almost Everything)*	Percentage of Participants Receiving > 50% Correct Responses Post-Activity
1. Circuit Scribe (electrical circuitry)	P	21	2.1	47.6%
	C	34	3.0	17.6%
2. Meccano Robot (mechanical/ computer engineering)	P	21	1.4	90.5%
	C	28	2.3	82.2%
3. Germ Glo (microbiology and pathology)	P	12	3.8	91.6%
	C	26	3.0	80.8%
4. Steve Spangler's:	P	9	2.1	88.8%

Larry's Lab (absorbent polymers)	C	17	2.7	82.4%

RQ3: Family Member's Perceptions of the Home Edition Experience through Epstein's 5 Categories of Parental Involvement

Parents and children frequently described developing (or re-learning) skills and content knowledge in their written responses, as shown in Table 2. However, participants (both parents and their children) most often noted their enjoyment of time spent with their family members *while* they were learning more about STEM areas.

Table 2. Exemplars of Epstein's (1986) five categories of parental at-home activities (with pseudonyms).

Parental Involvement	Description	Participant Quote(s)
1. Reading books	Parents and children read about germs and discussed the text together as part of Activity #3.	"Reading with critical questions was helpful, and the experiment was really effective to make the point." *-Mr. Smith, Caucasian Father*
2. Discussions between parent and child	Families were encouraged to discuss all content provided and to help one another throughout the activities. (*Note:* Analyses of family conversations not analyzed in this manuscript but is forthcoming.)	"We have definitely had the opportunity to explore & discuss different school/career options for [my son]. I feel better prepared in helping him discover the major he should pursue in college." *- Ms. Floyd, Caucasian Mother*
3. Participation in informal activities	Activities were chosen and designed to be enjoyed, while at the same time, learning STEM content and introducing STEM educational pathways and career options.	"I loved it. Me and my son had fun. I learned that the STEM club is not just a waste of time, and I am glad he is in the club. I felt overjoyed in the fact that my son has found an optional career path." *- Mr. McLean, African American Father*
4. Implementation of contracts between parents, children, and teacher	Parents entered into a voluntary "contract" to participate in *Home Edition* (a partnership with their child, school, families and university partners) with their child via the SCCHE recruitment materials.	"I am a stay at home mom that volunteers a lot in the schools. I feel having had my mind opened to more possibilities I can share, challenge and pass possibilities along to children. Thank you!" *- Ms. Brown, Caucasian Mother*
5. Tutoring and teaching the child skills and drills	Each of the four activities were designed such that both parents and children learned content and skills simultaneously in a collaborative manner with two-way assistance between parent and child.	"I feel that I learned about things I've never heard of. I learned the names of the four main germs." *-Ms. Galindez, Hispanic/Latina Daughter* "I learned that there are different types of bacterias." *-Mrs. Galindez, Mother*

DISCUSSION AND CONCLUSION

In this study, participants of the SCCHE, both parents and children, were more likely to be female and Caucasian than were represented in the larger STEM Career Club project. We wonder if the research aspect of the study was off-putting and would like to try this again without it requiring informed consent in order to benefit.

It was heartening that parents who had less than a college degree (approximately half) were willing to participate. A surprisingly large percentage of participants (over 70%) returned data following the activities with their children. This suggests that the activities and the study were meaningful to these families, and that the mode of delivery (via child and packaged in a vibrant bag or bucket) was well received. However, persistence faded as the activities progressed, despite the families reporting enjoyment of shared family interactions, learning about STEM content, and gaining insight into educational pathways and career opportunities. Some families noted challenges (e.g., time constraints, complexity of activities, lack of confidence) that may have impacted their level of success and persistence.

The majority of the homes in this study were "working-class" homes, whose students received free lunch (97% of the students in these schools), either because individual families qualify or because all students in the school receive free lunch due to the high percentage of poverty in the entire school. Yet, clearly participating parents felt responsible for helping educate and guide their children into the appropriate post-educational pathway and career. This is in contrast to findings by Lareau (1987) and Stanton-Salazar (2011) that "working-class" parents often have a separated view of home and school, in which where schools are solely responsible for educational decisions, not parents, and in contrast to the findings of more 'interconnected' upper-middle class parents (Lareau, 1987, 2000, 2011; Lareau & Horvat, 1999). Therefore, the findings of this study challenge those reported in the literature.

Recommendations

Given our findings, we have several recommendations. First, we recommend that home activities be scaffolded so that activities at the beginning of the year are generally easier/less time intensive and later activities perhaps become a bit more complex/time consuming to increase persistence. Second, we suggest that the learning experiences should take families no more than one hour to complete or should be easily broken down into parts that can be completed over several sessions. Third, we encourage that more invitations are sent to families for participation in-home STEM activities, which was requested by many families in the year following this study. We have strong data indicating the enjoyment of families on school-related projects and want this to increase the home-school connections at all grade levels, particularly for families in low SES areas. Fourth, we encourage more research into the at-home interactions of family members as they work together on academically oriented STEM activities. There is little in the literature documenting these interactions, and it could give us great insight into how to better involve families of students in high poverty settings.

Conclusions

The SCCHE project provided opportunities and resources for families to explore and discuss career pathways, which has been described as especially important for families with low SES, parents without post-secondary education, and minorities (Hill, 2015). The SCCHE intervention provided all the materials needed for all four *Home Edition* activities, thus allowing families to complete the entire experience within their home setting, avoiding transportation and materials concerns that have been described in the literature (Dearing, Sibley, & Nguyen, 2015). We hope that this study provides meaningful ways to enhance home-school partnerships, evidence-based applications, and encouragement for future extra school learning projects to help lead families to STEM.

ACKNOWLEDGEMENT

The authors would like to thank the STEM Career Club teachers, and students and their families, for their participation. We would also like to thank the *STEM Career Club: Home Edition* university team members at NC State University from the College of Sciences and the College of Education. Research reported in this publication was funded by an NSF-ITEST (supplemental) grant under award number 1433747.

REFERENCES

Bhargava, S., & Witherspoon, D. P. (2015). Parental Involvement Across Middle and High School: Exploring Contributions of Individual and Neighborhood Characteristics. *Journal of Youth and Adolescence*, *44*(9), 1702–1719. https://doi.org/10.1007/s10964-015-0334-9

Blanchard, M. R., & Gutierrez, K. S. (2016). *STEM career clubs: Enhancing the potential of underrepresented students in STEM careers through a strategic teaming model, Supplement Request for postdoctoral fellow*. (Funded). National Science Foundation, $89,371/1 year.

Blanchard, M. R., Gutierrez, K. S. Hoyle, K. S., Painter, J. L., & Ragan, N. S. (2018). *Rural, Underrepresented Students' Motivation, Achievement, and Perceptions in Afterschool STEM Clubs.* In Finlayson, O., McLoughlin, E., Erduran, S., & Childs, P. (Eds.), Electronic Proceedings of the ESERA 2017 Conference. Research, Practice and Collaboration in Science Education Part 2 (co-ed. Tytler, R., & Carvalho, G. S.), (pp. 264-272). Dublin Ireland: Dublin City University. ISBN 978-1-873769-84-3

Blanchard, M. R., Painter, J., Gray, D., Alsbury, T. L., Denson, C., Williams, B., … & Johnson, J. (2014). *STEM career clubs: Enhancing the potential of underrepresented students in STEM careers through a strategic teaming model*. National Science Foundation-Innovative Technology Experiences for Students and Teachers awarded grant (NSF-ITEST).

Creswell, J. W. (2013). *Research design: Qualitative, quantitative, and mixed methods approaches*. Sage publications.

Dearing, E., Sibley, E., & Nguyen, H. N. (2015). Achievement Mediators of Family Engagement in Children's Education: A Family-School-Community Systems Model. In S. M. Sheridan & E. M. Kim (Eds.), *Processes and Pathways of Family-School Partnerships Across Development* (pp. 17–39). Springer.

Epstein, J. L. (1986). Parents' Reactions to Teacher Practices of Parent Involvement. *The Elementary School Journal*, *86*(3), 277. https://doi.org/10.1086/461449

Gutierrez, K. S. (2016). *Investigating the Climate Change Beliefs, Knowledge, Behaviors, and Cultural Worldviews of Rural Middle School Students and their Families during an Out-of-School Intervention: A Mixed-Methods Study* (Unpublished doctoral dissertation). North Carolina State University, Raleigh, NC.

Hill, N. E. (2015). Family-School Relationships During Adolescence: Clarifying Goals, Broadening Conceptualizations, and Deepening Impact. In S. M. Sheridan & E. M. Kim (Eds.), *Processes and Pathways of Family-School Partnerships Across Development* (pp. 41–59). Springer.

Jeynes, W. (2006). Standardized tests and Froebel's original kindergarten model. *The Teachers College Record*, *108*(10), 1937–1959.

Jeynes, W. (2010). The salience of the subtle aspects of parental involvement and encouraging that involvement: Implications for school-based programs. *The Teachers College Record*, *112*(3), 747-774.

Jeynes, W. (2012). A Meta-Analysis of the Efficacy of Different Types of Parental Involvement Programs for Urban Students. *Urban Education*, *47*(4), 706–742. https://doi.org/10.1177/0042085912445643

Lareau, A. (1987). Social Class Differences in Family-School Relationships: The Importance of Cultural Capital, *Sociology of Education*, *60*(2), 73–85.

Lareau, A. (2000). *Home advantage: Social class and parental intervention in elementary education*. Rowman & Littlefield Publishers.

Lareau, A. (2011). *Unequal childhoods: Class, race, and family life*. Univ of California Press.

Lareau, A., & Horvat, E. M. (1999). Moments of Social Inclusion and Exclusion: Race, Class, and Cultural Capital in Family-School Relationships. *Sociology of Education*, *72*(1), 37–53.

Mapp, K. L., Johnson, V. R., Strickland, C. S., & Meza, C. (2008). High School Family Centers: Transformative Spaces Linking Schools and Families in Support of Student Learning. *Marriage & Family Review*, *43*(3–4), 338–368. https://doi.org/10.1080/01494920802073205

Mattingly, D. J., Prislin, R., McKenzie, T. L., Rodriguez, J. L., & Kayzar, B. (2002). Evaluating Evaluations: The Case of Parent Involvement Programs. *Review of Educational Research*, *72*(4), 549–576. https://doi.org/10.3102/00346543072004549

Seitsinger, A. M., Felner, R. D., Brand, S., & Burns, A. (2008). A large-scale examination of the nature and efficacy of teachers' practices to engage parents: Assessment, parental contact, and student-level impact. *Journal of School Psychology*, *46*(4), 477-505.

Stanton-Salazar, R. D. (2011). A Social Capital Framework for the Study of Institutional Agents and Their Role in the Empowerment of Low-Status Students and Youth. *Youth & Society*, *43*(3), 1066–1109. https://doi.org/10.1177/0044118X10382877

THE SKEPTICS - EXPERIENCES OF BILDUNG IN UNIVERSITY LEVEL PHYSICS

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This study seeks to answer the research question "What is the lived experience of Bildung in university level physics education?" by a phenomenological study based on interview data of six Norwegian master level physics students. The results show that the students experience becoming more skeptical and critical in different ways, and while not solely ascribing this to studying in general, or studying physics in particular, they also ascribe their change to their experiences as physics students. The different forms of skepticism are evaluated and compared with forms of skepticism known from literature (e.g. known divisions within the "skeptic's movement") with diverse results. The students process of Bildung is also evaluated, within a theoretical tradition from Humboldt and Klafki, and the results suggest that Bildung is a social process.

Keywords: Cognitive Development, Culture and Education, Values in Science Education

INTRODUCTION

The purpose of university education is not only to qualify young people for work life, but also to see "oneself as a member of a larger community" and in such a societal view to use ones powers for the larger good" (Committee on Yale College Education, 2003), this can be referred to as Bildung. The present study explores Bildung in university level physics by trying to identify effects a physics education has on students outside the area of physics itself, and the processes where this happens, by answering the research question "What is the lived experience of Bildung in university level physics education?"

Science and technology are commonly seen as less relevant to questions of Bildung than other fields of research (Schwanitz, 1999, p. 482; J. Sjöström, Frerichs, Zuin, & Eilks, 2017, p. 166). The validity of such claims are however heavily disputed, and to try to evaluate them, we both have to define Bildung a bit more closely, and evaluate science and science education in view of this definition.

BILDUNG AND SCIENCE

Attempts to define Bildung in any specific sense have been considered futile by many. Max Horkheimer famously declared, "Don't expect me to define it [Bildung]. There are areas in which clear and simple definitions are more than to the purpose, and the role of definitions in knowledge should not be underestimated in any way" (Siljander & Sutinen, 2012, p. 2), arguing that clear boundaries of concepts are not always necessary. Attempts to define have however been made. Liedman describes "The backbone of the concept of Bildung" as "the notion that knowledge, or at least some knowledge, fundamentally changes and develops a human being" (Liedman, 2001, p. 351), translation by Sjöström et.al. (J. Sjöström, et al., 2017). Klafki presents his concept of *categorical* Bildung, in which the individual and the world simultaneously open themselves up for one another (Klafki, 1973). In a university context, Wilhelm van Humboldt is important historically, and to this study also how he (and Klafki) describes Bildung also as a collective process (Klafki, 1991, p. 27).

A useful operative definition of Bildung is as a process making an educated person able to operate within the "the everyday world" and the "everyday language", as opposed to the separation of science into its own world and language (Hellesnes, 1992, p. 84). In a broad sense, Bildung thus connects science to society. This is also similar to the idea of Bildung as a process enabling you to become a *citizen* – an active participant in society, and not simply a vocational practitioner of a craft. This idea is found in both the tradition of classical Bildung and the Anglo-American tradition of liberal education (Adler, 1952, p. 57; Hancock, 1987; Paxson, 1985). This also explains why some see science as relatively less relevant to Bildung, as many other fields, like the humanities and the social sciences, directly research aspects of society.

Bildung and the nature of science

With a view of Bildung as coupling science to society, science education research identifies several relevant aspects of science. We might separate Bildung aspects of science into two parts; elements that can be useful also in society as a whole, like cognitive skills and values of science (Dagher & Erduran, 2014, p. 48) or scientific literacy (Jesper Sjöström & Eilks, 2018, p. 66), and aspects of science that themselves show sciences interconnectedness with society, like elements of the Family Resemblance Approach to Nature of Science, such as Social certifications and dissemination, Scientific ethos, Social Values and Professional activities (Dagher & Erduran, 2014, p. 28).

Norwegian scientists like physicist Svein Sjøberg and biologist Dag O. Hessen, give some examples of the contributions they believe science and technology have to Bildung, like how the natural sciences, not only their products, but also their methods, ideals and values are an important part of our cultural inheritance. Sjøberg explicitly also mentions the belief in rationality and reason, and in critical discussion in connection with these aspects of science (Sjøberg, 2009, p. 200). Hessen points out how "realization and cognizance in a broad sense, about the human being itself, and our place in it all", makes knowledge about the natural world central to both culture and Bildung (Hessen, 2011, p. 458).

This study will attempt to examine students experiences of Bildung in university level physics education qualitatively through interviews with Norwegian master level physics students, and thus answer the research question "What is the lived experience of Bildung in university level physics education?". This question is important to understand the mindset and motivations of physics students and the effect an education in physics can have on the same, and to disclose some of the hidden curriculum in physics.

mETHODology

This study is based on six individual semi-structured interviews with master level physics students (See interview guide in Figure 1) on Bildung-aspects of their physics education, using a phenomenological method. A natural starting point in the process of sorting, has been to be on the lookout for recurring content, and sorting this content thematically (Rennstam & Wästerfors, 2015, p. 69).

1. Open question about physics and the education the student has taken.

2. Of all those who start physics in the first year, some do not go on to a master's thesis. What is your impression of those of your fellow students who quit? When did they quit and why do you think they quit?

3. Transformative experiences - is there anything about physics education that has been a bit "wow" - that has changed you or the way you see things?

4. What about your world view? Is there anything about your education that has influenced how you look at the world beyond physics itself? Are there any areas you have changed views on?

4 B. Elaborative/follow-up questions in specific areas - politics – view of science - ontological/epistemological questions, the view of other disciplines (hard/soft science) etc., depending on the response on previous questions.

5. Is there anything you think physics education should have had more or less of in light of what you have said until now? Does it have the right focus? Had it been more inspiring and exciting if something had been done differently? If so, what? Is there anything you think of as "physics" you wish you had learned more about?

6. Is there anything you wish to say that I have not asked about in this conversation?

Figure 1: Questions from the interview guide.

From a phenomenological perspective this process should be oriented towards larger meaning-units. The researcher should attempt to look at the material as freely as possible from forgiven prepositions and expectations (Rennstam & Wästerfors, 2015, p. 75), or as Giorgi puts it, in a "more naïve, pretheoretical way" (Giorgi, 2009, p. 135). In line with this the present study was undertaken by systematically going through interview transcripts, indentifying such meaning-units, critically re-reading them, and evaluating recurring themes.

After such recurring-meaning units were disclosed, illustrative quotes were identified, and evaluated through meaning condensation (2009, p. 146).

rESULTS and discussion

The most common theme (larger meaning-unit) from the interviews was that all the students described how they during their education had become more skeptical and critical in different ways. Illustrative quotes, meaning condensation and further examples of recurrences can be seen in Table 1.

Is skepticism relevant to Bildung?

Skepticism can be connected to Bildung e.g. through the connection Sjøberg makes with critical discussion and reason (Sjøberg, 2009, p. 200). It also falls within the form of cognitive skills we previously considered relevant to Bildung. It does not in itself necessarily imply interconnectedness with society, but it can be useful in society, and as we can see from the diverse topics the students volunteer in Table 1, they have employed these skills to society. It thus makes sense to see this experience as relevant to Bildung as we have defined it.

Forms of skepticism

To an extent, the forms of skepticism can also be seen in connection with the "international skeptic's movement". Its original goal was to attack forms of pseudoscience like alternative medicine, paranormality and conspiracy theories, such topics were e.g. the focus of Carl Sagans influential "Demon-Haunted World" (Sagan, 1997), termed "classical skepticism" in Table 1. The focus has however shifted over the years. Given the students own descriptions of their development and the examples they give, it gives sense to label their experiences into this framework. This is summed up in Column 4 of Table 1. Two students explicitly mention the popular skeptically oriented Norwegian TV-program "Folkeopplysningen" (Popular Enlightenment) hosted by physicist Andreas Wahl, and many of the subjects of their skepticism correspond with topics the program has raised.

Table 1: Analysis of forms of skepticism from students S1-S6. Column 1: Student, Column 2: quote from interview, Column 3: Meaning condensation from quote. Column 4: Subjects of skepticism gathered from entire interview, Column 5: Short interpretation of "form of skepticism".

Student	Quote	Condensation	(Additional) mentioned subjects for "skepticism"	Interpretation
S1	No, it's much about this – I have learned to think independently. If I am to give an example, I use to get very pissed at alternative treatment and stuff like that. How it is done, how it is being worked with in politics. I think it should be illegal.	S1 states that he has learned to think independently and thinks e.g. alternative treatment should be prohibited.	- alternative treatment - organic food - humanities (money spent on)	Combines elements from "classical skepticism" with skepticism towards not humanities per se, but their priority in society relative to natural sciences.
S2	I perhaps feel that I have become a bit more skeptical. That I in a sense no longer accept something as true, just because. No, I think I want to get more to the bottom of things, and I believe I have become more concerned with being precise.	S2 states that she has become more skeptical. Deeper understanding and precision has become more important.	- tabloid news media - dietary advice - pedagogy and psychology (as science) - homeopathy	Combines elements from "classical skepticism" with skepticism towards the scientific rigor of pedagogy and psychology.
S3	… to be quite critical towards yourself and all the time think «if somebody was to read this, what will they think I did not think of? What could it be here, that is not what I want it to be?».	S3 states that she has become more self-critical, thinks of what a critical outside reader would think.	- climate denial - own preexisting views on abortion - pedagogy and social science (as science) - general lack of skepticism in society	General disapproval of lack of skepticism in society combined with skepticism towards e.g. climate denial.

S4	I look much more at the world, look at things and am more reflected on … everything, I hope. […] A lot of stuff could be solved if only people knew a little more about this one little thing. That enlightenment of masses is very important. And a lot boils down to – as a physicist you get very provoked by these people who believe the world is flat. Seriously – people managed to calculate this 3000 years ago, now we are done with this discussion. Stuff like this naturally provokes extra much.	S4 states that she looks upon the world in a more reflected way, believes in popular enlightenment and is provoked by e.g. flat earthers.	- flat earthers - climate denial - resistance against nuclear technology - gender biases - religion	Combines elements from "classical skepticism" with skepticism towards gender biases.
S5	What I feel with physics is that I have become very realistic, on stuff, so perhaps less feelings in politics, more objective approach to stuff. Sometimes to the extreme that one feels one gets sort of emotionless, that you just see things very black/white, as they perhaps are, but you lose some of the human romantic interpretation of stuff. Like this with organic food and such, genetic manipulation and stuff.	S5 states that he has become more objective and less emotional. Critical towards organic foods, etc.	- organic foods - resistance against genetic technology - emotions in politics	All elements fit into "classical skepticism".
S6	In general that people express themselves with a cocksureness they in no way have a reason to. You understand when you study physics, how very, very difficult it is to figure out even something simple. You have to simplify the situation extremely and then you have to be extremely careful to get real knowledge, and even then you can be wrong. So such cocksureness on subjects is often not in place. […] A usual example now is nuclear power, perhaps that one does not look at rational scientific things there. That public opinion sort of is just based on emotions.	S6 states that he has become more skeptical towards cocksureness and feels discussions about e.g. nuclear power are too emotionally driven.	- resistance against nuclear technology - CERN (money spent on) - lack of scientific rigor in evolutionary psychology, pedagogy and humanities and social sciences in general.	Combines elements of classical skepticism with skepticism towards priorities of expensive parts of physics itself, and the scientific rigor of humanities and social sciences.

Two central divides in the "skeptics movement" has been the view on religion (should it be an area of skepticism or not?) and the view of the humanities and social sciences (are they scientifically sound?). The most common view of religion among the students seems to be one not of personal religiosity but neither one of anti-religion. This is a view more similar to Stephen Jay Gould's "non-overlapping magisteria"(Gould, 2011, p. 269), than Richard Dawkins' "Root of all Evil" (Dawkins, 2006). However, if there was to be a conflict between faith and science, physics comes first. Similarly, some students are skeptical to some aspects of social sciences and the humanities. We can perhaps still see remains of the American "science wars, and the "Sokal affair" from the 1990's (Sokal & Bricmont, 1998), and the students are reluctant against viewing these fields as "science", but on the other hand they also see their importance. See Figure 2 for an illustration of a typical student positioning within this 2D-space of skepticism.

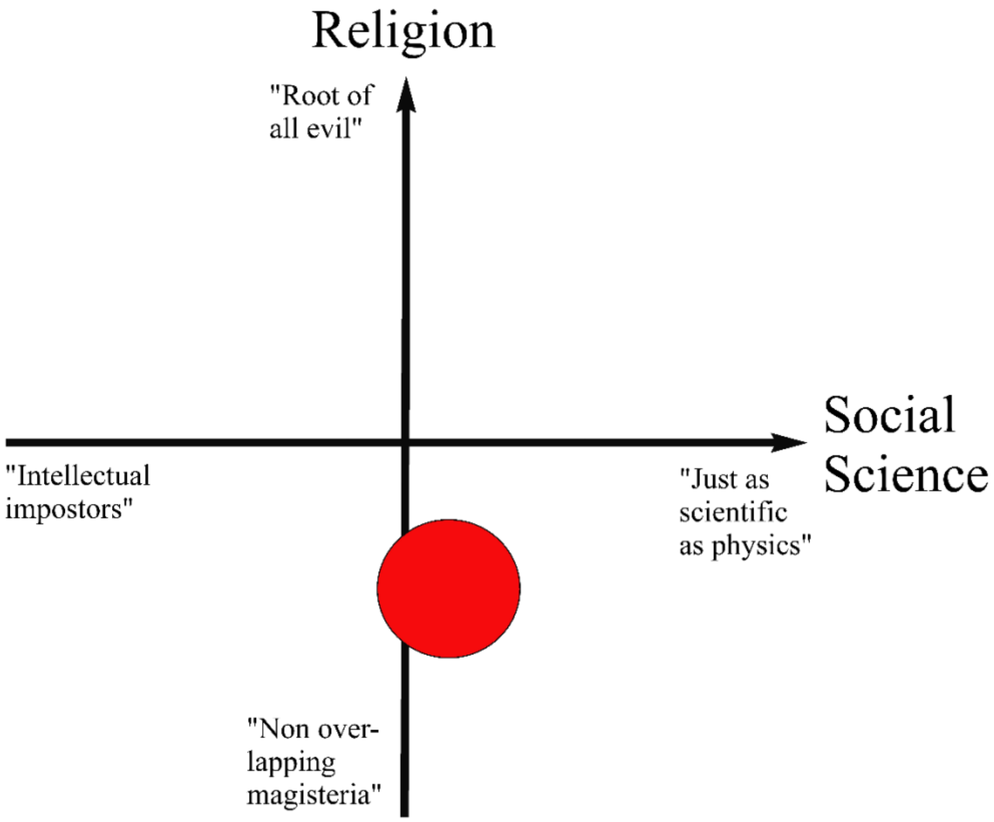

Figure 2: Illustration (not graph based on data) of how a typical student can be placed in a 2D space of "skepticism" where views of social sciences is along the x-axis, spanning from "intellectual impostors" (Alan Sokal's famous diagnosis of some postmodernists), to equating them scientifically with physics. On the y-axis are views on religion, spanning from "Root of all evil" (Richard Dawkins) to "Non overlapping magisteria" (Stephen Jay Gould).

The process of Bildung

The students in general had nuanced views on the reasons of their skepticism. As student S3 puts it:

> I have always liked to be critical, towards myself as well. But I also believe that I've become more like this as a result of studying physics, and also because I've gotten to know other people who are also critical. So I think that has helped quite a lot. The conversations you are having with others, not just about physics, but about politics, for example.

This fits with the idea of university Bildung as a collective endeavor that both Humboldt and Klafki presents. We can glimpse a process of Bildung that happens while physics students are socializing each other into a role as physicists, with a corresponding skeptical attitude.

In physics, you often operate with scales of both time and distance that might seem absurd and unfathomable to most non-physicists. To some students this perspective gave them a motivation to go out and change a world riddled with petty disagreements. To other students however, these vast scales made them numb and indifferent – as student S5 expresses it:

> And in a way, it's a bit so sad that you feel you have no impact on the world. Whatever you do, everything just goes on by itself, and then you die, and the earth continues to rotate.

These latter students do not seem to see themselves as (potential) active agents in the world. Do these reactions signal a missed opportunity for Bildung? The question arises in particular, as these students had expressed not being a part of a scientifically oriented student community.

CONCLUSION

The results show that physics students today do have an experience of going through a process of Bildung during their time at university. The most common experience is one of increased skepticism.

This study also supports the notion of Bildung as a social process, and further study should be undertaken to examine whether lack of student access to an academically oriented student community hinders Bildung.

Acknowledgement

I would like to thank Magnus Strøm Kahrs, Berit Bungum and Einar Sundsdal for important input into the direction of this project.

REFERENCES

Adler, M. J. (1952). The Great Ideas: A Syntopicon of Great Books of the Western World (Vol. 1). Chicago, London, Toronto: Encyclopedia Britannica.

Committee on Yale College Education. (2003). Report on Yale College Education. New Haven.

Dagher, Z. R., & Erduran, S. (2014). Reconceptualizing the Nature of Science for Science Education: Scientific Knowledge, Practices and Other Family Categories. Dordrecht Springer.

Dawkins, R. (2006). The God Delusion. Boston: Houghton Mifflin Co.

Giorgi, A. (2009). The Descriptive Phenomenological Method in Psychology: A Modified Husserlian Approach. Pittsburgh: Duquesne University Press.

Gould, S. J. (2011). Leonardo's mountain of clams and the Diet of Worms : essays on natural history (1st Harvard University Press ed.). Cambridge, Mass.: Belknap Press of Harvard University Press.

Hancock, D. (1987). The Greek Concept of Paideia and Modern Continuing Education. Texas Association for Community Service and Continuing Education Research Annual, 3(1).

Hellesnes, J. (1992). Ein utdana mann og eit dana menneske. In E. L. Dale (Ed.), Pedagogisk filosofi (pp. 79-104). Oslo: Ad Notam Gyldendal.

Hessen, D. O. (2011). Naturvitenskap - Dannelse eller bare utdannelse? . In B. Hagtvedt & G. Ognjenovic (Eds.), Dannelse - Tenkning - modning - refleksjon (pp. 454 - 471). Oslo: Dreyer.

Klafki, W. (1973). Studien zur Bildungstheorie und Didaktik: Beltz.

Klafki, W. (1991). Neue Studien zur Bildungstheorie und Didaktik: Zeitgemäße Allgemeinbildung und kritisch-konstruktive Didaktik (2nd ed.). Weinheim and Basel Beltz Verlag.

Liedman, S.-E. (2001). Ett oändligt äventyr – Om människans kunskaper. Stockholm: Albert Bonniers Förlag.

Paxson, T. D. (1985). Art and Paideia. The Journal of Aesthetic Education, 19(1), 67-78.

Rennstam, J., & Wästerfors, D. (2015). Från stoff till studie Om analysarbete i kvalitativ forskning. Lund: Studentlitteratur.

Sagan, C. (1997). The Demon-Haunted World: Science as a Candle in the Dark. London: Headline.

Schwanitz, D. (1999). Bildung : Alles was man wissen muß. Frankfurt an Main: Eichborn Verlag.

Siljander, P., & Sutinen, A. (2012). Introduction. In P. Siljander, A. Kivelä & A. Sutinen (Eds.), Theories of Bildung and Growth: Connections and Controversies Between Continental Educational Thinking and American Pragmatism. Rotterdam, Boston, Taipei: Sense Publishers.

Sjøberg, S. (2009). Naturfag som allmenndannelse - en kritisk fagdidaktikk (3 ed.). Oslo: Gyldendal Akademisk.

Sjöström, J., & Eilks, I. (2018). Reconsidering Different Visions of Scientific Literacy and Science Education Based on the Concept of Bildung. In Y. J. Dori, Z. R. Mevarech & D. R. Baker (Eds.), Cognition, Metacognition, and Culture in STEM Education: Learning, Teaching and Assessment (pp. 65-88). Cham: Springer International Publishing.

Sjöström, J., Frerichs, N., Zuin, V. G., & Eilks, I. (2017). Use of the concept of Bildung in the international science education literature, its potential, and implications for teaching and learning. Studies in Science Education, 53(2), 165-192. doi: 10.1080/03057267.2017.1384649

Sokal, A. D., & Bricmont, J. (1998). Fashionable nonsense : postmodern intellectuals' abuse of science. New York: Picador USA.

HANDS-ON SCIENCE TO PROMOTE LANGUAGE LEARNING IN BILINGUAL CONTEXTS

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The Luso-descendant community in Switzerland represents the third largest emigrant group counting with 39,906 students that attend the regular Swiss education. A closer look at the Swiss education system notes a stigmatizing trait in its relationship with the Portuguese community and we estimate that 2,733 secondary school pupils are victims of a discriminatory system that underrates them. This has important implications in terms of integration into the society and work-related settings. As a consequence, Swiss authorities strongly support initiatives aiming to promote teaching of heritage languages and that together with the regular education system should promote the motivation of students with Portuguese origin to pursue studies while developing their bilingual identity. In this project, we used inquiry-based learning methodologies and experimentation as tool to promote science and language integrated learning. Here, we transformed classrooms into non-formal learning environments and learners into active players in their learning process while diving into the scientific method. Primary and secondary school learners were encouraged to ask questions, formulate hypothesis, design experiments, test ideas, observe results and draw conclusions using their heritage language as an instrument for questioning, communicating and thinking. The success of our hands-on science sessions was evaluated through questionnaires that 106 participants answered before and after the class. The results obtained point to positive implications in terms of acquisition of knowledge, understanding about the scientific process, destruction of prejudices in relation to science, and the broadening of students' expectations for the future. Additionally, surveys addressed to the Portuguese Heritage Language (PHL) teachers so as to classify our sessions as "good" or "very good" with regard to the introduction of new vocabulary, students' ability to expose ideas, and increase in the motivation and enthusiasm to learn the heritage language. In summary, this study shows the benefits of introducing the scientific method through the use of experimentation, and that of practices centred on "learning by doing", in multidisciplinary educational contexts such as in PHL learning. However, a more comprehensive study is necessary to justify the application in a larger scale of such alternative methodologies that, together with the formal education system, should broaden students' future perspectives and increase their understanding and appreciation of the heritage language.

Keywords: Multilingualism, Interdisciplinarity, Inquiry-oriented learning

PROBLEMATIC

The recent acute rise in social media manipulation and fake news phenomena is a global problem that urges for multidisciplinary interventions (Lazer et al. 2018). Empowering individuals with the right amount of skills that allows them to critically evaluate information poses a potential solid way to address the issue. Although the efforts to introduce such strategies in a regular school system have been made (Jones, 2017), the importance of scientific literacy as a route to redesign how the public deals with information is still underappreciated. In addition to this problem, we live today in an age of uncertainty (Bauman, 2007) where students are prepared for a future that may possibly no longer exist. In order to solve an ecosystem of challenges never encountered before, we need to encourage problem-solving attitudes and equip the young generation with deeper and better understanding of scientific method that provides the guiding rules used to answer questions. These contemporary issues place science education at the centre while serving as a safeguard that strives to face global and local problems.

In an era rich of multicultural learning environments, a practice-oriented science classroom can also hold as productive language- and science-learning settings that promote social equity (Cuevas, Lee, Hart, & Deaktor, 2004; Lee, 2005; Lee & Fradd, 1998; Lee, Quinn & Valdés, 2013; Poza, 2016). The application of such methodologies should be global in scope but are particularly urgent in countries with higher prevalence of immigrant communities.

According to the United Nations Department of Economic and Social Affairs (2015), Switzerland is among the ten European countries with most migrant load when compared with total international migrant stock. Amid the almost 200 different nationalities residing in this country, the Luso-descendant community represents the third largest emigrant group counting with 39,906 students that attend the regular Swiss education (Federal Statistical Office, 2018). Here, and regardless of governmental efforts to support initiatives promoting the motivation of students with Portuguese origin, the percentage of Luso-descendant pupils enrolled in advanced secondary school classes with increased chances of pursuing higher education is still 27% lower when compared to that of Swiss students.

The use of innovative practices at the core of PHL teaching, such as the introduction of hands-on science activities in a pedagogical context, can be determinant to change representations and to increase students' self-esteem through the appreciation of their heritage language and culture (especially in multicultural and multilinguistic environments). However, in order to justify the application of such strategies at a large scale, it is important to carry out a research that allows to diagnose changes in several dimensions of students' attitudes. The study presented here arises from this need and seeks to verify the advantages of using science and experimentation in an educational bilingual context.

METHODS

Target group

This study was conducted in four different Swiss cantons and in close collaboration with five PHL teachers. 106 students, 45% boys and 55% girls at the age of 7-16 years old, were involved in the intervention and answered questionnaires.

Questionnaire

In order to estimate how the introduction of hands-on science activities in the classroom influenced students' attitude and ability to respond, all 106 participants in this study answered the questionnaire (before and after class). The inquiry consisted of 23 questions to evaluate the following parameters: 1) declarative knowledge, 2) knowledge about the scientific process, 3) deconstruction of representations or preconceived ideas about what it is to be a scientist, and 4) motivation and students' perspectives for future. To each answer was assigned a score: [-1] for wrong or negative responses in terms of future perspectives, [0] for blank or "do not know" answers, and [1] for correct responses or positive perspectives for the future. Questions in which participants chose more than one option were not considered in the analysis.

To evaluate our sessions regarding the introduction of new vocabulary, students' ability to expose ideas, and increase in their motivation and enthusiasm to learn the language of inheritance, PHL teachers answered a survey containing 15 questions. They were asked to evaluate classes in a scale ranging from 1 ("very bad") to 5 ("very good").

Statistical analysis

To determine the effect of our didactic methodology on the various criteria mentioned above, we used Mann-Whitney test. For each question, the difference in students' scores before and after the experimentation class was assessed. Additionally, for two statements assessing pupil's motivation and perspectives for future ("I love science" and "I would like to be a scientist") we analyzed the difference in scores between Primary School and Middle School pupils. All statistical analyses were performed in R program (R-Core-Team, 2018). The p-value lower than 0.05 was considered significant.

Hierarchical clustering

The heatmap generated using Euclidean clustering of student response scores (vertical) before and after intervention was performed using categorical information such as location, time, school year and gender (horizontal). Location corresponds to participant's residence (Sursee, Brugg, Wohlen, Dubendorf, Sarnen, Luzern or Aarau), and time to the period between before and after questionnaires (0, 7, 14 or 21 days).

RESULTS

Positive implications in student's attitudes for all criteria tested

This research shows that a methodology based on inquiry-oriented learning and hands-on experimentation has positive implications in transforming students' attitudes regarding all criteria tested. In particular, we verified that the use of practices focused on learning-by-doing (Dewey, 1916) can be determinant to learn and understand new concepts, to acquire knowledge about the scientific process, to deconstruct preconceived ideas and to raise students' motivation and perspectives for future (Figure 1). In a more detailed analysis, we observed an effective change and improvement in learners' responsiveness in 83.3% of the questions assessing acquisition of declarative knowledge, in 42.9% of the questions assessing their understanding about the scientific process, in 60% of questions on determining misconceptions about science and in 60% of questions on evaluating their motivations and prospects for future careers. In addition, all PHL teachers involved in the project evaluated our experimental sessions as "very good" regarding the introduction of new vocabulary (average score=4.8), students' oral communication (average score=4.7) and increase in the motivation to learn their heritage language (average score=4.7).

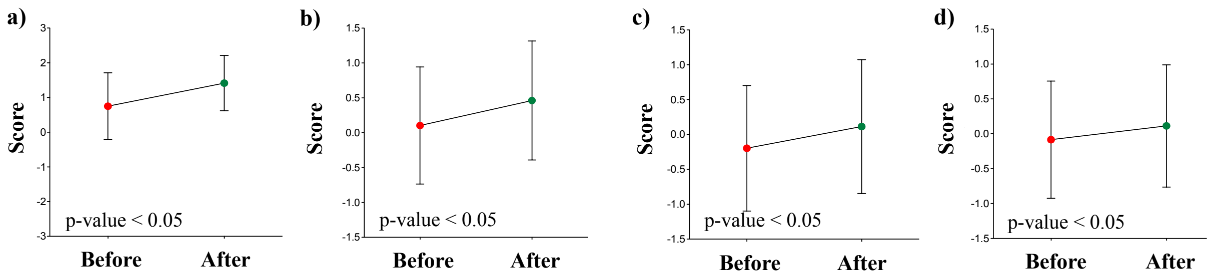

Figure 1. Assessment of hands-on science methodologies success. We evaluated efficacy of using inquiry-based learning techniques and experimentation to improve student's acquisition of knowledge (**a**), understanding of the scientific method (**b**), reduction of pre-concepts related to science (**c**), and expansion of their perspectives for future (**d**). Students (n=106) answered same questionnaire before and after each session. We observed significantly positive effects ($p<0.05$) in 5 out of 6 questions assessing acquisition of knowledge (83.3%), 3 out of 7 questions evaluating their understanding of the scientific method (42.9%), 3 out of 5 questions testing pre-concepts and student's perspectives for future (60%). Each graph represents statistically significant effects observed for one question per evaluated aspect. We used Mann-Whitney test to evaluate the effect of hands-on experiments activities. Each circle in plots represents mean and bars show 95% confidence interval.

Younger students are more interested in science

A deeper analysis to students' attitude towards the statement "I love science" and "I would like to be a scientist" shows that Primary School pupils are more interested in science-related topics and more motivated to pursue a scientific career when compared with Middle Schools pupils (Figure 2). Conversely, none of the further clustering categories (location, time and gender) showed to have statistically significant influence on responses of pupils (Figure 2a and b).

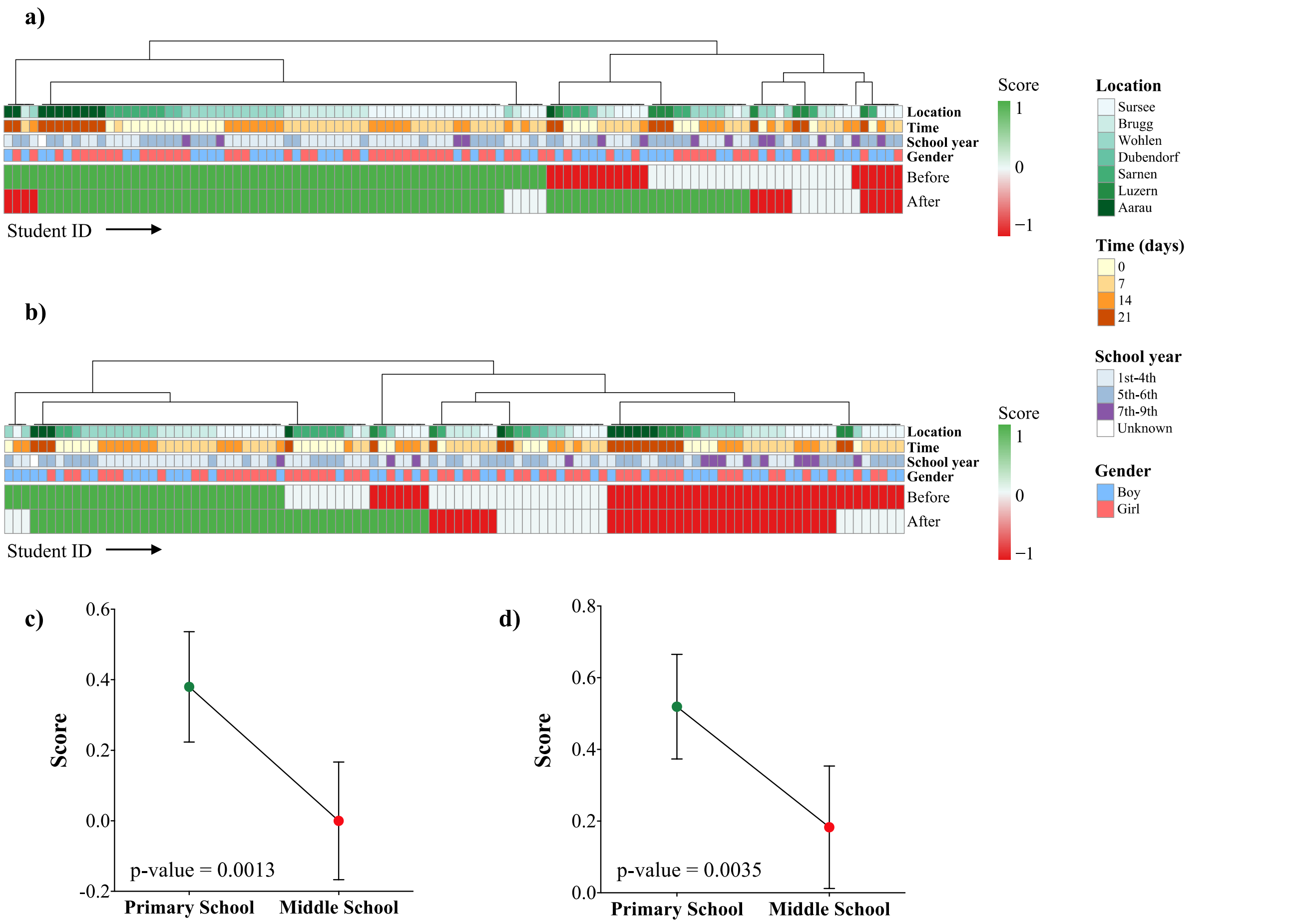

Figure 2. Factors influencing learners' attitude towards "I love science" and "I would like to be scientist". Euclidean clustering of participant position concerning the sentence "I love science" (**a**) and "I would like to be a scientist" (**b**), before and after hands-on science session. Answers were clustered taking into consideration four categorical factors (location, time, school year and gender). Assessment of score differences between Primary and Middle School pupils before (**c**) and after (**d**) intervention by using Mann-Whitney test. Each circle in plots represents mean and bars show 95% confidence interval.

DISCUSSION

In this section we discuss to what extent the use of experimentation in the classroom can be used as a transforming force of the learning process and of the relationship that learners establish with science and with their heritage language. First, it should be noted that although the Luso-descendant community of each Swiss canton has its own social characteristics and establishes different relationships with their heritage language, data obtained in this study point towards positive implications of student-centered practices and learning-by-doing methodologies in all the criteria analyzed here regardless of participants' area of residence. Second, the analysis of learners' behavior in relation to statements such as "I like science" and "I would like to be a scientist" allow us to conclude that our intervention seems to move towards a consolidation of increased interest in science. On the other hand, we also observe an improvement in participants' self-confidence by their changing attitude to statements like "If I want, I can someday become a scientist". However, regardless of our efforts, as learners move from Primary to Middle School, their excitement about science and their ambition to pursue a scientific career are greatly reduced. The idea that learners' attitudes towards science typically decline with age is not new (Murphy and Beggs, 2003; Pell and Jarvis, 2001) and calls for a redesign of the current school ecosystem that should safeguard pupils' curiosity and creativity.

In summary, we conclude that the results are consistent and place the use of science at the forefront of encouraging critical thinking and increasing self-esteem among participants. Hence, we propose the application of alternative methodologies along with the formal education system, that aims at broadening learners' perspectives for the future and increase the understanding and appreciation of their heritage language. Although this research supports the introduction of the scientific method through the use of experimentation, and practices focused on learning-by-doing in multidisciplinary educational contexts (e.g. when science education is combined with PHL learning), there is still a great need for an extended evaluation of different educational interventions in order to proceed with large scale applications.

Final considerations

The recommendations of Delors et al. (1997) in their report to the United Nations for Education, Science and Culture are the driving force for the project presented here. We believe that our teaching strategies are determinant in the empowerment of learners, where science and the scientific process emerge as a foundation in establishing critical spirit, and in transmitting the necessary knowledge and tools for the rebirth of individuals as solvers and creators of their own future. However, in order to apply this teaching methodology integrated with language learning, we propose not only the continuation of the project presented here – where scientists enter the classroom as motivators – but also the development of workshops that aim to empower teachers so that they are able to independently introduce our approach in their classroom. Only in this way, education can take on a multidimensional nature and can provide learners the necessary skills to become active participants in the society and creators of a renewed, more human and healthier world for all (Delors et al., 1997).

AUTHOR CONTRIBUTIONS

M.M. conceived and designed the study; organized and collected the data; wrote the manuscript. B.Y. performed all statistical analysis. M.L.G. supervised the study. All authors read and agreed with the final version of the manuscript.

ACKNOWLEDGEMENT

We thank the PHL teachers that welcomed the project in their classroom: Elisa Aeschimann, Jorge Lopes, Nicole Gomes, Paula Rodrigues and Raquel Rocha. To all the pupils involved in this endeavor, we thank for their enthusiasm and curious spirit. This project was supported by *Coordenação de Ensino de Português na Suíça - Instituto Camões, I.P.*.

REFERENCES

Bauman, Z. (2007). Liquid Times: Living in an Age of Uncertainty. Cambridge: Polity Press.

Cuevas, P., Lee, O., Hart, J., & Deaktor, R. (2005). Improving Science Inquiry with Elementary Students of Diverse Backgrounds. *Journal of Research in Science Teaching*, 42 (3), 337-357.

Delors, J., Al-Mufti, I., Amagi, I., Carneiro, R., Chung, F., Geremek, B., Gorham, W., Kornhauser, A., Manley, M., Quero, M.P., Savané, M., Singh, K., Stavenhagen, R., Suhr, M.W., & Nanzhao, Z. (1997). Educação um tesouro a descobrir [Learning: the treasure within] (UNESCO Publication No. ISBN 85-249-0673-1). Retrieved from UNESCO website http://dhnet.org.br/dados/relatorios/a_pdf/r_unesco_educ_tesouro_descobrir.pdf

Dewey, J. (1916). Democracy and education: An introduction to the philosophy of education. Retrieved from https://iwcenglish1.typepad.com/Documents/dewey_democracy_and_education.pdf

Federal Statistical Office (2018). Retrieved February 22, 2018, from https://www.bfs.admin.ch/bfs/en/home.html

Jones, C. (2017). Bill would help California schools teach about "fake news", media literacy. EdSource. Retrieved from https://edsource.org/2017/bill-would-help-california-schools-teach-about-fake-news-media-literacy/582363

Lazer, D.M.J., Baum, M.A., Benkler, Y.B., Berinsky, A.J., Greenhill, K.M., Menczer, F., Metzger, M.J., Nyhan, B., Pennycook, G., Rothschild, D., Schudson, M., Sloman, S.A., Sunstein, C.R., Thorson, E.A., Watts, D.J., & Zittrain, J.L. (2018). The science of fake news. *Science*, 359 (6380), 1094-109.

Lee, O. (2005). Science Education With English Language Learners: Synthesis and Research Agenda. *Review of Educational Research*, 75 (4), 491-530.

Lee, O., & Fradd, S.H. (1998). Science for All, Including Students From Non-English-Language Backgrounds. *Educational Researcher*, 27 (4), 12-21.

Lee, O., Quinn, H., & Valdés, G. (2013). Science and Language for English Language Learners in Relation to Next Generation Science Standards and with Implications for Common Core State Standards for English Language Arts and Mathematics. *Educational Researcher*, 42 (4), 223-233.

Murphy, C., & Beggs, J. (2003). Children's attitudes towards school science. *School Science Review*, *84* (308), 109–116

Pell, T., & Jarvis, T. (2001). Developing attitude to science scales for use with children of ages from five to eleven years. *International Journal of Science Education*, *23*, 847–862.

Poza, L.E. (2016). The language of ciencia: translanguaging and learning in a bilingual science classroom. *International Journal of Bilingual Education and Bilingualism*, 21, 1-19.

R-Core-Team (2018). R. A language and environment for statistical computing (Version 3.0.3). Retrieved from https://www.r-project.org/

United Nations, Department of Economic and Social Affairs (2015). *Trends in International Migrant Stock: The 2015 revision* (United Nations database, POP/DB/MIG/Stock/Rev.2015). Retrieved from https://www.un.org/en/development/desa/population/migration/data/estimates2/estimates15.asp

A WORD-LEVEL ANALYSIS OF BARKING AT PRINT FOR ENGLISH SECOND LANGUAGE SCIENCE TEXTS

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The ability to read science texts with comprehension is necessary for development of self-regulation in learning. However, particularly among learners in the developing world, barking at print, i.e. decoding with minimal comprehension, is highly prevalent when reading science texts. Eye-tracking is an effective way of studying reading difficulties such as barking at print. However, in a previous study a whole-text analysis of eye-movement metrics was insufficient to distinguish between the reading behaviour of English second language South African learners who read a science text with comprehension from those who barked at this text, suggesting that a word-level analysis may be necessary to diagnose this difference, and to understand the underlying cognitive engagement differences, from eye-tracking data. In this study we conduct such an analysis using a subset of the same eye-movement data as were used in the previous study. These data were collected from 57 grade 8 and 9 learners, 13 of whom were shown to have been barking at print while reading this text, and 19 of whom appeared to be reading with comprehension. Only the eye fixation durations for the scientific terms were included in this study. These scientific terms were classified, by a panel of experts, according to scientific linguistic cognitive demand. Barkers were found to fixate longer on the scientific terms than the other learners did, but inconsistencies in trends found between the groups and word classification levels suggest that the degree of linguistic cognitive demand of scientific terms is not the primary factor determining the degree of difficulty these learners experience during reading.

Keywords: Eye tracking, comprehension, reading

INTRODUCTION

Poor reading comprehension abilities of South African learners from socioeconomically disadvantaged backgrounds (Spaull & Pretorius, 2019) are certain to contribute to the high dependence such learners display on skilful translanguaging activities of their teachers as they learn science (Probyn, 2015). This dependence limits these learners' opportunities to learn science, particularly beyond the classroom experience, reducing the time learners are likely to spend on science learning and hindering the development of self-regulation in learning, a crucial requirement for meaningful learning of science to occur (Schraw, Crippen, & Hartley, 2006). Gaining an understanding of what such learners do as they engage with science texts is crucial for devising intervention strategies likely to be effective internationally wherever poor science reading comprehension hinders science learning, and particularly in contexts of poverty. Eye-tracking equipment is particularly valuable in aiding the development of such understanding since it exposes otherwise covert behaviour, from which deductions about the cognitive activity of the reader can be made (Alemdag & Cagiltay, 2018). Additionally, intelligent tutoring systems, programmed to make and respond appropriately to these deductions, can customise the learning experience for enhanced effectiveness (e.g. D'Mello, Mills, Bixler, & Bosch, 2017). This can only happen, however, if the relationship between eye movement metrics and particular cognitive activities are understood.

PROBLEM STATEMENT

A reader's reading state is an example of a group of cognitive activities which can be inferred from eye movement metrics. Eye movement metrics have been published for reading states of mindless reading, mind wandering, concentrated reading, scanning and skimming (e.g. Rayner, 1998). This body of literature is, however, largely restricted to studying reading non-scientific texts in the reader's home language. Previous work amongst South African township learners reading science texts in English as a second language (Stott & Beelders, 2019) has alerted us to the high prevalence of another type of reading, namely barking at print (Samuels & Farstrup, 2011), for which we were unable to find literature on eye movement metrics. Barking at print involves engaging in word decoding without developing comprehension beyond the surface level of representation (Cain, 2010).

In an initial investigation to address this gap in the literature (Beelders & Stott, 2018), we found that eye movements during barking at print are distinct from those published for what may be seen as the cognitively similar activities of mindless reading (reading nonsense text) and mind-wandering during reading. We found the distinguishing trait to be the greater variability in eye-fixation times per syllable during barking at print. This is consistent with the view that barking at print, unlike mindless reading and mind-wandering, does involve a degree of comprehension at the surface level of representation. For this to occur cognitive processing must be engaged in at sentence, phrase, or at least word level for at least some of the time. Further, in our initial study (Beelders & Stott, 2018), we found no statistically significant difference between the eye metrics of those learners in the sample who were deduced to have been barking at the science text used and those who were deduced to have been engaging in concentrated reading with comprehension. This led to the need to confirm the supposition that metrics at a word level differ for readers who are barking at print compared to those who are reading with comprehension. Also, there is a need to determine the underlying cognitive processing occurring which can account for the difference in comprehension.

Longer fixations (periods of time that the eye is relatively still) are known to indicate heightened concentration or perhaps a difficulty in understanding the text being read (Rayner & Pollatsek, 1989). Consequently, in this study we examine fixation times more closely at the word level, and we have chosen to do this only for the scientific words in the text used. This is done to better understand the cognitive processes present during the barking process and how these processes can be distinguished from those of concentrated reading with comprehension, with a focus on science text. This is done with the purpose of determining how eye-tracking metrics can validly be used to diagnose engagement in barking at print for science texts. Therefore, this research is guided by the following questions, with reference to reading science texts in a second language: (1) How do fixation durations and counts during reading differ at the word level for scientific words, when barking at print compared to when undergoing concentrated reading with comprehension? (2) What does this analysis suggest about factors affecting cognitive difficulties which result in barking at print?

CONCEPTUAL FRAMEWORK

The Theory of Multimedia Learning (Mayer, 2009) is used to understand cognitive processing. According to this theory, sense-making, which includes higher levels of reading comprehension, can only occur to the extent that the individual has cognitive processing capacity left over to devote to it after deduction of other forms of cognitive processing. These other forms of cognitive processing are extraneous processing, irrelevant to the target learning, and essential processing, which involves selecting relevant information. The extent to which cognitive capacity has to be devoted to essential processing is determined by the difficulty of the medium (including text), as perceived by the learner.

Eye fixation times can be used as indicators of cognitive processing (e.g. Park, Korbach, & Brünken, 2015). It is therefore to be expected that fixation times will be affected by word difficulty and it seems reasonable that barkers may undergo different cognitive processing patterns in response to various levels of word difficulty compared to concentrated readers, in which case it may be possible to diagnose barking based on this. The model of linguistic cognitive demand, created by Rees, Kind, and Newton (2019) for use with chemistry terms, and slightly modified to be applicable to physics terms too, provides a framework for analysing scientific terms according to the amount of cognitive load they are likely to offer to a particular population of people. According to this model, there are four dimensions along which each term should be analysed for linguistic cognitive demand: interpretive, sub-microscopic, similarity and multiple contexts. The interpretive dimension refers to the extent to which the reader is likely to be able to interpret the correct meaning from the sound of the word, with a lower score being assigned the more likely this is. The submicroscopic dimension has to do with whether the concept refers to the more cognitively demanding, abstract, invisible, realm of submicroscopic particles (assigned a higher score) or the more concrete, visible, macroscopic realm. We expanded this dimension from Rees et al.'s (2019) version, to include invisible, abstract concepts other than submicroscopic particles, for example electric fields. This is consistent with Stiller et al.'s (2016) finding that the degree that a word is specialized or abstract affects its readability. The dimensions of similarity and multiple contexts refer to the extents to which the readers are likely to be confused by alternative meanings of similar words or of that word in other contexts.

METHOD

Sample and data collection

The convenience sample used in this study consists of 57 grade 8 and 9 learners from South African schools and low socio-economic backgrounds, who participated in a science intervention hosted by one of the authors and who were willing to participate anonymously in this study. These learners read a science text in English, their second language, on an eye-tracking machine which recorded eye movements and from which standard eye tracking reading metrics were extracted. These learners then answered a comprehension test, on the basis of which they were divided into three reading categories: barkers (n=13), intermediate (n=25) and readers (n=19). Those referred to as readers are considered to have been undergoing concentrated reading with comprehension for most of the observation period and the barkers to have been barking at print for most of this time. We are less certain of the extent to which the intermediate group engaged in each of these types of reading.

Word classification

The scientific terms in the text were classified by an expert group of six science educators and academics who were all familiar with both the learners' contexts and the linguistic dimensions in Rees et al.'s (2019) model. Each member rated each term along each of the four dimensions of this model (each dimension on a scale of 1-10). Thereafter, a composite score was obtained for each term by adding the individual dimensional ratings for each term and for each expert. The terms were then grouped on the basis of this score, into three difficulty categories. Figures 1-3 show the mean ratings along each dimension for each term for these three difficulty categories (least demanding, moderate demand and most demanding).

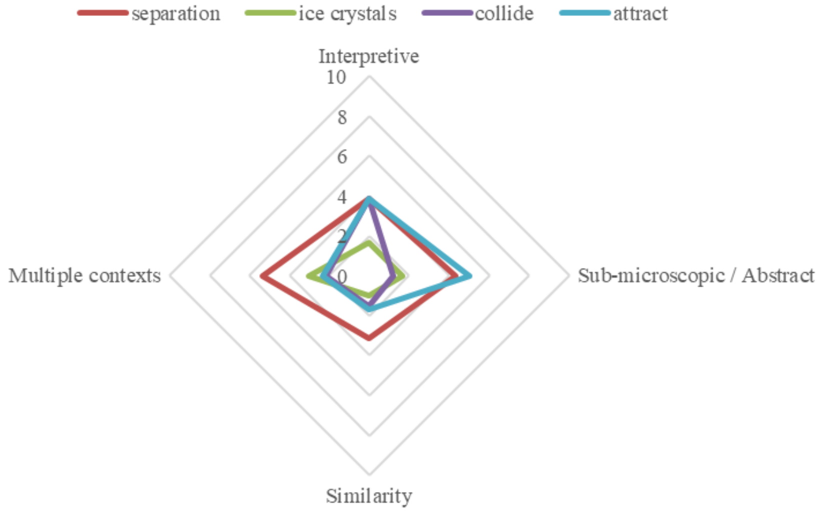

Figure 3: Mean dimensional ratings for the lowest cognitive load terms

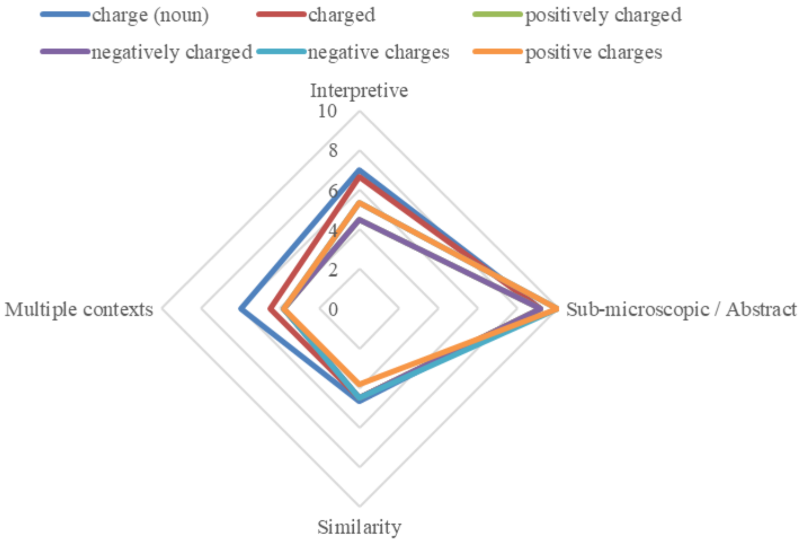

Figure 4: Mean dimensional ratings for the moderate cognitive load terms

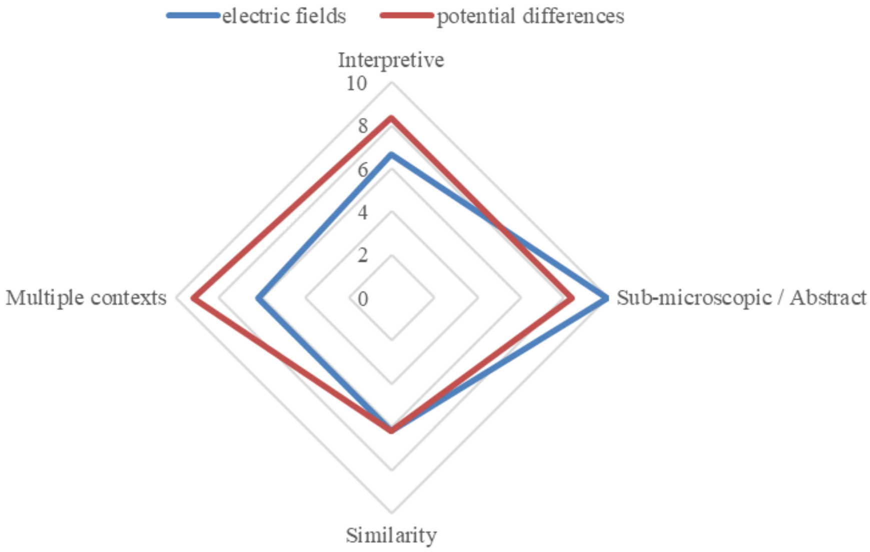

Figure 5: Mean dimensional ratings for the highest cognitive load terms

Data analysis

Qualitative analysis was performed by graphing the averages of the fixation durations and number of fixations for the words of each cognitive demand level for the three comprehension groupings of the learners (barkers, intermediate and readers). First the data for all the words within a cognitive level were grouped together, after which analysis was performed on a per word basis. Since the classification groups are small, statistics were not performed.

FINDINGS

Per cognitive level

Figure 4 shows the mean fixation duration for each comprehension level and for each cognitive demand level. The readers clearly had the shortest fixation durations for all cognitive demand levels and the barkers the highest. Fixation length, therefore, appears to be an indicator of the extent to which these learners experienced difficulty with the words.

All groups except barkers exhibited the longest fixation for the words classified as offering the lowest cognitive demand, suggesting greatest difficulty with these words. An examination of these words (see Figure 1) reveals potential reasons for this anomaly. Learners of this demographic are unlikely to be frequent readers of any type of text. It is therefore to be expected that they should experience difficulty when reading phonetically opaque words such as *crystals*. Although the term *ice crystals* was classified as offering low cognitive demand, and the word *ice* would surely have offered little difficulty to the learners, they may not have realised that they could chunk it with the less familiar word *crystals* to process the term as a unit. Later we examine the data word by word to explore these thoughts further.

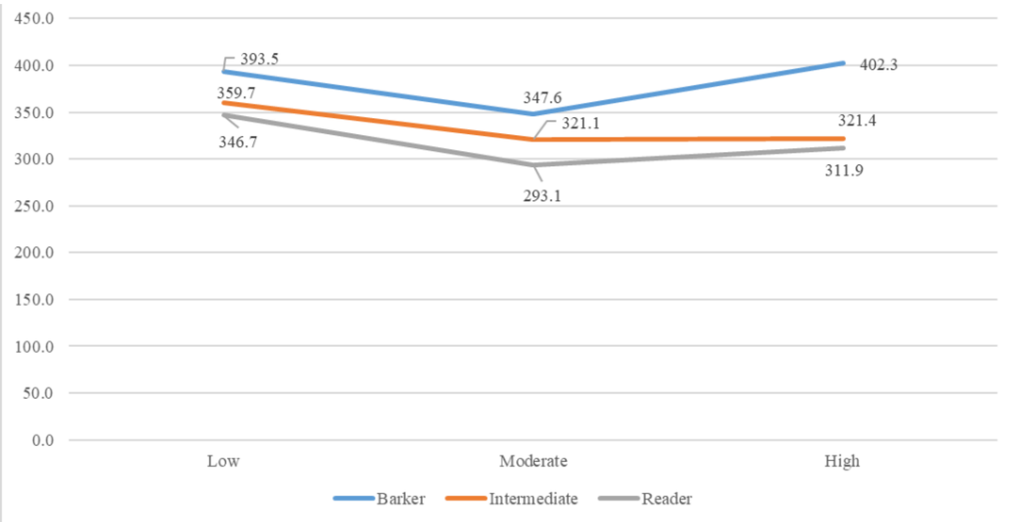

Figure 6: Mean fixation duration per cognitive demand level and per comprehension level

Inspection of the mean number of fixations (Figure 5) per cognitive demand level indicates that the readers and intermediate comprehenders had the most fixations on the moderate mid-level cognitive demand terms while barkers had the most fixations on the high cognitive demand terms. It is unclear what can be deduced from this regarding cognitive processing.

As shown in Table 1, a summary of the findings represented in the two figures above, for barkers the high cognition words caused many long fixations while the low cognition words caused few medium length fixations. Conversely for readers and intermediate comprehenders the high cognition words had few medium length fixations and low cognition words had medium number of long fixations. Moderate cognition words caused many short fixations for these groups. Note that by referring to long and short durations and many and few durations, the reference is relative to their respective mean fixations for the group. The absence of clear trends in this data may suggest that the system used to classify the terms may have little correspondence to the cognitive processing occurring.

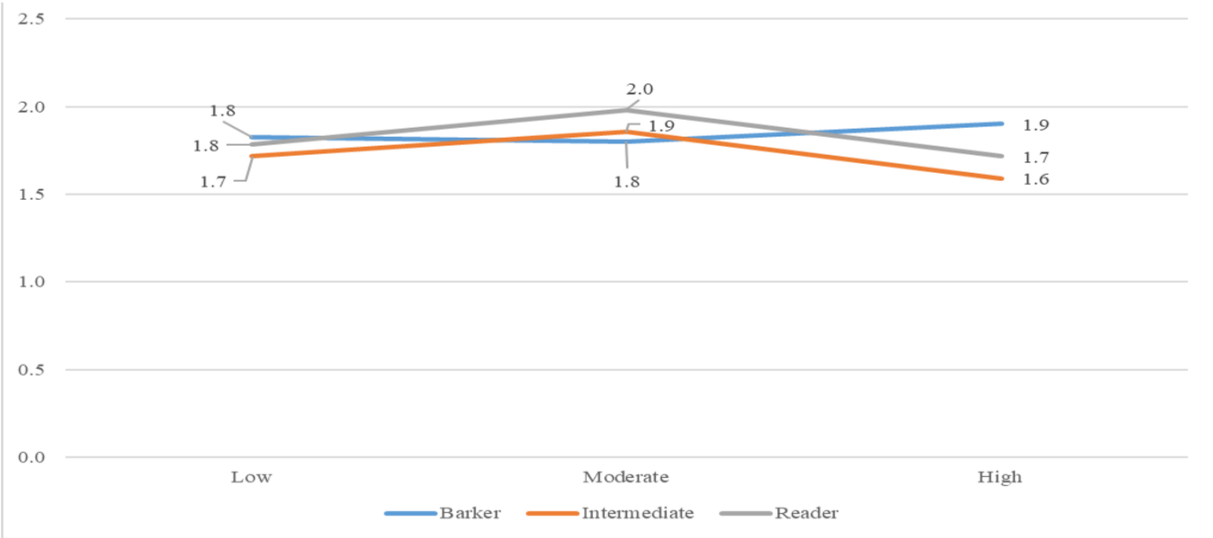

Figure 7: Fixation count per cognitive demand level and per comprehension group

Table 1: Summary of relative fixation counts and durations per cognitive demand level and per comprehension group

	Low cognition	**Moderate cognition**	**High cognition**
Readers	Medium fixations Long duration	Many fixations Short duration	Few fixations Medium duration
Intermediate	Medium fixations Long duration	Many fixations Short duration	Few fixations Medium duration
Barkers	Few fixations Medium duration	Few fixations Short duration	Many fixations Long duration

Per word

Figure 6 shows the mean fixation duration for each comprehension group and for each word for the low cognitive demand terms. The terms are demarcated on the graph using a dashed grey vertical line. On average, when reading fiction in English as a first language, fixations vary between 225 and 250 milliseconds (Rayner and Castelhano, 2007). The red horizontal crosshatch indicates this typical range. It is unsurprising that these learners, who were not only reading in a second language, but also reading scientific text, exhibited longer fixation durations than the published range except for the simple word *ice*. This is consistent with the view that fixation duration can be used as an indicator of the cognitive difficulty these learners experienced with the text.

In some instances the same trend is seen throughout the groups, for example the final occurrence of the term *ice crystals* showed an increase in the mean fixation duration on the word *crystals* for all groups. The variation in the mean fixation duration for repetition of terms is interesting. The higher cognitive load on the first and last occurrence of the term could indicate an increase in processing at the start and conclusion of a segment explaining a concept. The readers fixated longer on the last occurrence of the word *crystals* than they did on any of the other low cognitive demand words. Perhaps this was indeed because the readers were trying to make sense of the context and passage as a whole when they reached the end of the explanation. Although the other two groups showed a similar pattern for this term, their longest mean fixation duration in Figure 6 is found on the word *collide*. These learners are certain to have been unfamiliar with this word. Perhaps it and other unfamiliar words distracted these poorer readers from being able to make sense of the passage as a whole despite their attempts to do so. It should be noted that this discussion suggests that the increased fixation durations for the first and last instances of the word *crystals* indicates at least an attempt at engagement in sense-making cognitive processing, rather than cognitive processing associated with reading difficulty (extraneous) and basic comprehension (essential processing). The difficulty, even possible inability, to distinguish between these discrepant cognitive outcomes from eye-tracking data, makes interpretation of such data difficult.

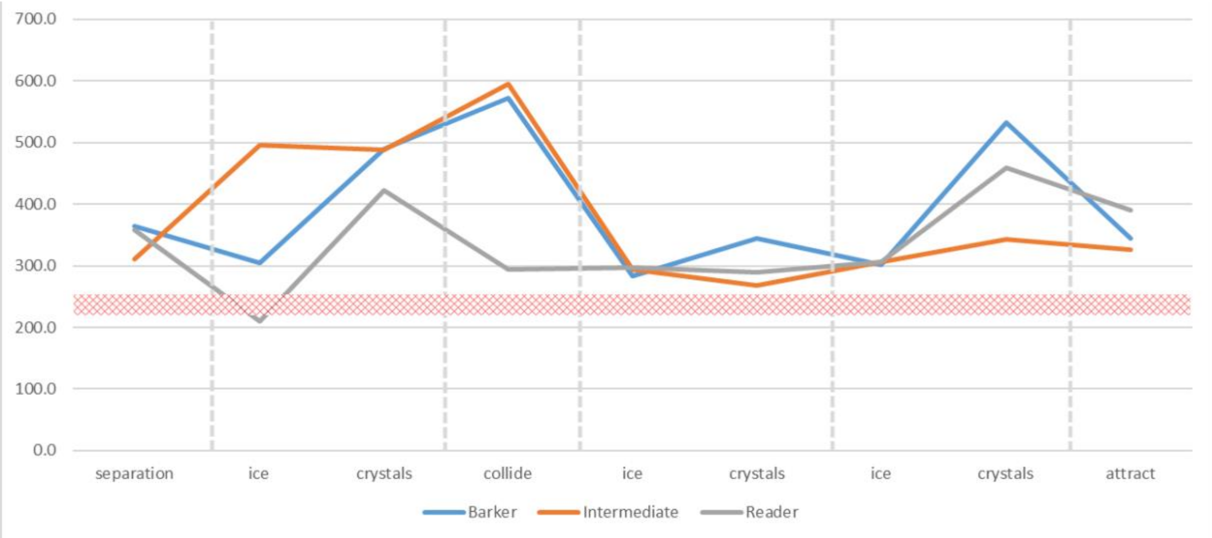

Figure 8: Mean fixation durations for low cognitive load

The fixation count shows that for instance, the barkers had more fixations on the first occurrence of the term *ice crystals* than on the other occurrences (although each occurrence of *crystals* has on average more fixations than the other low cognitive load words). They also, on average, had few fixations on the word *collide* meaning they processed the word in a single fixation and did not regress to the word. The phonetically opaque word *separation* also had a higher number of fixations. The readers had a higher number of fixations on the second occurrence of the word *ice*, as did the intermediate comprehenders. Frequent counts and long durations of fixations, as summarised in Table 1, suggest that the learners experienced difficulty with some words. However, the fixation counts do not shed much light on establishing a trend for the difficulty experienced within the groups and cognition levels.

The moderate cognitive demand terms (Figure 7) show minor fluctuations in the mean fixation durations. Individual words within terms have similar durations for all groups. Readers and barkers had the highest mean fixation duration on the word *positive* while this was the word that had the lowest mean fixation duration for the intermediate comprehenders. The first occurrence of *charged* caused respectively the longest and shortest mean fixation duration for intermediate comprehenders and readers. As with the low cognition words, these all have an average greater than the typical reading range.

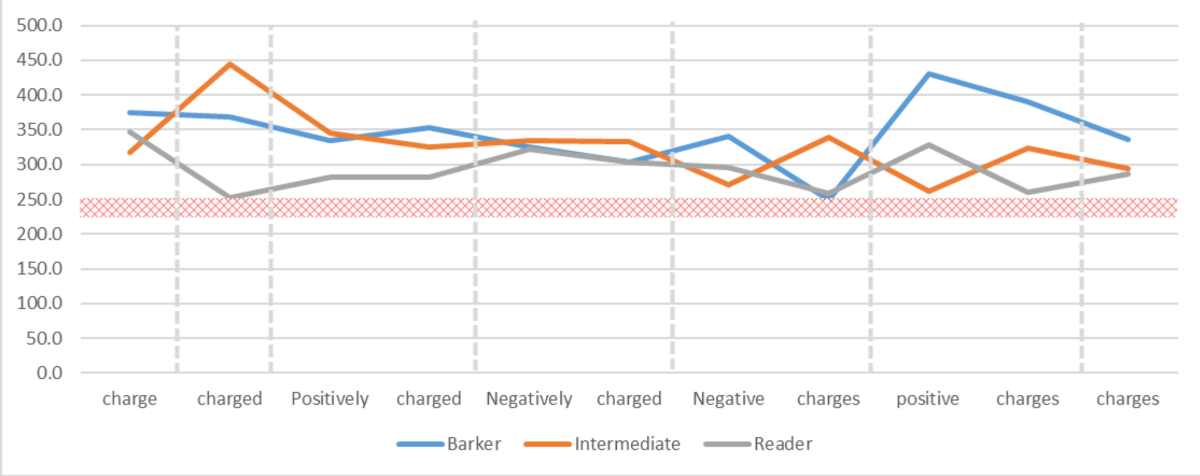

Figure 9: Mean fixation durations for moderate cognitive load

For all groups, the word *negatively* and *charges* had more fixations, on average, than the majority of the other words. All the moderate cognitive demand words had more than one fixation, even though the lengths varied from 5 letter words (*charge*) to 10 letter words (*positively* and *negatively*). Nevertheless, regardless of length they all required multiple fixations, on average.

High cognitive demand terms (Figure 8) show mild variations in the mean averages for individual words. The barkers clearly show longer fixations than the other comprehension groups. The fixation duration for the intermediate comprehenders for the word *electric* is the only word that falls within typical reading durations. Both readers and the intermediate comprehenders exhibited the longest average fixation duration on the word *fields* while for the barkers the word *potential* caused the highest fixation duration. For very poor readers, such as the barkers, the word *potential* can be considered to be a difficult word, given the phonetic opaqueness of its ending, hence it is not unexpected that this word caused some trouble for this group. Conversely, readers had the shortest fixation duration on the word *potential*, while for barkers this was *differences* and for the intermediate comprehenders *electric*. In terms of fixation counts all the words required multiple fixations and all were within the same range for all groups.

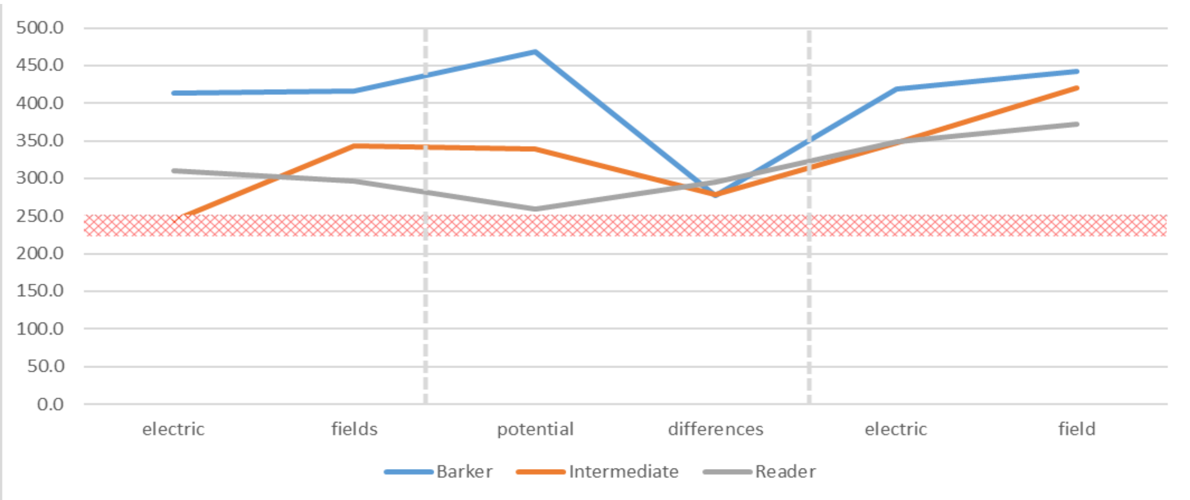

Figure 10: Mean fixation durations for high cognitive load

DISCUSSION

As has been argued above, the findings suggest that the cognitive demand of the scientific terms, according to Reese et al.'s (2019) framework, appears not to be a significant determining factor regarding word difficulty during reading science texts, with word familiarity appearing a stronger determinant. Although Reese et al.'s framework includes word familiarity in its dimensions of interpretation, similarity and multiple contexts, we suggest, below, why it seems to fail to identify cognitive difficulty in the manner used here.

Firstly, our modes of measurement (fixation counts and durations) appear to indicate a different type of cognitive processing (extraneous and essential) to that which Reese et al.'s framework was designed to measure (sense-making). For example, given the finding that the comprehension level of the barkers was so low as to elude our measurement, we deduce that their particularly long fixation durations were not indicative of engagement in sense-making. It is therefore to be expected that a classification of words using Reese et al.'s framework would correspond poorly to the measurement we used. This is because Reese et al.'s framework refers to the extent to which terms offer difficulty during engagement in sense-making while learning their meanings.

Secondly, the very different fixation durations displayed for the individual words within scientific terms, such as for *ice* and *crystals*, suggests that words within terms may have been processed individually, rather than as the unit used in the classification system. For Reese et al.'s framework to indicate the cognitive demand for learning particular concepts, it must be applied to terms according to their scientifically intended meaning, rather than to individual words according to their probably inferred meaning. This discrepancy undermines the value of this framework for interpreting the cognition occurring during reading, particularly in a context where the perceived and intended meanings are very likely to differ and their differences to have opposite cognitive implications. For example, both words in the term *positive charge* have multiple meanings other than those intended in this term, contributing to the term being classed as offering a medium amount of linguistic cognitive load. However, a learner's familiarity with each of these words in everyday usage could decrease the difficulty they experience in reading these words, without the learner comprehending the scientific meaning intended.

Consistent with the view that the word classification system used was inappropriate for the manner in which we used it, we could not discern any trend in the fixation count data we have displayed. Further, in the findings section we have discussed trends we find anomalous. For example, we found similar fluctuations in eye fixations for the three comprehension groups across the successive appearances of the term *ice crystals*. We have provided an explanation for these fluctuations which suggest that all were at least attempting to undergo sense-making, associated with longer fixations. This is inconsistent with the view we generally took in this analysis, i.e. that longer fixations indicate cognitive difficulties which hinder sense-making.

We believe that this discussion displays some of the complexity of reading difficulties and of eye-tracking data. This makes productive use of such data a complex task. This highlights the need for research, such as that reported here, which aims to aid development of diagnoses for barking at print using eye-tracking. Additionally, improving the understanding of cognitive difficulties experienced when reading science texts can help inform intervention programme development and guidelines for writing for greater accessibility.

CONCLUSION

In answer to the research questions, we make the following assertions regarding reading science texts in a second language: (1) Barking at print is associated with longer fixations on scientific words. While fixation counts show variation across the cognitive levels, no discernible trend or conclusion can be drawn from their fluctuations. (2) It appears that factors other than a scientific term's linguistic cognitive demand, as operationalized by Rees et al. (2019), determine the cognitive difficulty experienced by those who bark at print. We suggest that a learner's degree of familiarity with individual words, rather than terms as units, may be a significant contributing factor to the difficulty experienced while reading.

REFERENCES

Alemdag, E., & Cagiltay, K. (2018). A systematic review of eye tracking research on multimedia learning. *Computers & Education, 125*, 413-428.

Beelders, T., & Stott, A. E. (2018). Eye Movements during Barking at Print. In F. Lopez-Orozco (Ed.), *Eye Tracking and New Trends*. London: IntechOpen.

Cain, K. (2010). *Reading development and difficulties* (Vol. 8). Chichester, UK: John Wiley & Sons.

D'Mello, S. K., Mills, C., Bixler, R., & Bosch, N. (2017, 25 - 27 June). *Zone out no more: Mitigating mind wandering during computerized reading.* Paper presented at the International Conference on Educational Data Mining, Wuhan, China.

Mayer, R. E. (2009). *Multimedia learning* (2nd ed.). Santa Barbara, CA: Oxford University Press.

Park, B., Korbach, A., & Brünken, R. (2015). Do learner characteristics moderate the seductive-details-effect? A cognitive-load-study using eye-tracking. *Journal of Educational Technology & Society, 18*(4), 24-36.

Probyn, M. J. (2015). Pedagogical translanguaging: Bridging discourses in South African science classrooms. *Language and education, 29*(3), 218-234.

Rayner, K. (1998). Eye movements in reading and information processing: 20 years of research. *Psychological bulletin, 124*(3), 372.

Rayner, K., & Pollatsek, A. (1989). *The Psychology of Reading*. Englewood Cliffs, NJ: Prentice-Hall.

Rees, S., Kind, V., & Newton, D. (2019). Meeting the challenge of chemical language barriers in university level chemistry education. *Israel Journal of Chemistry, 59*(6-7), 470-477.

Samuels, S. J., & Farstrup, A. E. (2011). *What research has to say about reading instruction*. Newark, DE: International Reading Assoc.

Schraw, G., Crippen, K. J., & Hartley, K. (2006). Promoting self-regulation in science education: Metacognitition as part of a broader perspective on learning. *Research in Science Education*(36), 111-139.

Spaull, N., & Pretorius, E. (2019). Still falling at the first hurdle: Examining early grade Reading in South Africa. In N. Spaull & J. Jansen (Eds.), *South African Schooling: The Enigma of Inequality* (pp. 147-168). Switzerland AG: Springer.

Stiller, J., Hartmann, S., Mathesius, S., Straube, P., Tiemann, R., Nordmeier, V., . . . Upmeier zu Belzen, A. (2016). Assessing scientific reasoning: a comprehensive evaluation of item features that affect item difficulty. *Assessment & Evaluation in Higher Education, 41*(5), 721-732.

Stott, A. E., & Beelders, T. (2019). The influence of science reading comprehension on South African township learners' learning of science. *South African Journal of Science, 115*(1-2), 72-80. doi: https://doi.org/10.17159/sajs.2019/5146

IS MECHANICS OR WAVE MORE CHALLENGING FOR STUDENTS? SELF-CONCEPTS AND STYLES OF SCIENTIFIC REASONING

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Academic self-concept has long been regarded as an important indicator of students' academic achievement. Different subject's academic self-concepts are independent of each other and they have their own constructs (Bong & Skaalvik, 2003). We suggest that different topics of a subject, such as wave and mechanics in physics, have different styles of reasoning (Kind & Osborne, 2017), and hence students would have different academic self-concepts of these topics. We tested this hypothesis with questionnaires that measured students' academic self-concepts of these topics respectively. 107 Year 11 students (around 17 years old), who have learnt these two topics, from two schools in Hong Kong completed the questionnaires. We found a very week correlation between these two self-concepts (r=0.102). Written responses from 77 of these students revealed some ways that they approached these two topics, which were consistent with the heavy use of mathematical deduction and hypothetical modeling as reasoning styles in mechanics and waves respectively. Both quantitative and qualitative data point to the idea that there were topic-specific self-concepts in physics and that they were related to the use of different styles of scientific reasoning.

Keywords: Physics, Reasoning, Self-efficacy

INTRODUCTION

Scholars have been spending a lot of work investigating self-concept (Byrne, 1984). Students having a different level of self-perception shows different levels of cognitive, social, and emotional engagement in school (Bong & Skaalvik, 2003). Among all elements in self-concept's theory, academic self-concept is the most influential item in the education aspect. Since academic self-concept is defined as how students see their academic ability, the construct has a high correlation with academic performance (Bloom, 1976; Handsford & Hattie, 1982).

Marsh & Shavelson (1988) suggested a hierarchical model based on empirical data, showing the top of the hierarchy is general self-concept and it composes of different subject-particular self-concepts. All subjects' self-concepts are the components of the general self-concept and suggested to be somehow connected to the two major self-concepts, namely mathematical self-concept, and verbal self-concept. For physics, it was agreed to have a stronger linkage with mathematics while a weaker one with verbal self-concept (Marsh & Shavelson, 1988).

Kind & Osborne (2017)'s work in the style of scientific reasoning may give an insight to the educator in revisiting the relationship of physics self-concept with other self-concepts. Science was found to use different styles of reasoning and different types of knowledge use a different style in reasoning. While most of the content in mechanics relies on the mathematical deduction in reasoning, analogical and hypothetical models are commonly used in learning waves (Kind and Osborne, 2017). This difference in the required style of scientific reasoning may post a potential explanation of the difference in subjects' academic self-concepts.

Based on the discussion above, this research focuses on identifying if students could have different self-concepts on different topics. The findings should enrich the idea of self-concepts in the literature (e.g., Marsh & Shavelson, 1988). Furthermore, how students construct their subject's self-concept is going to be investigated to see if students collect different information in constructing their subjects' self-concepts. To frame the research, the following part presents the theoretical framework of the work.

LITERATURE REVIEW

Academic self-concepts

Academic self-concept has been an important indicator of academic achievement. It is defined as how students see their academic ability (e.g., Hansford and Hattie, 1982). It plays an important role in students' intrinsic motivation, positive emotion, and academic performance (Wolters & Pintrich, 1998; Bong & Skaalvik, 2003).

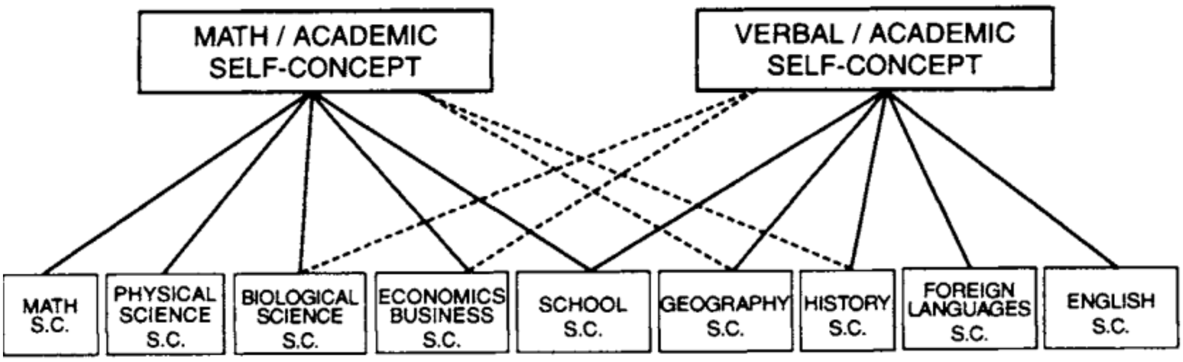

Figure 1: the hierarchical structure of academic self-concept (Marsh & Shavelson, 1988, p.378)

Marsh & Shavelson (1988) suggested a hierarchical model based on empirical data. There was a broad academic self-concept at the top of the hierarchy, which in turn was composed of two general self-concepts (i.e., Math and verbal self-concepts in Figure 1). Different subjects' self-concepts correlate with the two general ones to different degrees, which depend on the nature of the subject. Thus, different subject's self-concepts have their own formula of construction (Bong & Skaalvik, 2003).

The model suggested a relationship between general self-concepts and the subject's self-concept. Nevertheless, different disciplines of science worked rather differently in solving their disciplinary problems. It has been suggested that there are six distinct styles of scientific reasoning, namely (i) mathematical deduction, (ii) experimental evaluation, (iii) hypothetical modeling, (iv) categorization and classification, (v) probabilistic reasoning and (vi) historical-based evolutionary reasoning (Kind & Osborne, 2017). Therefore, there may be factors other than mathematics self-concept and verbal self-concept that correlate with physical science self-concept.

Style of scientific reasoning

How scientists argue and develop their reasoning can always be found in the history of science. Crombie (1994) examine different scientific thought in history and he revealed that scientific reasoning does not only have one style only. In fact, there were six distinct styles of scientific reasoning found, namely (1) Mathematical deduction, (2) Experimental evaluation, (3) Hypothetical modeling, (4) Categorization and Classification, (5)Probabilistic reasoning and (6) Historical-based evolutionary reasoning. These different styles of reasoning exist because they can successfully answer the questions and they become the standard of argument and reasoning now (Hacking, 2012).

Physics consists of several major topics, for example, mechanics, wave, electromagnetism, and atomic physics. Each topic, such as mechanics and wave, uses a different style of scientific reasoning. Most of the content in mechanics adopts Newtonian mechanics and it mainly relies on the mathematical deduction in reasoning (Kind & Osborne, 2017). Most of the ideas discussed in Newtonian mechanics, such as projectile motion and circular motion, are expressed a mathematical form. Such a form informs deductive predictions (Kind and Osborne, 2017). This exemplification by the Greek mathematical science is categorized as mathematics deduction in scientific reasoning. As mechanics mainly involves mathematical deduction as the style of scientific reasoning, there is no surprise that there was a close relationship between students' math self-concept and physical science self-concept (Bong & Skaalvik, 2003).

Science sometimes relies on hypothetical models to represent physical phenomena. These models help make predictions and '[simulating] the possible behavior of the world' (Kind & Osborne, 2017, p.12). By using hypothetical models, scientists are more able to share abstract concepts and do discussions and predictions. This reliance on the use of the hypothetical model is identified as one of the main styles of scientific reasoning. In learning wave, analogical and hypothetical models are commonly used. Since wave is a continuous process and is invisible, visual models are often used to explain related phenomena such as superposition, interference and the formation of a stationary wave. Through visualizing individual waves at different times, scientists can better understand the interaction of waves. Modeling is a key to make sense of phenomena related to waves.

RESEARCH QUESTIONS AND METHODOLOGY

Based on the discussion above, and the classroom observation that some students reported mechanics was more challenging for them while some reported wave, this study aimed at identifying if students could have different self-concepts in different topics. The findings should enrich the idea of self-concepts in the literature (e.g., Marsh & Shavelson, 1988). Our research questions were:

1. Were students' self-concepts of the physics topics 'wave' and 'mechanics' domain-specific?
2. How may students construct their academic self-concept of mechanics and wave respectively?

To answer the first question, we used two questionnaires (based on Bong & Skaalvik, 2003) to measure students' mechanics and wave self-concepts respectively. Correlation analysis was done between these two constructs. 107 physics students from two mixed-gender schools who had finished learning mechanics and waves were invited to complete the questionnaires. To answer the second question, 77 students from 3 classes in a school were invited to answer two follow-up open-ended questions (Comparing mechanics and wave, which topic do you think is easier? Why do you think that?). Through using open-ended questions, the researcher is then more able to probe into their mind and understand the underneath reason for having high/low academic self-concept towards a particular topic in physics (Turner III, 2010). Answers to the open-ended questions were coded by the first author. The coding was based on the styles of scientific reasoning (Kind & Osborne, 2017) and was double confirmed by another researcher in order to maintain its fairness and objectivity.

To minimize distractions when answering, the data collection was held in a closed classroom. This avoidance of distraction can improve students' willingness to disclose and hence research can obtain a more accurate and in-depth data from students (Turner III, 2010).

RESULT & DISCUSSION

All 107 students agreed to participate and completed the questionnaires. The Cronbach alpha reliability coefficient for mechanics self-concept and wave self-concept, using individual students as the unit of analysis, were 0.882 and 0.916 respectively. The correlation between these two constructs was weak and insignificant (r=0.102, p=0.297), meaning that the two constructs have little correlation with each other and they had little or no relationship with each other.

In relation to the second research question, it was found that students tended to have different reasons for choosing wave and mechanics as an easier topic for them. For mechanics, students tended to formulate their academic self-concept based on their perceived competence in mathematics:

Ben: (choosing mechanics as easier)	*…Mechanics mainly uses mathematics to analyze daily life phenomenon. I can use mathematics and calculation to understand the relationships…*
Billy: (choosing mechanics as easier)	*I am studying mathematics (module 2), some of the content such as trigonometry and vectors can improve my understanding of physics.*

It is not surprising for students to construct their mechanic's self-concept based on their perceived competence in mathematics. Mechanics' self-concept may closely link with mathematics self-concept because mechanics has a high reliance on the mathematical deduction in reasoning. This echoes with the finding that the physical science self-concept has a strong correlation with the mathematics one (Bong & Skaalvik, 2003). In mechanics, most of the physical phenomenon is expressed and exemplified by the Greek mathematical sciences and learners usually use mathematical deduction as a main way of argument. This idea is categorized as a mathematical deduction in Kind & Osborne's (2018) work about the style of scientific reasoning. From that, it seems that when students construct their mechanics' self-concept, they collect information about their mathematics ability, which is reported as a distinct nature of the topic. This information not only help construct the mechanics' self-concept in a positive way, but it can also be in a negative way:

Beatrice: (choosing wave as easier)	*Calculation (in questions concerning waves) is easier, I always get wrong in doing calculations about mechanics.*
Benjamin: (choosing wave as easier)	*It is because I don't have to deal with complicated mathematics.*

Even though Beatrice and Benjamin chose wave as an easier topic, they rated their mechanics' self-concept as low through the lens of mathematics. This echos with the finding that the physical science self-concept has a strong correlation with the mathematics one (Bong & Skaalvik, 2003). Students choosing wave as easier, on the other hand, tended to construct their wave self-concept through reviewing their ability in using internal visualization and visual representation:

Betty: (choosing wave as easier)	*...because the wave's waveform is easier to be visualized. On the other hand, vectors in mechanics are hard to imagine.*
Bobby: (choosing wave as easier)	*...because concepts in force and motion are relatively abstract and hard to be understood. However, concepts in wave motion are easier to imagine. Just draw a diagram and you can understand, which is not the case in force and motion.*

The responses showed a biased collection of information on the ability in coping with visual representations. Here, the word visual representation can be interpreted as model manipulation. Models usually use visual representations to show the interactions between entities. Students usually need visual representations to know how a hypothetical model is simulating the science behind in a phenomenon and they generate pictures to manipulate the model in mind. Here, representation is defined as what Hegarty (2004) suggested: 'any display that represents information in a visual-spatial medium' (p.1). Based on this definition, dynamic visualizations are also considered as representation. This idea is coherent to Kind and Osborne (2017) which students tried to understand the world through hypothetical models. Unlike mathematical deduction, hypothetical modeling is another style of reasoning which requires the construction of analogical and hypothetical models to represent the world. In this way of reasoning, models, and representation are taking a central role to reason on the relationships between different entities. Based on what Kind and Osborne (2017) suggested, scientists usually use representations to manipulate models so as to depict some abstract phenomena, and this is the nature of the topic wave and optics. From that, it seems that students also construct their wave self-concept through the lens of hypothetical modeling: they collect information about their perception of whether they can manipulate models and representation. Students who perceive better at producing internal visualization and manipulating models may have a better wave self-concept.

IMPLICATION AND CONCLUSION

In this research, we found a very weak correlation between students' mechanics' self-concept and wave self-concept. That is, students did have different self-concepts in these two topics. We ascribed the differences to the use of different reasoning styles in mechanics and wave (i.e., mathematical deduction and hypothetical modeling respectively). The conjecture was supported by students' written responses about some ways that they approached these two topics.

Based on our findings, we suggest that there may be topic-specific self-concepts among other physics topics. Academic self-concept may not be just a general perception of a subject. It may be determined by several academic self-concepts that are of smaller grain size. This research opens a further discussion on how we should see academic self-concept. Obviously, future work is needed to investigate whether mechanics self-concept and wave self-concept are the components of mechanics self-concept. By extension, there may be topic-specific self-concepts in physics and other subjects.

Apart from the topic-specificity of academic self-concept, this paper also explores the diversity of construction basis of different academic self-concepts. In previous work, physical science academic self-concept is only considered as being root in mathematics. However, the responses from students suggest that students may collect different information from a different aspect. The construction formula of different topics' self-concept may depend on the nature of knowledge: mechanics relies more on mathematical deduction while wave relies more on hypothetical modeling as the main style of reasoning (Kind & Osborne, 2017). The interaction between different constructs in Marsh & Shavelson's (1988) hierarchy can be more complicated than suggested before.

We acknowledge that mechanics also demands hypothetical modeling (and other reasoning styles), and wave demands mathematical deduction etc. Further studies should be conducted to delineate the role of different reasoning styles in different topics/subjects, and how they may explain topic-specific self-concepts.

ACKNOWLEDGMENT

I would like to take this opportunity to express my greatest gratitude to my advisor, Dr. Cheng, Maurice Man Wai. This work would not have been possible without the advice and assistance provided by him. Furthermore, I would like to thank my school principal, Mr. Yau Chi-Leung, for all the assistance and support during data collection. Finally, I sincerely thank my fiancé, Josephina, who listened and share my ups and downs in my journey of life. Without the support from them, this work could not be done smoothly.

REFERENCES

Bong, M., & Skaalvik, E. M. (2003). Academic self-concept and self-efficacy: How different are they really?. Educational psychology review, 15(1), 1-40.

Byrne, B. M. (1984). The general/academic self-concept nomological network: A review of construct validation research. Rev. Educ. Res. 54: 427–456.

Bloom, B. S. (1976). Human characteristics and school learning. McGraw-Hill.

Crombie, A. C. (1994). Styles of scientific thinking in the European tradition: The history of argument and explanation especially in the mathematical and biomedical sciences and arts (Vol. 1). London, England: Duckworth.

Hacking, I. (2012). 'Language, truth and reason'30 years later. Studies in History and Philosophy of Science Part A, 43(4), 599-609.

Hansford, B. C., & Hattie, J. A. (1982). The relationship between self and achievement/performance measures. *Review of Educational Research*, 52(1), 123-142.

Hegarty, M. (2004). Diagrams in the mind and in the world: Relations between internal and external visualizations. In *International Conference on Theory and Application of Diagrams* (pp. 1-13). Springer Berlin Heidelberg.

Kind, P., & Osborne, J. (2017). Styles of scientific reasoning: a cultural rationale for science education?. *Science Education*, 101(1), 8-31.

Marsh, H. W., Byrne, B. M., & Shavelson, R. J. (1988). A multifaceted academic self-concept: Its hierarchical structure and its relation to academic achievement. *Journal of educational psychology*, 80(3), 366.

Turner III, D. W. (2010). Qualitative interview design: A practical guide for novice investigators. The qualitative report, 15(3), 754.

Wolters, C. A., & Pintrich, P. R. (1998). Contextual differences in student motivation and self-regulated learning in mathematics, English, and social studies classrooms. *Instructional science*, *26*(1-2), 27-47.

INDUSTRY-SCHOOL PROJECTS AS AN AIM TO FOSTER SECONDARY SCHOOL STUDENTS' INTEREST IN SCIENCE-BASED TECHNOLOGY CAREERS

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Industry-school partnerships offer authentic learning opportunities and can support the development of students' interest in a STEM career. The expectancy-value model of achievement-related choice helps to explain how several factors influence career choice. Interest-enjoyment values and attainment values are most important in students' motivation to participate in out-of-school technology and design activities. Our research question is the following: Is there a development in secondary school students' career interests in science-based technology-related professions over time? We employed a longitudinal, mixed-methods research design. The sample consists of 213 secondary school students from 9 classes and 72 students from 4 classes in 4 neighbouring schools who served as a control group. All of the students filled out a questionnaire before and after the visit. The questionnaire items were based on scales relating to an expectancy-value model. Four groups of students were interviewed with respect to the industry visit experiences. Analyses indicated that attitudes for applying technology became relevant for predicting career interest in a technology profession in the project group. However, career interest did not increase over time. In the qualitative analysis, four topics emerged that elucidated why career interest did not increase. Overall, the results demonstrate that factory visits combined with embedded tasks are one way to overcome fixed self-concepts and allow the students to reconsider a career in the technology and engineering industry towards the end of secondary school.

Keywords: science-based technology, expectancy-value model, career interest

INDUSTRY-SCHOOL PARTNERSHIPS

Industry-school partnerships offer authentic learning opportunities (Watters, Pillay, & Flynn, 2016) and can support the development of interest in a STEM career (Sasson, 2018). This is important because multiple research studies register a growing decline of student interest in STEM subjects (Becker, 2010; NGSS Lead States, 2013; Organisation for Economic Co-operation and Development (OECD), 2006b; Xie & Achen, 2009). Effects of out-of-school learning opportunities, such as visits to industry workspaces, museums or science centres, are also found to foster development in science learning, the development of self-efficacy, and even the sense of belonging to a local area (Sasson, 2018). Generally, out-of-school activities have a strong influence on student interest in science over time (Simpkins, Davis-Kean, & Eccles, 2006). For many such events, participants reported that they enjoyed and learned most from hands-on activities (Laine, Veermans, Lahti, & Veermans, 2017; Levine, Serio, Radaram, Chaudhuri, & Talbert, 2015). Examining student attitudes helps to explain the impact that out-of-school activities can generate. The results show that interest-enjoyment values and attainment values are most important to students' motivation to participate in out-of-school technology and design activities (Masson, Klop, & Osseweijer, 2016).

The objective of our industry-school partnership project was twofold. First, the students should experience science-based technology in a local factory. The more specific and long-term target was to induce positive attitudes among students towards a career in the technology and engineering industry. In many countries, technology is not yet a prominent feature of science education. The US National Science Education standards, for instance, integrated technology and engineering in 1996, but despite these early efforts, engineering and technology have not received the same level of attention in science curricula, assessments, or the education of new science teachers in comparison to traditional science disciplines (NGSS Lead States, 2013). Out-of-school experiences can be a promising way to overcome possible shortcomings of the curriculum.

The general public as well as teachers consider technology to be an applied science (Jones, Buntting, & de Vries, 2013). However, this view is somewhat incomplete (Jones, 2012). In school, teachers and students should develop an understanding of technology and science as two areas that can interact but are also distinct in nature. This means that technology is often an applied science. Sometimes, however, there is no interaction when products are created without a proper understanding of the scientific background (De Vries, 2001). For instance, secondary school students could learn to assemble and use a 3-D printer in class without having knowledge of the molecular structure of a thermoplastic. Another ambiguity is that technology education is often confounded with the use of computers in schools. Therefore, in this study we apply the term science-based technology as it is defined in the Programme for International Student Assessment (PISA) (Fensham, 1988; Organisation for Economic Co-operation and Development (OECD), 2006a). In Swiss lower-secondary schools (grades 7-9) the subject of technology has not been a significant part of the curriculum up to now. The new Swiss 'Curriculum 21' describes technology as part of science with respect to being able to talk about the relevance and the sustainability of technological inventions such as genetic engineering, electric engines, or communication technologies. Students should also possess the capability to use and understand everyday tools (hair dryer, loud speaker, LED, etc.), as well as to test and optimize technical devices. The practical implementation of the new Swiss curriculum is still ongoing. Hence, it is reasonable to assume that Swiss science teachers do not put much emphasis on teaching technology in the secondary classroom yet as this was not a topic in earlier curricula. Studies of science teachers' knowledge regarding teaching technology in German-speaking countries do not exist, but research projects, such as that by Goreth, Geißel, and Rehm (2015), aim to close this gap. Research has shown that the early years of secondary education are crucial in terms of the impact a teacher can have on students' views of science and careers involving science (Regan & DeWitt, 2015). Therefore, it is important that Swiss secondary school teachers receive professional training on how to conduct motivating technology lessons in the science classroom.

Our research is embedded within a Swiss-Austrian development project in secondary schools that lasted for two years. According to Archer et al. (2010) students' identities, which are largely formed around the age of 13, are responsible for their career choices in secondary school. Therefore, it is sensible to create projects for that age group, which help students to determine what career possibilities the science-based technology field has to offer. The expectancy-value model of achievement-related choice demonstrates how several factors influence career choice. The model also explains how constructs and processes such as self-schema, short- and long-term goals, and identity formation change over time in part in response to the accumulation of new experiences and the acquisition of new information (Eccles, 2011). Based on this model, we investigated the development in the students' career interests in technology-related professions over the duration of the project. We examined the following questions:

1. Are there differences in the development of career interest between the intervention and control groups?
2. Which factors explain the development of career interest in the science-based technology field?
3. Are there differences in the relationship of the predicting factors between the intervention and control groups?

Method

Our longitudinal research design was embedded within a bi-national STEM implementation project. The fully mixed concurrent equal status design (Schoonenboom & Johnson, 2017) combines QUAN + QUAL student data. The project started in 2016 and ended in 2018. The principal aim was to network industry and school and to motivate secondary school students regarding science-based technology topics and career aspirations. As part of the project, secondary school students visited a local company with a STEM background and worked on STEM tasks related to the company's products. Each local industry-school part of the project was designed by teachers and industry partners according to their requirements.

The sample for this study consists of 213 Swiss secondary school students (grades 7-9) from 9 classes who took part in the 3 industry-school projects and 72 from 4 classes in 4 neighbouring schools as a control group. The age range lies between 12 and 17 years. In addition, we conducted group interviews in four schools from the project group, N = 16 students (4 x 2 female, 2 male).

The student questionnaire consists of 85 items on students' attitudes towards mathematics and science-based technology, and of some variables related to the students' background, e.g., gender, father or mother's job, and importance of technology at home. Our items refer to the expectancy value model of achievement by Eccles and Wigfield (2002).

The interview followed a structured guideline. After questions relating to technology and science at school, the students had to report about the factory visit, including what they had liked and disliked. Then, they were asked about their perceptions of technology and whether their interest in technology had increased. Finally, a section on each student's career choice followed, which explored their intentions at the moment and explanations for their choice, including whether they would consider an apprenticeship with the company that they visited.

RESULTS AND DISCUSSION

A CFA was used to check whether the scales would load on the expected two factors expectancy and values. However, it showed that the scales had to be arranged differently. One factor comprises expectancy, costs and attainment values, while the other factor includes interest values e.g. enjoyment of the activity (Fig 1). Measurement invariance over time was tested and scalar invariance was reached. For the first factor (expectancy) F-Tests showed no difference over time and group. The second factor (applying) showed a significant small decline over time for the intervention group (Eta2 = .02) compared to the control group. Career choice declined a little too in the intervention group and also with a similar small effect compared to the control group.

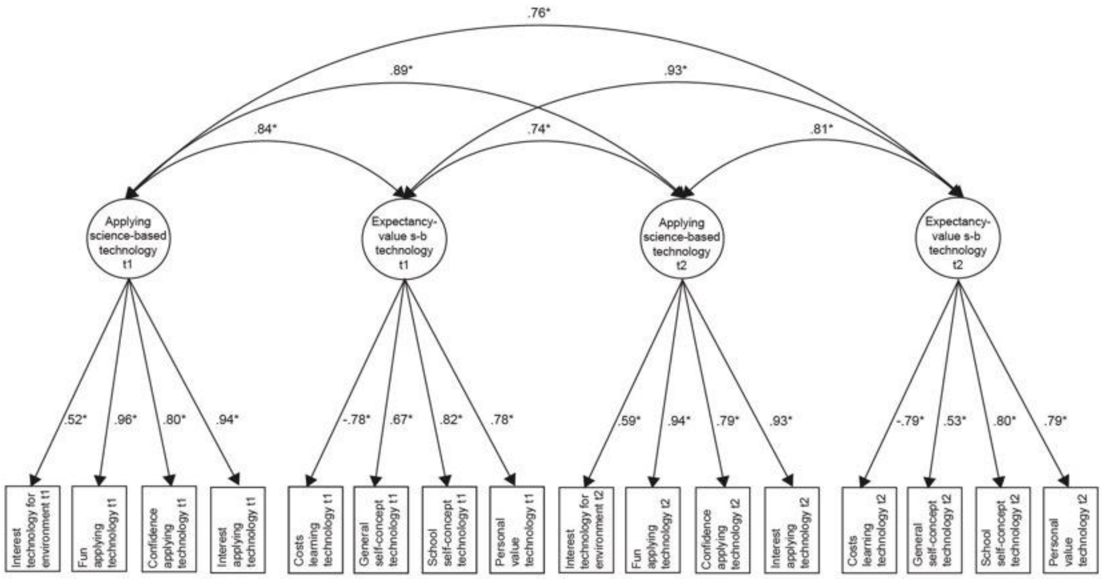

Figure 1: Longitudinal CFA-Model for expectancy-value and applying science-based technology attitudes

Our first question relates to the effect of our project on the students' career interests. To answer this question, expectancy-value and application of technology attitudes were compared over time in two groups with no effect for expectancy-value and with very little effect for application attitudes (Smit, Robin, De Toffol, & Atanasova, 2019). Unexpectedly, we found also no effects of the industry-school project on the development of the students' career interests. Second, we investigated which of the variables explained career interest. From the context variables, gender was the strongest predictor, having a negative effect on career choice. The other context variables showed only indirect effects mediated by expectancy or applying technology. Overall, career choice proved to be of medium stability over time. The two main factors in our research model to explain career choice need to be explained for each group separately. With respect to the third question, interesting differences resulted between the two groups regarding the prediction of career choice over time (Fig. 2). In the control group career choice is predicted solely by expectancy while in the intervention group expectancy and applying technology explain career interest over time. This result might indicate that the industry-school project leads to a change of students' perception of science-based technology professions. Applying science has become a more salient feature of such jobs.

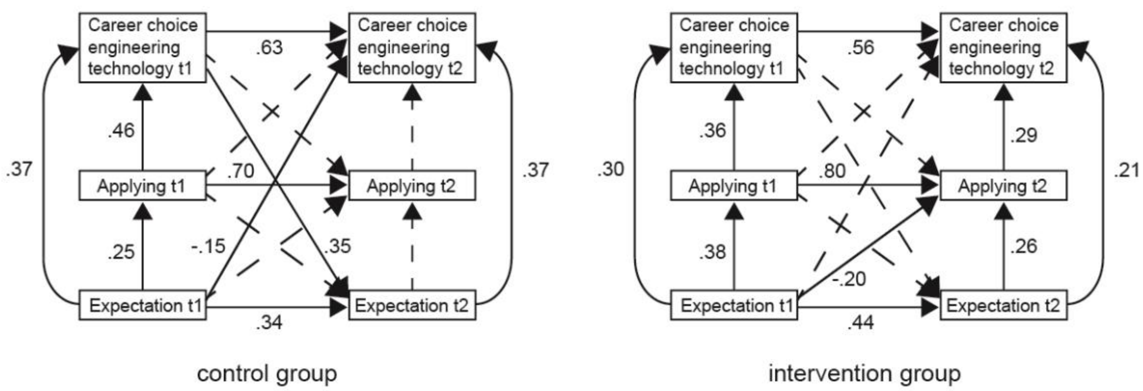

Figure 2: Two-group model for explaining development of STEM career choice

The qualitative results point out that the growth of career interest as part of an industry-school visit with accompanying preparation and reflection in school faces some obstacles. Is the visit at the right time of the students' career planning? Is the student open to considering a job in the technology field? Additionally, the image of the company is of importance as well as the working conditions. Finally, the activities must appeal to the student. As the students can choose among many apprenticeships, one of these factors can prevent students from continuing further inquiries about the job. Hence, the chance for a company to reach an applicant through an industry visit is not very high; however, very often in small to medium companies, there are not more than two apprenticeships available per year anyway.

Overall, our results show that factory visits combined with embedded tasks could be one way to overcome fixed self-concepts based on school science experiences. Even if career interest did not increase for the class as a whole, the insight into job-related science-based technology and working on practical tasks allowed the students to reconsider a career in the engineering industry towards the end of secondary school. Finally, it should be considered for further research that because of the specific orientation of technology towards application, more studies are needed that explore differences between science and science-based technology attitudes and knowledge and how they interact in developing career interest in technology professions.

REFERENCES

Archer, L., DeWitt, J., Osborne, J., Dillon, J., Willis, B., & Wong, B. (2010). "Doing" science versus "being" a scientist: Examining 10/11-year-old schoolchildren's constructions of science through the lens of identity. Science Education, 94(4), 617-639.

Becker, F. S. (2010). Why don't young people want to become engineers? Rational reasons for disappointing decisions. European Journal of Engineering Education, 35(4), 349-366. doi:10.1080/03043797.2010.489941

De Vries, M. (2001). The history of industrial research laboratories as a resource for teaching about science-technology relationships. Research in Science Education, 31(1), 15-28.

Eccles, J. S. (2011). Gendered educational and occupational choices: Applying the Eccles et al. model of achievement-related choices. International Journal of Behavioral Development, 35(3), 195-201. doi:10.1177/0165025411398185

Eccles, J. S., & Wigfield, A. (2002). Motivational beliefs, values, and goals. Annual Review of Psychology, 53(1), 109-132.

Fensham, P. J. (1988). Approaches to the teaching of STS in science education. International Journal of Science Education, 10(4), 346-356.

Goreth, S., Geißel, B., & Rehm, M. (2015). Erfassung fachdidaktischer Lehrkompetenz im technikbezogenen Unterricht der Sekundarstufe 1.

Instrumentenkonstruktion und erste Befunde. Journal of Technical Education (JOTED), 3(1), 13-38.

Jones, A. (2012). Technology in science education: Context, contestation, and connection. In B. J. Fraser, K. Tobin, & C. J. McRobbie (Eds.), Second international handbook of science education (pp. 811-821). Dordrecht, NL: Springer.

Jones, A., Buntting, C., & de Vries, M. J. (2013). The developing field of technology education: a review to look forward. International Journal of Technology and Design Education, 23(2), 191-212. doi:10.1007/s10798-011-9174-4

Laine, E., Veermans, M., Lahti, A., & Veermans, K. (2017). Generation of student interest in an inquiry-based mobile learning environment. Frontline Learning Research, 5(4), 42-60.

Levine, M., Serio, N., Radaram, B., Chaudhuri, S., & Talbert, W. (2015). Addressing the STEM gender gap by designing and implementing an educational outreach chemistry camp for middle school girls. Journal of Chemical Education, 92(10), 1639-1644. doi:10.1021/ed500945g

Masson, A.-L., Klop, T., & Osseweijer, P. (2016). An analysis of the impact of student–scientist interaction in a technology design activity, using the expectancy-value model of achievement related choice. International Journal of Technology Design Education, 26(1), 81-104. doi:10.1007/s10798-014-9296-6

NGSS Lead States. (2013). Next generation science standards: For states, by states. Washington, DC: The National Academies Press.

Organisation for Economic Co-operation and Development (OECD). (2006a). Assessing scientific, reading and mathematical literacy. A framework for PISA 2006. Paris: OECD Publishing.

Organisation for Economic Co-operation and Development (OECD). (2006b). Evolution of student interest in science and technology studies. Paris: Global Science Forum.

Regan, E., & DeWitt, J. (2015). Attitudes, interest and factors influencing STEM enrolment behaviour: An overview of relevant literature. In E. K. Henriksen, J. Dillon, & J. Ryder (Eds.), Understanding student participation and choice in science and technology education (pp. 63-88). Dordrecht: Springer Netherlands.

Sasson, I. (2018). Participation in research apprenticeship program: Issues related to career choice in STEM. International Journal of Science Mathematics Education Research Journal. doi:10.1007/s10763-017-9873-8

Schoonenboom, J., & Johnson, R. B. (2017). How to construct a mixed methods research design. KZfSS Kölner Zeitschrift für Soziologie und Sozialpsychologie, 69(2), 107-131. doi:10.1007/s11577-017-0454-1

Simpkins, S. D., Davis-Kean, P. E., & Eccles, J. S. (2006). Math and science motivation: A longitudinal examination of the links between choices and beliefs. Developmental Psychology, 42(1), 70.

Smit, R., Robin, N., De Toffol, C., & Atanasova, S. (2019). Industry-school projects as an aim to foster secondary school students' interest in technology and engineering careers. International Journal of Technology and Design Education. doi:10.1007/s10798-019-09538-0

Watters, J. J., Pillay, H., & Flynn, M. (2016). Industry-school partnerships: A strategy to enhance education and training opportunities (064695749X). Retrieved from Brisbane:

Xie, Y., & Achen, A. (2009). Science on the decline? Educational outcomes of three cohorts of young Americans. Population Studies Center Research Report, 09-684.

AN INNOVATIVE DESIGN IN RESEARCH, EDUCATION, AND PRE-COLLEGE MENTORING PROGRAM

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In an increasingly complex world, there is limited research that focus on designing rigorous school counseling programs that meet students' needs, enhance their learning, and increase their motivation to pursue tertiary education. As a result, a group of experts gathered minds and experience to tackle this significant issue of career guidance and pre-college counseling. In this case study, 24 grade 10 students were provided with the opportunity of experiencing hands-on and minds-on project-based authentic interdisciplinary modules stemming from their interests and designed by seniors and graduate students. This innovative approach attempted to foster student conceptual understanding, increase their motivation towards learning science, and promote their growth as they prepare to take on post-secondary education. Implications for practice and directions for future research in the context of education and higher education are discussed.

Keywords: higher education, experiential learning, motivation

I. INTRODUCTION

In an increasingly complex world (Osberg & Biesta, 2010), a lot of research and professional development has been done on designing school curricula that match 21st century skills (e.g. Alismail & McGuire, 2015; Care, Kim, Vista, & Anderson, 2018; Partnership for 21st Century Skills, 2009; Schleicher, 2012). However, less focus is on designing rigorous school counseling programs that (a) consider the needs and interests of students, (b) reinforce what they study at schools, and (c) foster decision making and 21st century skills to help students transition smoothly from school into tertiary education (CERD, 2019; OECD, 2012; Yorke, 2000).

In Lebanon, Grade 10 is a common path for all students prior to following the scientific or literary tracks (Loo & Magaziner, 2017; Nuffic, 2016). However, students greatly lack awareness on how to select their majors or align their future path with their interests and abilities (Vlaardingerbroek, Al-Hroub, & Saab, 2017). In fact, career guidance and support programs – if present – are limited and often very theoretical. To further confirm these findings, national meetings and interviews with schoolteachers revealed problems within school curricula and a deficiency in school counseling programs. Both challenges led to the (a) failure of Lebanese science school curricula to cater to students' interests and nurture 21st century knowledgeable and skillful learners, (b) lack of student interest in science, (c) inability of students to apply science concepts to solve real-world problems, (d) prevalence of traditional teaching, limited practical skills and opportunities to engage students in investigations, inquiry, and experiments, and (e) absence of robust school counseling program to help students make informed decisions regarding their future career path (Osman, 2014).

If we are to prepare students for the future, we need to attract their attention by creating an authentic and positive learning environment that develops their problem-solving skills within a meaningful context (Hallissy, Butler, Hurley, & Marshall, 2013; Schleicher, 2010). As a result, we wondered how we could construct a pre-college mentoring program that could (a) support school curricula in reinforcing content, skills, and authenticity, (b) increase student motivation and conceptual understanding, and (c) provide students with life skills to help them select careers related to their fields of study.

Previous research in science education has shown that positive classroom experiences through hands-on engagement result in improved motivation and attitude towards science (Osborne, Simon, & Collins, 2003; Vlaardingerbroek, Taylor, Bale, & Kennedy, 2017). However, whether such a change improves understanding of theoretical science is to be unraveled.

In this study, we discuss a pilot precollege boot camp program, the first initiative of its kind in Lebanon. We worked collaboratively with three university professors and their senior, Masters, and PhD students to design a scaffolded pre-college mentoring program to reinforce concepts taught at school, increase student motivation, enhance learning, provide training on basic life skills and hands-on career counseling to ultimately encourage students to pursue tertiary education. The fields of Cancer Biology, Neuroscience, and Mechanical Engineering (ME) were selected because they are aligned with subsequent secondary school science curricular units (i.e. that of Grades 11 and 12), are difficult to learn at schools (mainly due to the lack of labs and/or lab sessions), and are authentic with genuine problems from students' daily lives; cancer biology is a human-related disease, neuroscience deals with neural stem cells in embryonic and adult brains, and ME addresses energy consumption with emphasis on the solar chimney and cooling systems.

We sought to investigate the effect of the designed pre-college mentoring program on Grade 10 students' (a) conceptual understanding of some basic yet complex theoretical science concepts and (b) motivation towards learning science. We also aimed to explore their perspectives on making educated decisions regarding their future college major and career path.

II. METHODOLOGY

This case study adopted a descriptive mixed-methods design, planned across five phases (Figure 1). Quantitative and qualitative data collection methods were used to explore possible gains in Grade 10 students' understanding of scientific concepts, observe developments of their motivation towards learning science, and obtain an in-depth understanding of their perspectives on engaging in similar projects as means to make informed decisions concerning their post-secondary studies and careers.

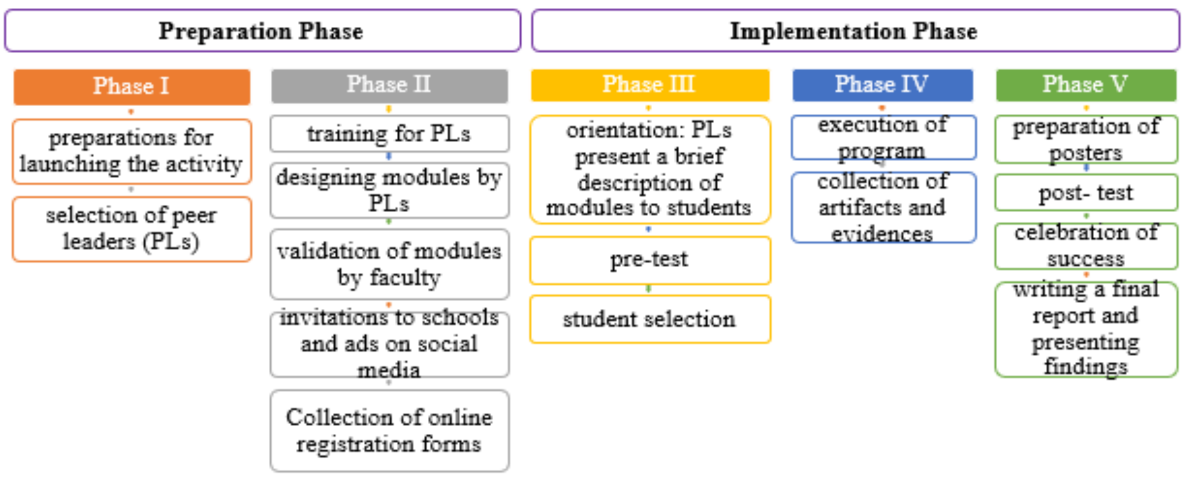

Figure 1. Phases of the study

A. Participants

Two peer leaders (PLs) from each of the three fields were selected according to the following criteria: they are seniors and/or graduates from the American University of Beirut (AUB), exhibit great leadership and communication skills, and are committed. Upon their nomination by faculty, the PLs and their faculty supervisors attended three one-day workshops on active teaching strategies, working with students, and providing constructive feedback to students.

For this study, we targeted Grade 10 students. From a pool of 120 student applicants pertaining to a total of 38 public and private schools across Lebanon, 8 students were selected per field based on results of a subject proficiency test and open-ended questions on interest, purpose, and career motivation. The total of 24 participants who were blindly chosen pertained to 7 private and 1 public schools in 3 governorates.

B. Training Modules – Experiential Learning

The training modules were developed by peer leaders and faculty members, then reviewed by the researchers. Activities included hands-on-minds-on sessions, visits to different facilities of authentic research, discussions with guest speakers and experts in their field, discussion of research studies, and career-related classes (Figure 2). Each module was taught by PLs under faculty supervision over a period of 4 weeks (8 sessions) at AUB labs and classrooms.

The researchers attended different sessions to assess students' motivation level and conceptual understanding, as well as provide constructive feedback to PLs. Then towards the end of the module, students were asked to submit a scientific poster to reflect on their experience.

C. Data Collection Tools

At the start and end of the program, students completed a subject proficiency test and a motivation questionnaire.

Test items were developed by PLs based on the topics to be covered in the modules and validated by 3 university faculty advisors (experts in the field). The final version of the topic proficiency test included 13 open-ended items for ME, 15 open-ended items for Neuroscience, and 16 open-ended items for Cancer Biology. These items assessed students' understanding of the theoretical aspect of their topic of interest as well as laboratory protocol and results.

The motivation questionnaire consisted of (a) 25 items that identified students' motivation towards science using a validated Likert-type scale (Glynn, Brickman, Armstrong, & Taasoobshirazi, 2011) and (b) 3 open-ended questions that explored students' personality and interest in relation to their future.

Both the subject proficiency test and questionnaire were administered during a 1-hour session held at AUB following an orientation that provided an overview of the modules, where students selected one of the three fields: ME, Neuroscience, or Cancer Biology. Final selections of students were objective as peer leaders corrected the assessment papers with reference only to a code identifier for the participants.

Figure 2. Sample activities within the (A) Cancer Biology, (B) Neuroscience, and (C) Mechanical Engineering training modules

By the end of the modules, students also engaged in informal discussions with the researchers and faculty advisors about their opinion of the program. PLs and some students shared their opinions in short testimonies in the closing ceremony. Thoughts and opinion were video recorded.

Lastly, all 24 participants were sent a questionnaire (exit survey) to assess the training module they attended and reflect on their experience. The response rate was 83.33% (20/24).

D. Data Analysis

A summary of data analysis strategy used for each type of question is presented in Table 1. Means and standard deviations were used to analyze students' responses to the knowledge items. Frequencies and percentages were used to analyze students' responses related to motivation. Since the sample size per subject was small, no inferential statistics were computed. Open-ended items were analyzed by the peer leaders based on a defined correction scheme. In general, exams and questionnaires were evaluated and reviewed by two PLs; disagreements in corrections were discussed until consensus was reached.

As for the post-implementation focus group discussions, testimonies, and exit survey, emerging themes and recommendations were identified and analyzed using thematic content analysis.

Table 1. Analysis scheme of items in the topic proficiency test and motivation questionnaire

Category	Target	Type of Items	Analysis
Knowledge items: **Conceptual understanding**	Students' understanding of theory and experiment results	MCQs and short-answer questions	*Descriptive Statistics:* Means and standard deviations for scores
Knowledge items: **Practical skills**	Students' understanding of lab protocol and results *Does this understanding differ between Cancer Biology & Neuroscience students?**	Short-answer questions **The same questions were used to investigate whether one group outperforms the other based on topic taught*	*Descriptive Statistics:* Means and standard deviations for scores *Student t-test*
Student Motivation **(Glynn et al., 2011)**	Level of motivation in learning science based on 5 constructs: • intrinsic motivation • grade motivation • career motivation • self-determination • self-efficacy	25 Likert-type scale items	*Descriptive Statistics:* Frequencies and percentages
Interest & Career Choice	Students' personality and interest in relation to their future	3 Open-ended items	*Thematic content analysis*

III. RESULTS

Data collected showed that – overall – students showed increased understanding of complex concepts and higher motivation towards learning science. They were also better informed on how to select their majors.

A. Conceptual Understanding

A comparison of average scores on the topic proficiency tests pre- and post-program showed a variation across modules (Figure 3). While there was a 5.93% overall increase in performance for Cancer Biology students post-program, both Neuroscience and ME students had scored better on the pre-test on average compared to post-test results; on average, the change in performance for students in Neuroscience was -6.28%, and a greater change (-13.38%) was observed in the scores of Mechanical Engineering students. However, differences in student performance on the pre-test and post-test knowledge items within each group were not statistically significant ($p>0.05$).

Moreover, analysis of post-tests results showed an increase in the average individual percentage change of students' conceptual understanding, practical skills, and overall performance in Cancer Biology, with the change being largest for the practical skills (+16.59%) compared to pre-test performance. However, while Neuroscience students showed a greater change in conceptual understanding compared to students in the Cancer Biology module (+5.25% compared to +2.88% respectively), the average change in performance of ME students was 13.05% lower after the training sessions.

To investigate whether one group outperforms the other in the hands-on items based on topic taught, the same practical exam was used with students from Cancer Biology and Neuroscience. A comparison of student performance indicated statistically significant differences in the pre-test ($p<0.01$) but not in the post-test ($p>0.05$) practical items.

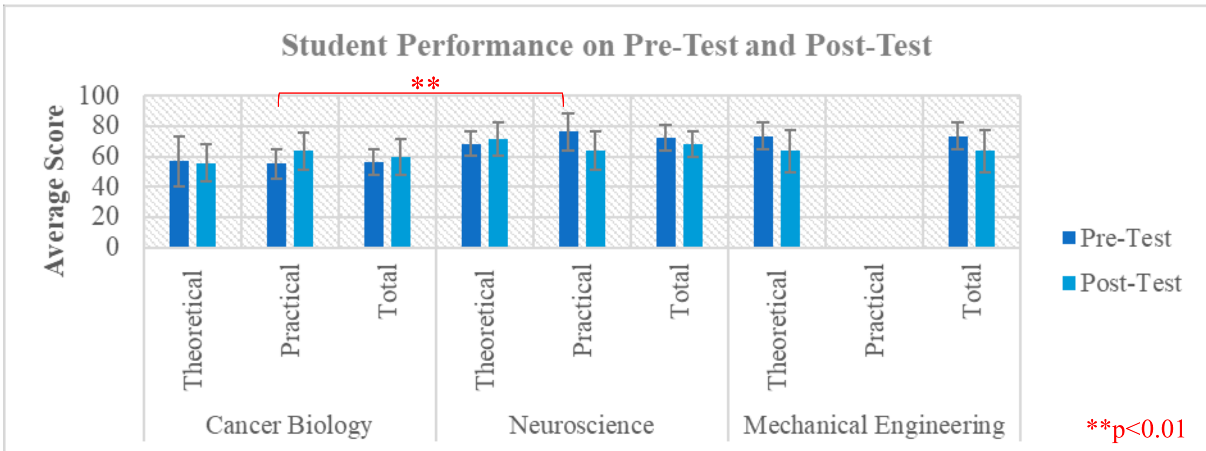

Figure 3. The average student performance on the subject proficiency test administered before and after the Cancer Biology, Neuroscience, and ME training modules

The change in student conceptual understanding was also reflected in focus group discussions, testimonies, and exit surveys. When asked about their opinions, 90% of students believed that the program provided them with an authentic opportunity that favored learning and a better understanding of the subject. As one student stated:

> *"This experience gave me a clear idea of what neuroscience is - besides being a fancy word - and offered me a fresh outlook on biology in general. I realized how much neuroscience contributes to the advance of the medical field!"* Neuroscience Student 5

B. Motivation

For Cancer Biology students, motivation towards learning science increased overall during the post-test. The increase was greatest for s*elf-determination* and *self-efficacy* factors. As for student in the Neuroscience module, motivation also increased overall during the post-test. While the increase was greatest for the *career motivation* and *grade motivation* factors, *self-efficacy*, was lower after the training. Unlike students in the other two modules, ME students showed a lower motivation overall and in all 5 factors after the program, with the decrease being greatest for *grade motivation* and *self-determination* factors (Figure 4).

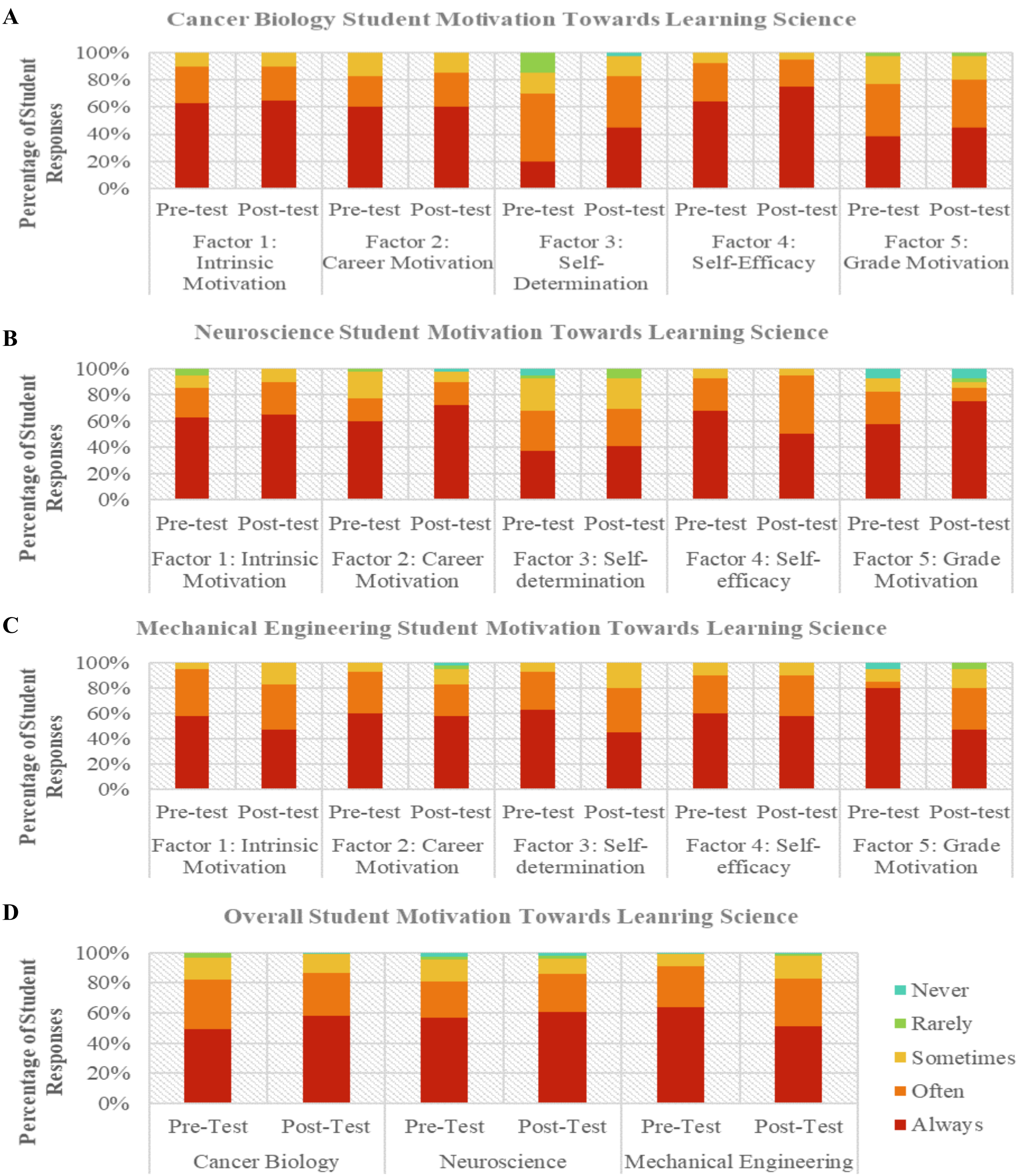

Figure 4. Student motivation levels of Grade 10 student participants before and after the intervention for individual factors in (A) Cancer Biology, (B) Neuroscience, and (C) ME, as well as (D) Overall

Recurring themes of passion and increased awareness constantly emerged, with numerous anecdotes support these findings.

> *"The training made me fall in love all over again with the job…it is possible to become a neurosurgeon!" Neuroscience Student 6*
>
> *"I have a passion for biology and I want to do something that will help cure people in my future career" Cancer Biology Student 4*
>
> *"This program opened my eyes to [Heating, Ventilation, and Air Conditioning] which I didn't know was previously a part of ME. It also made me be curious..." ME Student 3*

Furthermore, discussions with students and PLs revealed that the authentic and practical aspect of the training was key to student motivation towards learning. In fact, the hands-on experiments were unanimously the most engaging aspect of the project, where some students saw a real lab and worked with real tools for the first time.

C. Perceptions and Future Careers

Themes emerging from thematic analysis revolved around two main concepts: increased learning and guidance for future careers.

First, increased learning was illustrated in student responses which reflected how they were able to understand complex ideas.

> *"This experience gave me a clear idea of what neuroscience is - besides being a fancy word - and offered me a fresh outlook on biology in general. I realized how much neuroscience contributes to the advance of the medical field!" Neuroscience Student 5*

Students believed that the knowledge and skills they gained will help them choose their major and future career. Students voiced their interest in such programs that pave the way to a goal-oriented and brighter future.

> *"My choice of major at the university shifted from engineering to the sciences after experiencing what it truly meant to be a scientist." Neuroscience Student 2*
>
> "*It helped me deciding what I want to be in the future." Cancer Biology Students*

Students also expressed that this project allowed them to experience part of college life. They were thrilled to experience how the program can foster social collaboration and offer career guidance; they made new friends and met instructors who might become their supportive mentors as they take their education forward. One student even contacted the Research Science Institute at MIT for a possible follow-up project.

On the other hand, PLs stated that the project was a priceless teaching and learning experience for them as well, as they took on the challenge to design interdisciplinary teaching modules that target real-world problems, acquired pedagogy skills in teaching, and became aware of school students' needs and interests.

Last but not least, common suggestions for improvement included increasing the number of sessions and lab experiments, covering a wider range of topics, supplying complementary teaching resources and home assignments, and strengthening curricula through partnerships with schools.

IV. DISCUSSION & CONCLUSIONS

In this era, high school teachers struggle to motivate their students to learn and continue their education. When activities challenge students to develop knowledge and deep understanding, students are provided with a motivating experience to appreciate the field and related career options (Gregson, 2011). However, when students experience science through a plethora of information to memorize rather than via engaging hands-on laboratory experiences (Danaia, Fitzgerald, & McKinnon, 2013), it is not surprising to notice a decrease in conceptual understanding and motivation similar to our observation with the ME students. In fact, the discrepancy between the engaging planned ME module and observed results may be attributed to prevalence of lecturing rather than authentic workplace science, and to the turnover of PLs due to university exams and a tight schedule. On the other hand, the increased motivation and conceptual understanding of Cancer Biology and Neuroscience students may be due to recent confirmation that students thrive on problem-based, interactive, authentic learning (e.g. Darling-Hammond, Flook, Cook-Harvey, Barron, & Osher, 2019).

In addition to insightful observations from the authors, feedback from student responses to open-ended questions and focus group discussions, PLs, and faculty dictates that precollege programs could be better designed by taking the following features into consideration: (a) containing research-driven activities (complex concepts from school syllabi), (b) engaging students with challenging interdisciplinary real-world problems that promote their motivation and foster better learning, (c) establishing an incentive system to increase commitment of students and PLs, (d) providing an opportunity to explore 2 or more fields, and (e) partnering with schools to develop a well-structured school counseling program that serve both academic and social needs.

As preliminary results were discussed with the Ministry of Education and Higher Education, implications for practice underscore collaborations towards reaping success at the school and university, with a promising integration of high-level innovative thinking in supporting school programs that foster 21st century skills and prepare students to become self-directed citizens.

This case study is of a narrow-scale implementation within a specific context (24 students in 3 majors at one university in Lebanon), so its results are not generalizable. Though we believe we have had a successful attempt, future studies are needed to (a) extrapolate this project to other subject areas, teachers, and a larger number of students, (b) revise the curriculum for authentic learning, and (c) provide genuine opportunities for students to make educated study and career choices. In fact, a scaled-up 2019-2020 project with 106 students (11 schools) and 10 departments (25 faculty) have indicated promising results with improved performance in all majors. Details will be presented in subsequent manuscripts.

In conclusion, we are now more confident of the importance of pre-college mentoring programs. They complement formal school curricula to improve learning, understanding, motivation, and the ability to make better decisions regarding career choices. Instead of abstractly talking about careers or interacting with university counseling websites, pre-college counseling programs should serve two purposes: academic and social. In this regards, partnerships between schools and universities is essential to engage students in authentic learning environments that help them practice a field of interest rather than listen about it, as well as acquire basic life skills that help them choose their careers based on interest and abilities, ultimately meeting the needs of the society they live in.

V. ACKNOWLEDGEMENT

We would like to thank Dr. Hala Gali-Muhtasib, Dr. Kamel Abou Ghali, and Dr. Noël Ghanem for their guidance and for believing in the mission of this project. This work would not have been possible without the project PLs: Dr. Maamoun Fatfat, Mr. Anthony Bejjani, Ms. Rose Marie Akiki, Ms. Rana

Sarieddine, and Ms. Douaa Al-Assaad; their contribution was invaluable for the successful implementation of the modules.

We would also like to acknowledge Dr. Imad Saoud, the Biology Department Chair at AUB in 2018, and the time and support of all faculty, staff, personnel, schools, parents, students, and guest speakers without whom the project would not have been possible.

This project was supported by the Fulbright Program and sponsored by the U.S. Department of State.

VI. REFERENCES

Alismail, H. A., & McGuire, P. (2015). 21st Century Standards and Curriculum: Current Research and Practice. *Journal of Education and Practice, 6*(6), 150-154.

Care, E., Kim, H., Vista, A., & Anderson, K. (2018). *Education system alignment for 21st century skills: Focus on assessment*. Retrieved from https://www.brookings.edu/wp-content/uploads/2018/11/Education-system-alignment-for-21st-century-skills-012819.pdf

Center for Educational Research and Development [CERD]. (2019). *Statistical Bulletin for the Academic Year 2018-2019*. Retrieved from https://www.crdp.org/files/201908300826465.pdf

Danaia, L., Fitzgerald, M., & McKinnon, D. (2013). Students' perceptions of high school science: What has changed over the last decade? *Research in Science Education, 43*(4), 1501-1515.

Darling-Hammond, L., Flook, L., Cook-Harvey, C., Barron, B., & Osher, D. (2019). Implications for educational practice of the science of learning and development. *Applied Developmental Science*. doi:10.1080/10888691.2018.1537791

Glynn, S. M., Brickman, P., Armstrong, N., & Taasoobshirazi, G. (2011). Science Motivation Questionnaire II: Validation with science majors and nonscience majors. *Journal of Research in Science Teaching, 48*, 1159-1176.

Gregson, R. (2011). Bring Back The Wow: A model for engaging students with real scientists doing real science. *International Journal of Learning, 17*(12), 293-306.

Hallissy, M., Butler, D., Hurley, J., & Marshall, K. (2013). *Redesigning Education: Meeting the challenges of the 21st century*. Dublin: Microsoft Ireland Retrieved from http://blog.teachnet.ie/docs/MSLearningPaperMay13.pdf.

Loo, B., & Magaziner, J. (2017). Education in Lebanon. *WES: World Education News + Reviews.* Retrieved from https://wenr.wes.org/2017/05/education-in-lebanon

Nuffic. (2016). *Education system Lebanon: described and compared with the Dutch system*. Retrieved from https://www.nuffic.nl/en/publications/education-system-lebanon/

Organisation for Economic Co-operation and Development [OECD]. (2012). *Equity and Quality in Education: Supporting Disadvantaged Students and Schools*. OECD Publishing Retrieved from http://dx.doi.org/10.1787/9789264130852-en.

Osberg, D., & Biesta, G. (2010). *Complexity Theory and the Politics of Education*. Rotterdam, The Netherlands Sense Publishers.

Osborne, J., Simon, S., & Collins, S. (2003). Attitudes towards science: A review of the literature and its implications. *International Journal of Science Education, 25*, 1049-1079.

Osman, E. (2014). *Using Learning Progressions to enhance Lebanese students' understanding of complex genetic concepts.* (PhD Dissertation), Lebanese University, Beirut, Lebanon.

Partnership for 21st Century Skills. (2009). *Professional Development: A 21st Century Skills Implementation Guide*. Retrieved from https://files.eric.ed.gov/fulltext/ED519459.pdf

Schleicher, A. (2010). The case for 21st-century learning. Retrieved from https://www.oecd.org/general/thecasefor21st-centurylearning.htm

Schleicher, A. (2012). *Preparing teachers to deliver 21st-century skills", in Preparing Teachers and Developing School Leaders for the 21st Century: Lessons from around the World*. OECD Publishing, Paris.

Vlaardingerbroek, B., Al-Hroub, A., & Saab, C. (2017). The Lebanese Education System: Heavy on Career Orientation, Light on Career Guidance. In R. G. Sultana (Ed.), *Career Guidance and Livelihood Planning across the Mediterranean.* (pp. 255-265). Rotterdam: SensePublishers.

Vlaardingerbroek, B., Taylor, N., Bale, C., & Kennedy, J. (2017). Linking the experiential, affective and cognitive domains in biology education: a case study – microscopy. *Journal of Biological Education, 51*(2), 144-150.

Yorke, M. (2000). Smoothing the transition into higher education: What can be learned from student non-completion. *Journal of Institutional Research, 9*(1), 35-47.

COMPARING THE CONTEXTS TO UNDERSTAND SCIENCE

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Context-based science learning (CBL) creates instances for authentic inquiry pertaining to students' environment. It allows students to build their conceptions through interactions between a scientific model and an observable and specific example. In order to avoid the risk of building their conceptions from paradigmatic examples, this article presents research based on the contexts effects. reflecting the symposium*, principles and experimental modalities will be presented (part 1). One of the main results about context and conception lies in the fact that correspondences between the identified conceptions and the geothermal contexts of students have been established (part 2). In a design-based research, a modeling tool allowing to calculate contexts gap and predict contexts effects have been developed and* described (part 3). *The analysis of interactions and affective dimensions during presents the concept of contexts effect as a complex object both a psycho affective event (eureka effect) and as a constructed sequence of interaction (Contexts effect séquencies, part 4).*

Keywords: context effects, innovation in teaching/learning Modeling, Context gap Calculator, conceptions, geothermal energy, Collaborative Learning, Emotion.

The relationships between the students' natural and technical contexts and scientific learning were investigated in the context based framework context (King 2011). Context effect based learning is a collaborative method involving two groups of learners from different contexts with an inquiry process on a common issue. Each group discusses the involved concepts relating to examples in their context. Thanks to numerous distance collaborations, students work with their counterparts throughout the inquiry thus questioning their own conceptions as they are exposed to the other groups' conceptions. Everyone shares their culture, acquires digital skills and also disciplinary knowledge, of which the limits and possibilities are more precisely identified. The protocol, which has already been put into place during several iterations, is more effective if the contexts show clear differences.

The objective of this paper is to present learning based on the effects of contexts as a learning method but also to present various works related to these teachings.Several questions concerning learning based on the effects of contexts, are addressed. The first is the relationship between scientific conceptions and the contexts of a territory. The concept of context effect was initially defined as a cognitive break. This paper presents results from two different methodologies that centralize the socio-emotional and international dimension in order to show the complexity of this concept. How can we predict the appearance of a context effect? The part named "Development of a Modeling Tool for the Context Effects Based Teaching" presents the development of an external context deviation calculation tool. This tool is built on the assumption that the larger the external context deviations, the greater the chance of a context effect.

CONTEXT EFFECT BASED LEARNING, PRINCIPE AND EXPERIMENTAL MODALITIES

Context in Science Education

The emphasis placed on students' environment is an important factor in the teaching of Natural Sciences. Authentic learning experiences (Schwartz et al 2004) insist on the importance of teaching sciences within a framework of real investigation processes, thereby creating real problem-solving opportunities for students. In 2011, King, Winner and Ginns pursued this work by proposing a context effect based learning approach. The students' natural environment is the context emphasized in this study. It is the framework of their research which also enables the construction of contextual learning that is in close connection to the students' environment. The limit in this approach lies in the risk that students construct representations that are very contextualized, for which they are unaware of. Tardif, (1999) suggests viewing learning as a transfer between contextualized knowledge, de-contextualized knowledge and re-contextualized knowledge. This learning model resituates the relationship between learning and context with respect to the students' representation. Zimmermann & al (2004), links these two types of contexts under the terms internal (links to conceptions) and external (links to environment) and is interested in the relationships that can exist in instances of communication. This article proposes teaching methods in the science field, that will take into consideration external as well as internal contexts, while allowing students carrying out an inquiry in their external context to construct through their exchanges and collaboration on conceptions that are not limited to their contexts. A context effect is an event that arises during a teaching/learning relationship between two actors. If the effects of contexts were first presented as an obstacle to learning, the teachings described in this text aim to provoke them in order to express the different students' conceptions during collaboration.This event is related to the difference between their internal contexts. It may be expressed as different manifestations of emotions (laughter, conflict, incomprehension) and lead built more complex scientific conception.

Principles and design modalities in an iterative approach

Education based on the emergence of context effects has been put in place on several scientific themes. Knowing different observables between Guadeloupe and Quebec: the concept of adaptation of frogs (tropical arboreal or pond), fruit (i.e. apple and banana), agricultural production of sugar (maple syrup and cane sugar) and the exploitation of geothermal energy according to the geological contexts.These interactions have been of 2 or 3 months duration have allowed learners of primary, secondary and higher education to collaborate during scientific investigations. The results show different modes of emergence of context effects.

These effects of contexts differ by the external contexts involved, by the moments of emergences during the inquiry and by the emergence modalities. Numerous learning has also been demonstrated, and expert representations appear.

Methodological issue

Design-Based Research (DBR) is a well-recognized methodology for its relevance in design projects of technological environments in education Anderson & Shattuck (2012). As its name indicates, it is inspired by the science of design, and is oriented towards the design of artifacts; it brings together theoretical concerns and field considerations for the development of solutions.

Inspired by Brown (1992), the founding works (Barab and Squire, 2004, Wang and Hannafin 2005), were quickly adapted to the questions of science education (Sandoval and Bell, 2004). The DBR has been built around two characteristics. The first is the twofold goal: the advancement of theoretical knowledge and the iterative conception of a solution, the two elements being considered as a single whole. The second characteristic is the in situ mode practiced both in terms of collaboration with the actors in the field and for the tests and micro-experiments conducted during the different phases.

The mixed methodology uses to collect data on each iteration include analyzing of texts produced by students, pre-test and post-test interviews, and videoconference recordings. The phenomenon of context effect has been described as a process of cognition expressed during interactive sequence with strong emotional dimension (incomprehension, surprise, satisfaction).

Principles and Learning scenario

In order to bring out a lot of context effect, a number of principles can be proposed: choosing students who can collaborate with each other, maximize external contexts opposition, allow students to develop contextual conceptions, compare its to conceptions build in a different context and then integrate it's to build a more complex conception, dependent on the contexts and more aware of the limits and generalities of the concepts. The modalities of the learning scenarios are based on these principles (table 1).

Table 1. Principles and learning scenario

Learning Scenario	Principles
Objects of scientific study that are observable and part of the students' environment	Different external contexts
A common problem for all students	Collaborative students: levels close but not necessarily identical
Small work teams	
Students who can introduce themselves, meet	
Field investigation	Buid contextual representations
development of a particular methodology	
Writing a response proposal in each context	
Multiplying moments of collaboration	Confronting contextual representations
Alternate working moments in context and synchronous and asynchronous exchange times throughout the project	
Present findings synchronously to peer teams	
Metacognitive phase and explanations of the representations of each other	Build together expert representations

Learning model and contextualized conception

Teaching that is based on the emergence of context effect is an innovative teaching method based on the collaboration between students carrying out field investigations in different contexts. In the examples studied. Many learning opportunities occurred and seem to be structured according to two axes. First, the students acquire specialty competencies while carrying out a study within their own context. Then, after a collaboration with the other teams from the other context, the students build expert responses that are characterized by a more complex approach with respect to concepts (diversity of situations) and a better description of the limits of these concepts. Those experiments also allowed observing and describing in-situ context effects.

The "CLASH" model used in these learning situations is based on a shock of internal contexts and gives a significant place to contexts in learning. This generic model was originally designed to be applied to environment learning. By placing students in inquiry, field observation, data collection, and then confronting them with the results of a peer team in a different context, these students are challenged when faced with differences in context for the same object of study.

In keeping with the concept of situated conception (Clément, 1999) wich is expressed according to the conjunctures, the conceptions in the natural sciences are also contextualized : they are constructed with respect to the observal nature by integrating the diversity studied environments. Hence the question of the uniqueness of a relation between a general model and a particular example derived from the epistemology of physics might not be optimal for understanding naturalistic concepts.

COGNITIVE ELEMENT ANALYSIS IN LEARNERS' DRAWINGS

Specific theoretical framework

Conceptions may correspond to a system of interactions between knowledge structures, value systems and social reference practices of individuals (Clément, 2010). The context-based approaches (King, Winner, & Ginns 2011) emphasize the importance of including learners' environment in teaching, in order to promote a better understanding of the world in which they live and also to improve their motivation. Context effects-based pedagogical approaches therefore insist that contexts and conceptions be an integral part of the learning process. In order to set up these approaches, it is necessary to clearly identify learners' initial conceptions, as well as contextual differences that may exist between various geographical areas, with respect to the studied object. The West Indies are volcanic islands resulting from the subduction of the North and South American plates under the Caribbean plate and they thus have significant geothermal activity. The involvement of local actors in the development of this energy industry presupposes its integration in education. The present study focuses on learners' conceptions in three Caribbean territories, that in spite of a relatively close geological context, present different geothermal contexts and uses of geothermal energy. In Guadeloupe, a geothermal power plant located in Bouillante city produce 8% of the island's electricity. In

Dominica, despite a proven significant geothermal potential, no geothermal power plant exists. However, several boreholes were drilled between 2011 and 2014. Finally, in Martinique, some exploratory studies were carried out, but there is currently no geothermal facility. Our study aims to examine the relationship between learners' conceptions on a geothermal topic and the local contexts in which they are living. Furthermore, the study of geothermal energy is of interest in the field of science teaching since it is related to many general scientific and technological concepts such as energy, geology and technology.

Methods

A questionnaire survey was carried out in three islands of the West Indies (Guadeloupe, Dominica and Martinique) with a representative sample of 14-15 year-old students for a total of 1349 individuals (496 students in Guadeloupe, 372 in Dominica, and 481 in Martinique.) The questionnaire had several open-ended and closed-ended questions. Students were also asked to draw a geothermal power plant. In order to analyze those drawings, an initial list of 18 elements was first established. These elements, although directly referred to concepts related to geothermal energy, were also elements commonly found in drawings, even if they were not directly related to geothermal energy. Sometimes they were easily identifiable objects (volcanoes, crust, mantle or core, thermometer, etc.) or concepts that we believe contribute to a complete understanding of geothermal energy and its industrial production process (transformation, exchange, use or distribution). Coding was done according to the presence or absence of the elements in the drawings and some elements were regrouped, such as those related to renewable energy (wind turbines, solar panels, etc.). To avoid an errroneous analysis, a validation of the coding was carried out (Ehrlén. 2009).

Results

A descriptive analysis of the drawings reveals differences in students' views between the three islands. The most represented elements in the three islands are: ground, heat, tubes, and plants. In addition to these four elements, the most represented element in Martinique is: renewable energies, in Guadeloupe: transformation, and in Dominica: nuisance. Some drawings illustrating these specificities appear in Figure 1.

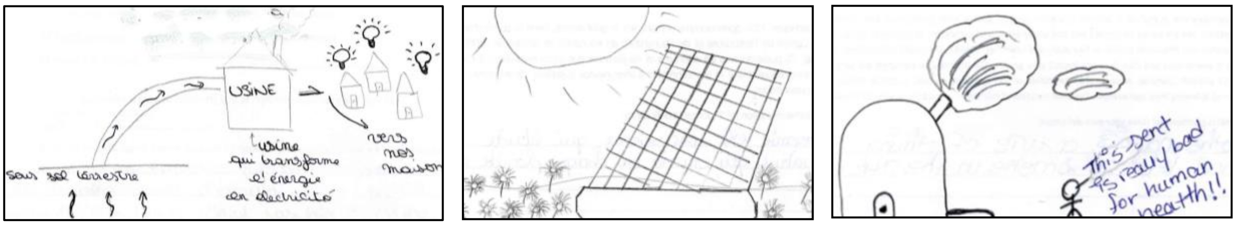

Figure 1. Examples of drawings from each island (from left to right: Guadeloupe, Dominique, Martinique).

Different methods, such as the Multiple Correspondence Analyses (MCA), were used (Figure 2): At the top left (in blue), are the grouped points corresponding to elements referring to renewable energy (wind turbine, solar panel, hydroelectricity…). Martinique is situated in this blue area. It is also very close to the "individual" element which is also represented in the drawings that illustrate individual uses in the form of heat or hot water. Guadeloupe is in the second zone (in orange), which groups together the elements that correspond to a representation of the soil, a plant, heat, nuisance, tubes, groundwater, a turbine, electricity and distribution. Guadeloupe students have a more industrial and technical perception of geothermal energy. They are also the ones who drew the most elements. Finally, the last zone (in green), includes the elements: earth, human, volcano and boreholes, as well as Dominica Island. The idea of human exploitation of a volcanic resource is well established in Dominica. According to this analysis, Martinique students have conceptions related to the environment and renewable energies, whereas Guadeloupe students' conceptions are related to industrial activity and Dominica students' conceptions are related mainly with respect to human exploitation of a volcanism resource.

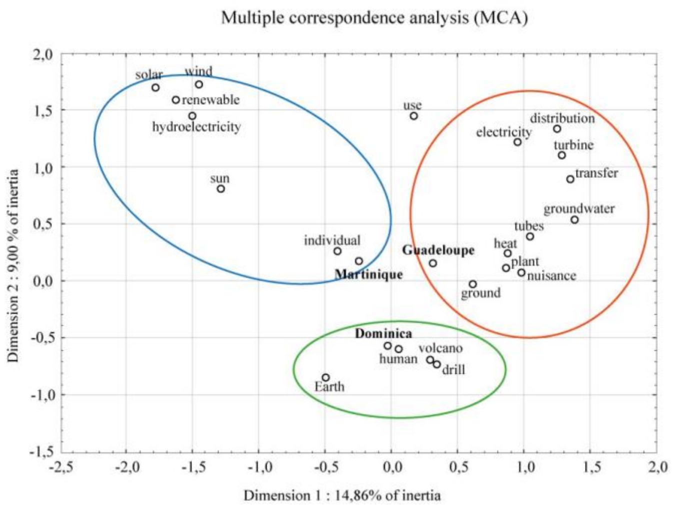

Figure 2 : MCA analysis between Guadeloupe, Martinique and Dominica

Observations from the analyses of the students' drawings highlight three main elements: (1) Very few students were able to include in their drawings more than two elements directly related to geothermal energy. This indicates a lack of knowledge in this area. (2) The MCA analysis reveals that conceptions are different depending on the island. (3) Others MCA analysis show that students from the same island have similar conceptions. In Guadeloupe, the presence of a geothermal power plant is well known by students. Conceptions are thus linked to the industrial aspect of the resource. In Dominica, despite efforts to exploit the resource in recent years, no facilities have been created. In addition, the media setbacks related to exploitation difficulties may have tarnished the image of this industry. The transcribed conceptions are related to the harmful aspect of the resource. Finally, in Martinique, because of the lack of geothermal facilities, students mainly describe the renewable aspect of the resource, and link it to the environment. These differences in learners' prior conceptions of geothermal energy are essential considerations. They can serve as a support for the setting up of pedagogies involving pupils from the three islands, such as those based on context effects.

ELABORATION OF A MODELING TOOL FOR THE CONTEXT EFFECTS BASED TEACHING

This part presents a research project in science education that is positioned at the intersection of computer science and context in learning. The main objective is to create a software tool that will participate, from the inception to the achievement, in the design of a leaning scenario, based on context effects. To this end, the software will allow to compute context differences between two learning environments. Input data include a chosen set of parameters, specific to the phenomenon or object that students are expected to explore in each learning context. The calculator has been elaborated according to the design based research theory. It is to be used in dynamic learning situations, with several iterations including field experiments, in order to collect comparable data in each context.

Specific theoretical framework

Our study focuses on the contextualization of science education involving fieldwork. Context is defined here as everything that surrounds an object and that has connections with it. Our main objective was to create a software tool, in order to support the design and development of context-sensitive tasks, inside a chosen learning scenario, by considering Context Effects (Forissier, Bourdeau, Mazabraud, & Nkambou, 2014). This software allows to provide several external contexts instantiations (Van Wissen, Kamphorst, & Van Eijk, 2013), in relation to the scientific object of study, and to compare them in order to predict the emergence of Context Effects. The software tool compares two geothermal learning contexts modeling, in order to highlight the points or concepts that show differences between the two contexts in that specific field. Using this comparison, one can bring to light significant differences and take advantage of them for the construction of a context-sensitive learning scenario. Learning is expected to happen more efficiently due to the gaps between contexts that may enrich learners' interactions within and between the two contexts. Our position is that context gaps during student's collaboration are what create context effects. Teaching based on context effects is an innovative approach in science education and allows students to develop rich and complete conceptions, and to open their minds to very different world contexts.

Methods

Taking into account contextual sensitivity in science teaching is important, especially if one targets inter-or trans-contextual educational activities. To enable this, we have designed a tool called Mazcalc which can be used when the object of the study is context sensitive. While using Mazcalc, the user is progressively led to model contexts and calculate their differences (context gaps) according to a built-in method. Four user profiles (four access levels) are supported, each related to a specific role: (1) cognitive computer scientist, (2) context and content modeling expert, (3) instructional designer, and (4) teacher. Each role has access to the appropriate tools to produce the resulting artifact: configured system and meta model (ontology), general and specific context models, context gaps and pedagogical scenario, and trans-contextual training activities.

A context is always defined with respect to the object of study. For this study, geothermy was used as the use-case for validating our tool. The object of study is represented by a model of context consisting of a set of parameters to which a variable is assigned, for each context modeled. The parameters have properties, which define the rules that will be applied for the gap calculation. They can be composite, dependent or independent (if they are composite, the parameter value assignation gives rise to a new parameter that, depending on the first one, can give rise to another composite parameter, forming a tree where values by level are weighted). Parameters' variables (ordinal or nominal) are either qualitative (fuzzy) or quantitative (numeric). They can also be continuous or discrete. Usually, a parameter is part of one or several groups of context parameters called, families.

The expert must first specify the relevant set of parameters of the object under study, whatever the context. As previously said, these parameters can be grouped into families and have scales (domain) of values that can be numeric or fuzzy. Once such a general model is specified, it can then be instantiated in one or more contexts (specific models). During the instantiation, the subset of the relevant parameters is determined and their values for the context are specified. It is possible to extend the subset of the parameters by adding new parameters specific to this context. It can follow a resolution that would include these local parameters in the model under certain conditions. The computation of the context gap is a process of alignment between two or more instances of context that highlights the differences between the parameters, and therefore the difference between the models. The calculation rules used vary according to the nature of parameters (variables and their current values). The overall result is viewable in several forms and can also be transmitted to a host system that uses Mazcalc services. The prototype was implemented as a user-friendly Web application leading to the current version of the tool (Psyché et al., 2018). An application programming interface (API) version of the tools is currently under development and will make it easier to connect Mazcalc services with any application where context-gap is to be considered. In the following section, we describe how the tool has been used for 'geothermal energy' as the object of study.

Context gaps computing for geothermal energy

In this section, we discuss how the Mazcal has been used for creating a context model of the geothermal energy concept, in Guadeloupe (French West Indies) and in Montreal (Quebec). The Caribbean Islands are located in a subduction zone, creating a great potential for geothermal energy. In Guadeloupe, this potential is harnessed, in Bouillante, and a geothermal power plant uses the groundwater heat. In northeastern America, the bedrock mainly consists of ancient Precambrian rocks from the Canadian Shield, which does not allow electricity production. There, the geothermal heat is used to regulate the temperature in buildings, to create spas and to grow crops. It is called low temperature geothermy.

We first specify a general context of geothermy by setting a number of relevant parameters into Mazcalc. Two specific context models are then created, making possible to easily compute context gaps between Quebec and Guadeloupe. Variables are assigned to the parameters, related to the expected context model for each context. The contexts gaps' values provided by the calculator can be plotted on a graph and provide a qualitative and quantitative support to teachers about what is different between the two contexts. They can thus be used as a support for the creation of pedagogical scenarios based on contexts effects. In fact context effects are expected to emerge during interactions between students in relation with the parameters for which gaps between the two contexts are important.

CONTEXT EFFECTS IN COLLABORATIVE LEARNING: VERBAL AND NON-VERBAL INDICATORS

In this part, we propose to analyze the interactive dimension of the manifestation of context effects in learning, focusing on both verbal and non-verbal indicators. In the following sections, we mainly analyzed between group verbal exchanges and within group affective dynamics to detect the so called “Eureka effect” happening when contrasting contexts induce debates and understanding.

Verbal indicators

« Collaboration is a coordinated, synchronous activity that is the result of a continued attempt to construct and maintain a shared conception of a problem » (Roschelle & Teasley, 1995, p. 70). Collaborative interactions concern ideas, representations, understanding and grounding (Schwarz & Baker, 2017). From this definition, researches on collaborative learning have investigated the role of communicative interactions to achieve a task and co-elaborate knowledge (Schwarz & Baker, 2017). Studies focus specifically on debate in which argumentation in interaction is engaged in order to answer a specific question by purely verbal means (Baker et al., 2007). Two main processes of creation of knowledge are associated with debate: the production of arguments or counter-arguments and the negotiation of meaning (Baker, 2002). According to this approach, we propose a model to analyze knowledge-building process in collaborative learning based on context effects.

We transcribed and analyzed several moments with a context effect on the TEEC corpus. We identified four steps on how knowledge is co-elaborated between groups in relation with a context effect (Figure 3). The context effect begins with a question asked by the teacher or by a learner (step 1). The question typically concerns knowledge and representations about concepts (e.g. functioning of a heat pump) that are necessary to pursue the common task. The question provokes debate where verbal indicators of context effect can be observed (step 2): comparison between the two contexts (e.g. “we use a heat pomp for that, you use it for that”), negotiation of meaning (e.g. “it is functioning like this because”) or argumentation (e.g. “you are wrong, it is functioning like this”). The debate leads to the understanding of the difference between the two contexts (step 3). We observe a typical verbal expression as “ah, okay” or “ah, I understand” (e.g. “ah okay, it is because the temperature of the water is different”). There may have back and forth between the first three steps if the concept is not totally understood and/or if all the learners did not understand it. In such case, we observe learners who have understood the gap between the two contexts explain it to those who dit not understand it. This leads to the distribution of knowledge between learners and to the mutual understanding (step 4). Verbal indicators for mutual understanding are paraphrases and reformulations as well as expressions of a common approval (e.g. “we all agree to say that...”).

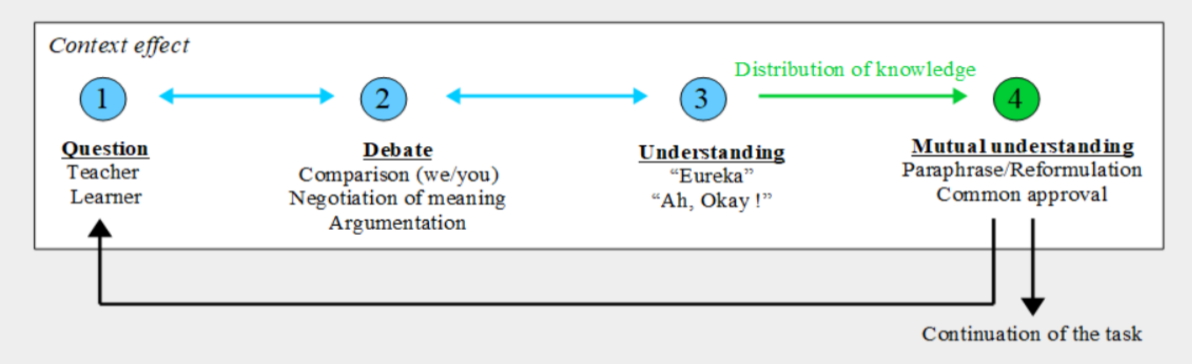

Figure 3. Model of the interactive dimension with context effect.

Non verbal cues

These last decades, affective computing has drawn more and more attention from many research communities: computer science, psychology, neuro-science, etc. It was defined as "computing that relates to, arises from, or influences emotions or other affective phenomena" (Picard, 1997). The general name of "socially aware computing" was introduced later (Pentland, 2005). In fact, there is more than words in social interactions: non-verbal behavior convey information about feelings, mental state, personality, and other traits of people. This happens through a wide spectrum of non-verbal behavioral cues like affective/cognitive states and conversational regulators.

A potential "Eureka effect" seems characterized by several affective states (and their corresponding cognitive states): (a) active listening or lack of understanding/frustration, (b) understanding/surprise followed by happiness and (c) mutual understanding (cognitive and emotional propagation). Figure 4 illustrates these three states. Of course, all these emotional states are more or less subtle due to the extravert/introvert disposition of learners. These information are collected by analyzing the internal dynamic of learner's faces. But other cues (the so-called conversational regulators) can also be meaningful: (a) head pose (when learners turn toward each over) and mouth movements indicate potential turn taking, (b) head nod (resp. shake) indicates that learner agrees (resp. disagrees) with another one and (c) body movements can indicate either surprise or disengagement.

We use the following pipeline to extract low level information (i.e. faces and face poses, facial landmarks) and infer high level indicators (emotions and turn takings). We use *face_recognition* (Geitgey, 2016) to give an Id to each learner in the first image of the sequence. Then, we perform spatial face tracking throughout the sequence. We get 3D facial features, including face pose and facial landmarks using *PRNet* (Feng et al. 2018). We also use the latter to analyze who is talking and when in the video. Finally, we infer emotions using *Emotion-recognition* (Ayman, 2018).

Figure 4. "Eureka" effect. State 1: active listening. State 2: understanding. State 3: cognitive propagation.

At this point, the methods presented in this paper are under development, but several correlations have already appeared. In the next few months, we will use them to treat various corpus of data in order to refine them. We also plan to cross verbal and non-verbal analyses and deliver a global analysis tool.

CONCLUSION

At the end of this paper, contexts effects learning appears as an innovative method based on intercultural collaboration during comparison of the natural contexts of the students involved. It is technologically equipped with a context gap calculator. It provide knowledge on the close relationships between scientific concept and the natural contexts on the example of geothermal energy. The concept of contexts effect, originally defined as an event during conceptual changes, is today conceived through two other dimensions: a psycho-affective event (eureka effect) and a sequence of didactic interactions.

REFERENCES

Anderson, T. et Shattuck, J. (2012). Design-Based Research: A Decade of Progress in Education Research? *Educational researcher*, 41(1), 16-25.

Aronson, E. (1978). The jigsaw classroom. Retrieved from https://www.jigsaw.org

Aronson, E., & Patnoe S. (2011). *Cooperation in the classroom: The jigsaw method (3rd ed.).* London: Pinter & Martin, Ltd.

Ayman O. (2018). Emotion-recognition. https://github.com/omar178/Emotion-recognition

Baker M.J. (2002) Argumentative interactions, discursive operations and learning to model in science. In P. Brna, M.J. Baker, K. Stenning & A. Tiberghien (Eds.) *The Role of Communication in Learning to Model* (pp. 303-324). Lawrence Erlbaum Associates, Mahwah N.J.

Baker, M.J., Andriessen, J., Lund, K., van Amelsvoort, M., & Quignard, M. (2007). Rainbow: A framework for analysing computer-mediated pedagogical debates. *International Journal of Computer-Supported Collaborative Learning*, *2*(2-3), 315-357.

Barab, S., Squire, K. (2004). Design based research: Putting a stake in the ground. *The Journal of the Learning Sciences*, 13(1): 1-14.

Brown, A.L. (1992). Design experiments: Theoretical and methodological challenges in creating complex interventions in classroom settings. *The Journal of the Learning Sciences*, 2(2), 141-178.

Bourdeau, J. (2017). The DBR methodology for the study of context in learning. In *International and Interdisciplinary Conference on Modeling and Using Context* (pp. 541-553). Springer, Cham.

Clément, P. (1999). Situated conceptions. Theory and methodology. From the collection of data (on the brain) to the analyse of conceptions. In Méheut M. & Rebmann G.(éd), *Fourth European Science Education Summerschool: Theory, Methodology and Results of Research in Science Education*. U.Paris: ESERA, SOCRATES, p.298-315.

Clément, P. (2010). Conceptions, représentations sociales et modèle KVP. *Skholê : cahiers de la recherche et du développement*, *16*, 55-70.

Ehrlén, K. (2009). Drawings as representations of children's conceptions. *International Journal of Science Education, 31*(1), 41-57.

Feng, Y., Wu, F., Shao, X., Wang, Y., & Zhou, X. (2018). Joint 3D face reconstruction and dense alignment with position map regression network. In *European Conference on Computer Vision*, (pp 557-574), Springer.

Forissier, T., Bourdeau, J., Mazabraud, Y., & Nkambou, R. (2014). Computing the context effect for science learning. In P. Brézillon & A. J. Gonzalez (Eds.), Context in Computing (pp. 255-269). New York: SpringerGeitgey A. (2016). Machine Learning is Fun! Part 4: Modern Face Recognition with Deep Learning.

King, D.T., Winner, E. & Ginns, I. (2011). Outcomes and implications of one teacher's approach to context-based science in the middle years. *Teaching Science*, 57(2): 26-30.

Pentland, A. (2005). Socially aware computation and communication. *Computer 38*(3), 33-40.

Picard, R.W. (1997). *Affective Computing*. MIT Press, Cambridge, UK,

Psyché, V., Anjou, C., Fenani, W., Bourdeau, J., Forissier, T., & Nkambou, R. (2018). Ontology-Based Context Modelling for Designing a Context-Aware Calculator

Roschelle, J., & Teasley, S.D. (1995). The Construction of Shared Knowledge in Collaborative Problem Solving. In C. O'Malley (Ed.) *Computer Supported Collaborative Learning*, (pp. 69-100). Berlin: Springer-Verlag.

Sandoval, W. A., & Bell, P. (2004). Design-Based Research Methods for Studying Learning in Context: Introduction. Educational Psychologist, 39(4), 199-201. doi:10.1207/s15326985ep3904_1

Schwartz, R.S., Lederman, N.G.& Crawford, B.A. (2004). Developing views of nature of science in an authentic context: An explicit approach to bridging the gap between nature of science and scientific inquiry. *Science. Education.* 88, 610–645.

Schwarz, B. B., & Baker, M. J. (2017). *Dialogue, argumentation and education: History, theory and practice*. Cambridge University Press.

Tardif, J. (1999). *Le transfert des apprentissages*. Montréal : Les Éditions Logiques.

Van Wissen, A., Kamphorst, B., & Van Eijk, R. (2013). A constraint-based approach to context. In P. Brézillon, P. Blackburn, & R. Dapoigny (Eds.), Modeling and Using Context (Vol. 8175, pp. 171-184). Berlin, Heidelberg: Springer

Wang, F., Hannafin, M.J. (2005). Design-based research and technology-enhanced learning environments. *Educational technology research and development*, 53(4), 5-23.

Zimmermann, A., Lorenz, A., & Oppermann, R. (2007). An Operational Definition of Context. *Lecture Notes in Artificial Intelligence*. 4635, 558-571

PART 3: STRAND 3

Science Teaching Processes

Co-editors: *Sabine Fechner & Roald Verhoeff*

CONTENTS

STRAND 3: INTRODUCTION

SCIENCE TEACHING PROCESSES

In this chapter the relations between particular teaching practices and students' cognitive and affective development are explored. Inquiry-based teaching receives ongoing attention as an inspiring way of learning science. 4 studies in this chapter focus on designing inquiry-based activities and supporting teachers to guide these:

Moreno, Mas and Skorsepa studied students' understanding, interest and difficulties in Physics within the context of a specific inquiry-based activity using Microcomputer-Based Laboratory. 150 students aged 13 to 18 were asked to model traffic speed detection by a sensor and study the graphs produced. Although students perceived difficulties in working with the sensors and graphs, they did enjoy working with them.

Jimenez, Hamed, Lederman and Lederman present the results of a validated questionnaire measuring Spanish students' and pre-service teachers' understandings of scientific inquiry. The authors emphasize the presence of a positivist perspective of science among middle and high school students and pre-service teachers. They argue that more attention should be paid to student-centered approaches that promote "understanding" of scientific inquiry instead of only "doing" scientific inquiry.

Rivero and Lewis consider science teachers' reflection as a necessary practice for teacher preparation programs and schools to improve teaching through inquiry-based instruction. Their multi-methods qualitative study describes the reflective practices of 15 novice teachers in a Midwestern US city and the factors that support or limit these practices.

Teichrew and Erb focus on modelling as the basis for experimenting and interpreting collected data in scientific inquiry. They present an open online learning environment to prepare students for experiments in optics in which no precise learning steps are specified. The authors show that such open inquiry learning should go hand in hand with an instructional design that engages students in a purposeful experimentation process.

Several studies refer to science as a difficult school topic that may even raise feelings of anxiety among students. 3 studies in this chapter explicitly focus on such affective aspects of science learning:

Kirmizigül and Kaya follow the definition of anxiety as the total of negative experiences such as failing to solve a science problem or failing a science exam. Within the context of the course on "Reflection in Mirrors and Absorption of Light" their quasi-experimental design compared computer-aided instruction with hands-on activities in terms of the effect on students' anxiety levels.

A diagnosis of difficulty-generating characteristics in physical problems is offered by Freese and Winkelmann. For the reader the main difficulties may sound familiar, e.g. an increased share of scientific language, mathematization, modelling or a lack of reference to everyday life. Students themselves were found to experience problems in formulating concrete difficulties and in asking for targeted support.

Energy has also been reported as a difficult and less attractive topic. Toli and Kallery developed an intervention including experimental hands-on activities, outdoor activities, problem solving situations and software to enhance secondary students' interest in the topic of energy. Their efforts paid off as they indicate a strong positive correlation between high levels of interest and levels of engagement and academic achievement.

Teachers face challenges on a daily basis as they try to connect the curriculum requirements with a diversity of individual students' needs and difficulties. studies in this chapter explicitly address a variety of such teacher challenges:

Pawlak and Gross take on the challenge to develop inclusive chemistry classrooms. Creating a safe and supportive environment for all students that do hands-on experiments appears as one of the major concerns that teachers have. From their explorative study, the authors conclude that establishing rules and routines are key to inclusive chemistry lessons.

Thomas argues that teacher professional development can learn from insights in teachers' procedural metacognitive knowledge. Based on interviews with sixteen science teachers and twelve pre-service science teachers the author sketches a varied picture of teachers' metacognitive abilities and stimulates the debate on this understudied area.

Two contributions report on studies that focus on bringing specific science topics into the classroom.

Zloklikovits and Hopf present a teaching-learning sequence to introduce electromagnetic radiation in the eighth grade. They guide the reader through their iterative design cycle of implementation and evaluation that they did with individual students and address difficulties in students' conceptual understanding of 'heat', 'radiation' and 'energy'. Santini, Bloor, Quilio and Sensevy address the issue of teaching and learning a phenomenon that isimpossible to get into classrooms; earthquakes. Based on the Joint Action Theory in Didactics, the authors present a collaborative designing process in which they devised a simulation that confronted students with a genuine aspect of seismology.

The three final studies in this chapter offer a creative perspective on science education and offer insights in narrative-, art- or play-based teaching methods. Canducci and Demartini aim to promote learning of physics by organizing and managing content as narrative structures or 'conceptual stories'. They provide a story on the conservation of energy and the Copernican revolution and analyze and reinterpret the typical elements of narration in such conceptual stories. They conclude that narratives stimulate curiosity and involvement and help students to deeply internalize scientific information, improving long-term scientific literacy.

Mutvei, Tobieson and Mattsson report on a chemistry course for future primary school teachers that included hands-on exercises, group discussions and aesthetic learning processes sessions. Their approach based on intermodal art theory and the philosophy of phenomenology engaged participants in a variety of learning situations, including the making of art. The authors argue that this promoted creative thinking and deepened the students understanding of chemistry, which empowers them for their future

profession as teachers.

Adriana Cardinot and Jessamyn Fairfield provide an overview of their workshop on a play-centric approach to science education. The challenge they present is to design a gameplay in which learners enjoy the play while they also absorb and embrace the science involved, e.g. astronomy. A 7-step design strategy is presented to take up this challenge.

Roald Verhoeff & Sabine Fechner

RESEARCH-BASED PHYSICS USING SENSORS AT SECONDARY: STUDENTS' CHALLENGES AND DIFFICULTIES PERCEIVED

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The analysis of students understanding and perceptions on interest and difficulties faced in the implementation of an Inquiry Based activity using Microcomputer-Based Laboratory in Physics at secondary school is presented. The activity is contextualized in the traffic and speed of vehicles. The analysis using SPSS software of a perception post questionnaire answered by 150 students of secondary school (aged from 13 to 18) is presented. Conclusions showed students' perceptions on the most engaging parts of the activity, and also revealed difficulties that they have.

Keywords: Inquiry-based teaching, Data Logging, Secondary school

THEORETICAL BACKGROUND

Microcomputer-based laboratory (MBL, Thornton, 1990) allows students to work out many features of science competencies, having a quick and continuous interaction with new learning that they acquire. Since 1980s, a number of benefits of experimenting with sensors and computer devices for science education has been identified. One of them is still considered the most powerful element: simultaneous graphical representation of real-time measuring (Brassell, 1987; Barton, 1997; Beichner, 1990). Moreover, the proposal of MBL instructions presented as an inquiry-guided activity (IBSE) and structured as a learning cycle has revealed to be effective in achieving significant learning (Pintó & Hernández, 2010; Tortosa, 2012; Ye, Lu, & Bi, 2019). There is empirical evidence that with the implementation of inquiry-guided MBL activities, the perceived competence and interest of students and the enjoyment reported by learners are highly correlated (Urban-Woldron, Tortosa, & Skorsepa). Nevertheless, significant differences about its efficiency in the classroom among different laboratory activities, have been detected both on students and on teachers' perceptions. (Guitart, Stratilova-Urvalkova, Smejkal & Tortosa, 2014, Skorsepa & Tortosa, 2014). A fine analysis on single activities is desired to delimit the potential of this methodology.

AIM OF THE STUDY

The context of this study is a European research project finally aiming at supporting science teachers for integrating MBL activities into science classrooms. The purpose of the study was, after performing a Physics activity, to investigate the following research questions:

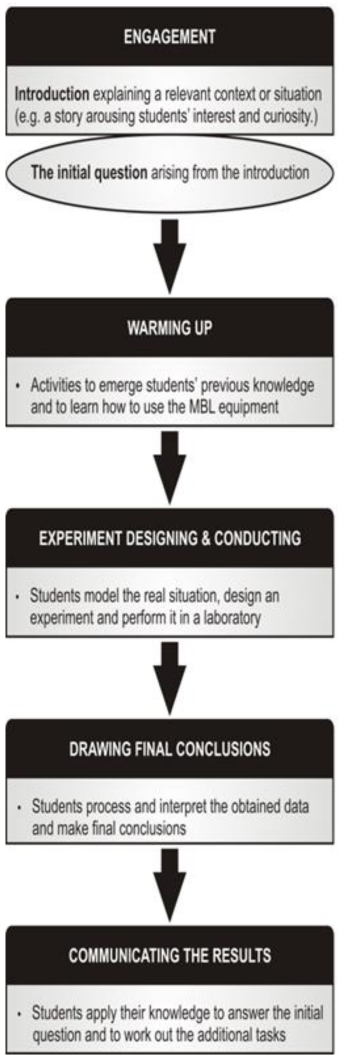
1. Do students identify the objectives of the activity?
2. What parts of the activity do students perceive as the best ones?
3. What kind of difficulties do students perceive in this activity?

METHOD

The activity

The Physics activity reported is contextualized in the traffic and speed of vehicles, students must work to answer the question: How can a radar know the speed of a car? Students are guided to model the situation in the laboratory walking themselves in front of a sensor of distance and studying the graphs produced. From their results students must be able to answer the proposed question. The activity reported is "Average speed control - how to detect the speed of a moving car?" (available at www.comblab.eu , COMBLAB Project, 2012). It was designed with the research-based framework of COMBLAB activities (Tortosa et al, 2013). Figure 1 shows the framework of COMBLAB activities in relation to the Physics activity that students performed in this study.

In the experimental part, the activity has the potential to encourage students to "play" like scientists as they are led by a POE (predict-observe-explain) didactical sequence (White & Gunstone, 1992).



The activity begins in the context of speed control on roads, specifically with a relatively new speed technique called section control, or point-to-point control, that is a control of the average speed. Students are asked to answer the questions "How do policemen find out if somebody drives too fast?" and "Do you have an idea of how it is possible to find out the average speed of an object if the vehicle is detected when enters the section, and when it leaves it?"

Students use a motion detector that plots position-time graphs of their body. They predict the graph in relation to their movement. They perform the movement and realize the difference between they move slowly or quickly, and when they move towards or away from the motion detector. They also get familiarized with the equipment and learn about how to us it.

Students walk and collect data when they walk with different constant speeds. They first predict the shape of graph and then they plot graphs of their motion with sensors. Experiments and data collection are scaffolded for students at lower secondary school and would be less guided for older students.

Students make calculations with the obtained data. They are asked to calculate the average velocity by using the position-time graph registered by the equipment. This part is scaffolded by given tables to fill in with data and calculations. At the end they write an explanation about how the average velocity of an object can be calculated from the position-time graph. They also explain how to walk to match a given graph and finally they draw their conclusions.

Students answer the main questions of this activity in the initial context. They are asked to write an explanation about how the average speed of a car can be found out and what physics magnitudes are required to measure to de detect the average speed of a moving car using the section control or point-to-point control technique.

Figure 1. Research-based framework of the COMBLAB -MBL activities and description of the performed activity

Participants and setting

The activity was implemented with 150 students aged from 13 to 18 (80 males), by their Physics teachers in three secondary schools in the area of Barcelona (Spain). The three secondary teachers received two sessions of teacher training on microcomputer-based laboratories and on Inquiry-based science before implementations Distance sensors were provided to schools if they are not used in their classrooms. A post questionnaire on the activity was answered by students after implementation. Data were collected from these questionnaires that included 19 items. Four items were chosen to be analysed in this article. These 4 items are mentioned in this work as items 1, 2, 3 and 4:

1. I understood the objectives of the activity.
2. List the objectives of the activity
3. What parts of the activity did you like the most?
4. What parts of the activity did you find the most difficult?

In ITEM 1, students chose from a four-level Likert scale ranging from: 1 (strongly agree) to 4 (strongly disagree). Students could add comments if they wished. Questions two, three and four are open questions and data had been analysed by categorizing of the open answers.

In ITEM 2, answers have been categorized from 1 (good content and good context), 2 (good content or good context), 3 (insufficient answer) and 4 (totally erroneous answer). A second order categorization was established for categories 1, 2 and 3, to analyse if students' answers are more related to the Physics content or to the context or they are not related to science.

In ITEM 3, a first order categorization attending the feelings (positive, neutral and negative) expressed by the students has been made, and a subsequent second order categorization was performed to determine the kind of action (making, thinking, observing or other) related to that feeling.

In ITEM 4, a first order categorization has been made to determine the kind of difficulty expressed by students in terms of action (making, thinking, observing or other) and a second categorization for the topic of justification (it includes 12 categories related to MBL, lab work, design of experiments, interpreting the graphs, or filling in the worksheet)

RESULTS AND ANALYSIS

Data were analysed in several statistical ways using IBM SPSS software (IBM Corp., 2010): descriptive statistics, analysis of frequencies and comparative analysis (e.g. gender). Non-parametric Mann-Whitney U test (for ordinal data) and chi-square test (for nominal data) were used in comparative analysis (significant level .05).

Most students (92.1%) perceive that they understand the objectives of the activity (M =1.74; SD = .641; N(valid) = 139) as they totally agree (35.3%) or agree (56.8%) with the statement in ITEM 1 (Figure 2a). Nevertheless, when students were asked to list the objectives of the activity (Figure 2b), most of them (54.6%; M = 2.8; SD = .571; N(valid)=110) provided not sufficient answer. That is, students overrated (or overestimated) their opinion about how they understand the objectives of the activity. In fact, only 24.5% of them reported objectives of a good content or context or both (content and context). Only 1.8% of students reported both, good content and good context at the same time. On the other hand, 22.7% of respondents provided either good content or a good context but not both of them, where about 2/3 of answers were related to good content and 1/3 to good context. It is obvious from the analysis of frequencies that most students answered insufficiently when listing the objectives of the activity (69.1%). The complete second order distribution of responses to ITEM 2 is depicted in Figure 3. Mann-Whitney U test (ITEM 1, $U = 2\ 377$; $z = .139$; $p = .890$) and chi-square test (ITEM 2, $p = .225$) revealed no differences in responses by gender.

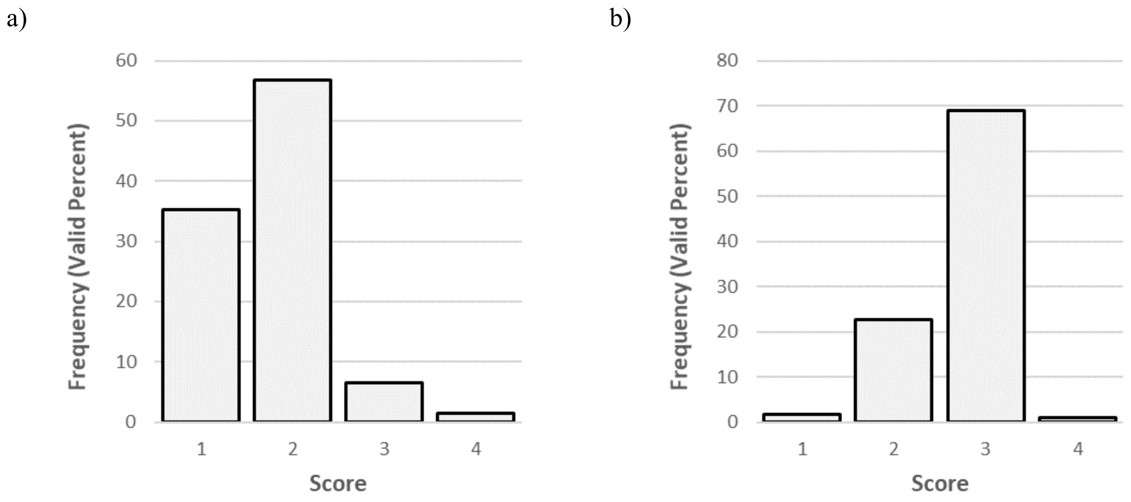


Figure 2. Frequencies of responses to ITEM 1: *I understood the objectives of the activity* (a) and ITEM 2: *List the objectives of the activity* (b)

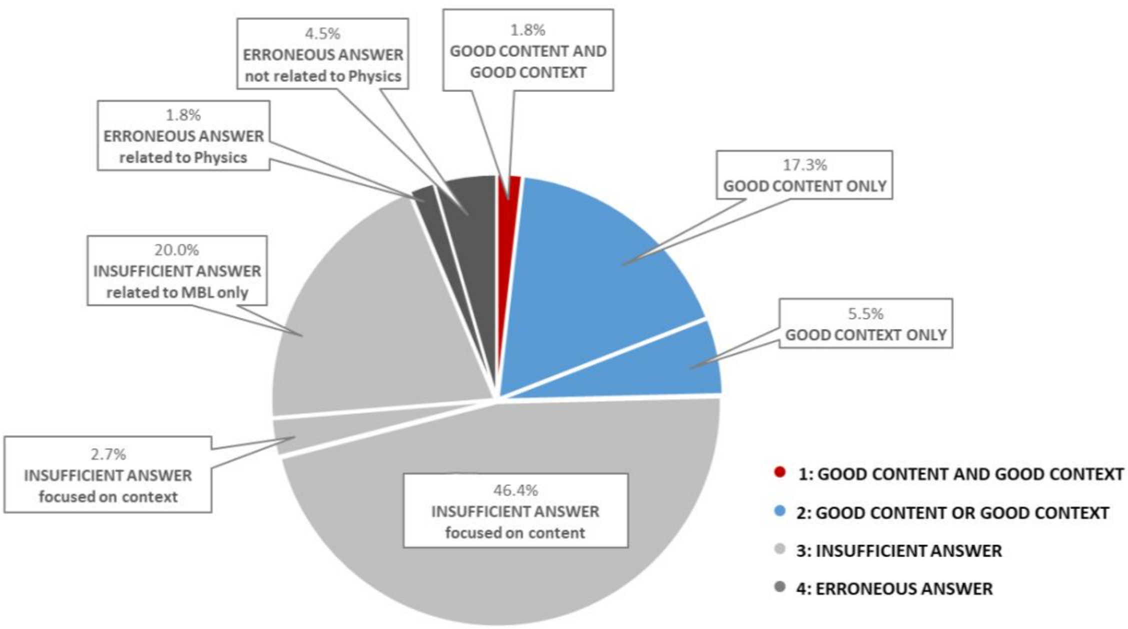


Figure 3. Second order distribution of responses to ITEM 2: *List the objectives of the activity*

It is also important to note that the results mentioned above are based only on valid answers. However, we have accounted 41 respondents (27.2% of total cases) who provided no answer in ITEM 2. During the statistical treatment, these cases were classified as missing values but it is still questionable whether the student with no answer didn't know the answer (to list the objectives) or he/she just ignored answering the item.

In the answers to ITEM 3, most students expressed positive (34.1%) or more or less positive (neutral) (59.3%) feelings. Second order analysis of the responses revealed that students of both groups mainly preferred "making" (88.1% of students with positive feeling and 87.7% of students with neutral feeling). "Thinking" and "observing" where less frequently attractive for the students of both types of feelings expressed (Figure 4).

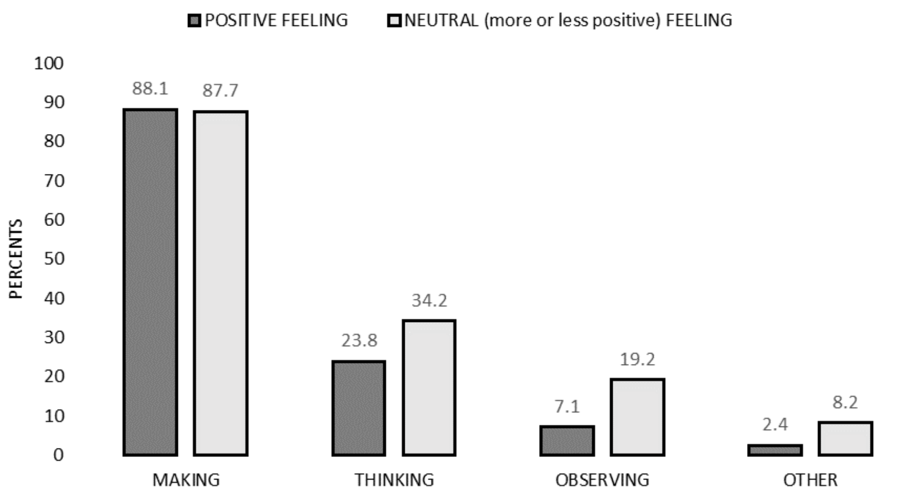


Figure 4. Second order distribution of positive and neutral (more or less positive) students' feelings in ITEM 3: ***What parts of the activity did you like the most?***

Moreover, almost 90% of students with positive and more or less positive (neutral) feeling justified their answer and the analysis shows (Figure 5) that they favoured mostly "working with graphs" (45.0% of students with positive feeling and 58.1% of students with neutral feeling) and "working with sensors of MBL" (37.5% of students with positive feeling and 52.5% of students with neutral feeling). Notice that each student could provide (and mostly provided) more categories of action (making, thinking etc.) and more categories of justification of his/her feeling. This is why the number of responses in second order analysis of students' feeling and its justification extends the number of respondents involved in the study. Again, similarly to ITEM 2, it is still questionable if students who didn't expressed any feeling (28 missing values, almost 1/5 of all cases) didn't want to provide their answer or didn't like anything related to the activity. We have also encountered 8 negative feelings (6.5%). However, none of them was justified, so it is impossible to analyse the reasons.

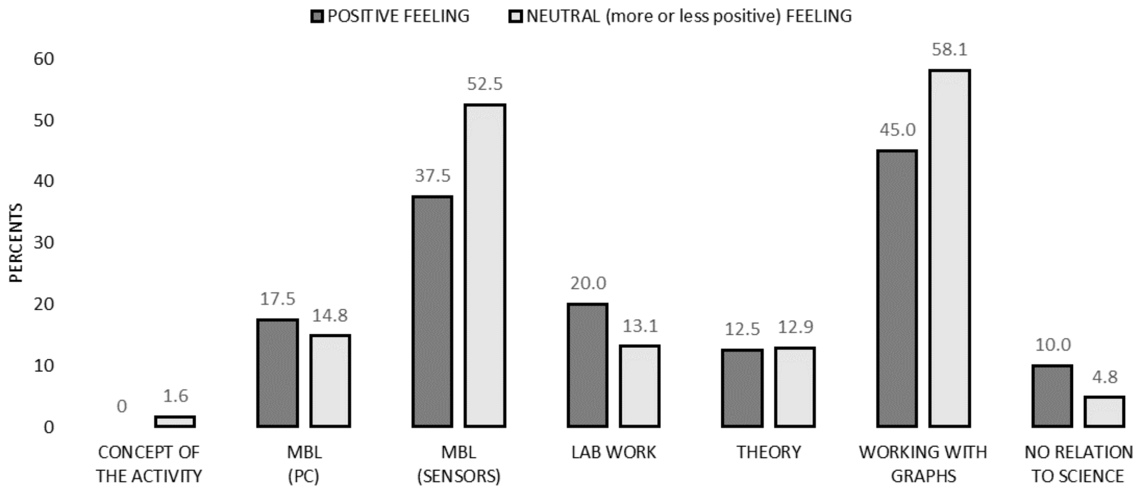


Figure 5. Justification of positive and neutral (more or less positive) students' feelings in ITEM 3

Our records in ITEM 4 show that 89 students (58.9%) reported some difficulties during performing the activity. The analysis of frequencies of difficulties reported (Figure 6) reveals that most of them are related to "thinking" (87.6%). However, more than 1/4 of the valid answers reported difficulties in "making" as well.

The categories in which students reported their difficulties are shown in Figure 7. If we don't take into account that students reported "filling in the questionnaire" as the most difficult thing (the questionnaire for collecting feedback from the respondents), it is interesting to find out that working with graphs was considered difficult in 43.1% of cases. The other difficulties reported were related to the theory (25.0%), explaining and interpreting (19.4%), and only 11.1% working with MBL. Other categories, as designing the experiment, predicting the results, and filling in the worksheets were not reported so frequently. Gender was found a factor not generating the statistically significant difference, as the chi-square test ($p = .151$) revealed no divergence between male and female students in how they perceived potential difficulties.

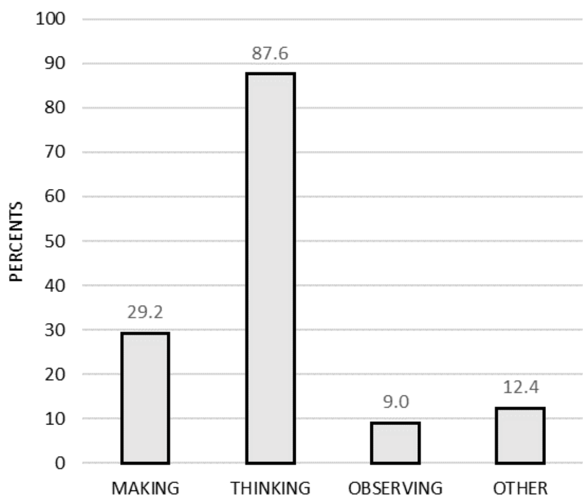


Figure 6. Difficulties of students reported in ITEM 4: ***What parts of the activity did you find the most difficult?***

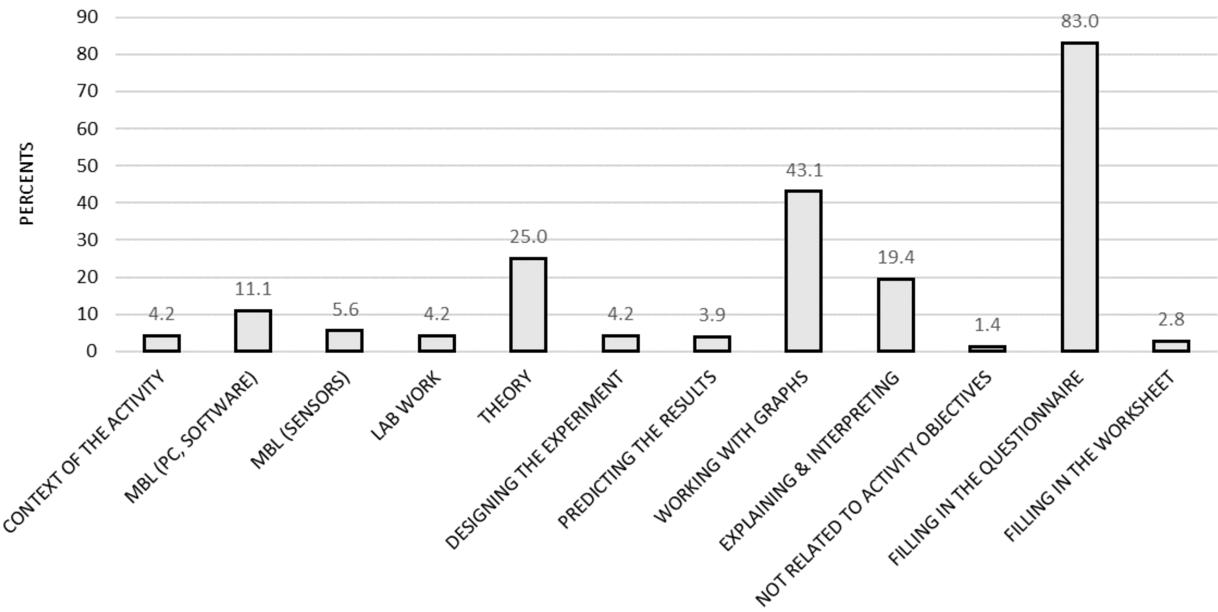


Figure 7. Justification of students' difficulties in ITEM 4

CONCLUSIONS

As regards the first research question - *Do students identify the objectives of the activity*, many of respondents do not express the objectives of the activity at a satisfactory level. Our findings show clearly that the sample of students can be divided into two groups. The first group represents ¾ of students who didn't identify the objectives properly, as 75.4% of them reported insufficient or totally erroneous answers. This fact is worrying even if some of them partially mentioned (but inadequate) ideas related to content, context, MBL, or at least Physics. The other group, representing ¼ of students, provided valid or more or less valid answers. However, it is correct to say that only negligible part of them (less than 2%) provided evidence about comprehending both, content and context of the activity. Most of the students from this group provided either a good content or a good context but not both. Moreover, it is obvious that students who identified the objectives at a satisfactory level perceived them more related to the content than to the context.

In addition, these findings are in contrast with the fact that almost all students (more than 90%) were more or less confident that they understand the objectives of the activity. Linking these findings together, we obtained a strong evidence that students tent to overrate or overestimate their opinion about their own knowledge and their level of understanding. This is why we suppose that there is a couple of new questions arising from our conclusions: (i) *What is the level of students' self-reflection?* and (ii) *Do our findings reflect the general knowledge about the level of students' self-reflection?* However, these questions were not intended to be investigated in this study.

Answering the second research question - *What parts of the activity do students perceive as the best ones*, we can conclude that parts of the activities that students like more are working with sensors and computers (MBL) (62,4%) and working with graphs (53,5%). According to our results, we can resume that students working in the computer-based lab tend to be attracted more by hands-on activities than by thinking or observing. This is a relevant result that highlights the use of MBL and its potential to involve students in working with graphics and measuring equipment.

In response to the third research question - *What kind of difficulties do students perceive in this activity*, it can be summarized that students consider thinking and reasoning the most difficult parts of the activity. One of the interesting outcomes was that more than 40% of students find out difficulties in working with graphs. Paradoxically, they previously reported working with graphs as the part of the activity that they liked the most. However, we suppose that those two perceptions can even coexist because working with graphs can be difficult but attractive for the students at the same time. Our findings also revealed that students really don't have a taste for theory. It was confirmed twice in our study, when students reported "theory" as less attractive part of the activity and also as one of the most difficult part of the activity.

Findings about the difficulties of the identification of the objectives of the activity make us reflect on the activity it-self. COMBLAB activities where reviewed, and refined, but in this case, after results, we consider to include some change in order to enhance the connection between the real situation and what students perform in the lab using MBL equipment, and also to encourage students to design experiments to answer the initial questions.

It should be underlined that these conclusions are related to the analysis of one specific activity, although providing relevant information, the analysis of the results of other activities are needed to allow a deeper understanding before concluding more general outcomes.

ACKNOWLEDGEMENT

We acknowledge The National Project No. ITMS 312011F057, *IT Academy – Education for the 21. Century*.

REFERENCES

Barton, R. (1997). How do computers affect graphical interpretation? *School Science Review*, 79(287), 55-60.

Beichner, R. J. (1990). The effect of simultaneous motion presentation and graph generation in a kinematics lab. *Journal of Research in Science Teaching*, 27(8), 803-815.

Brasell, H. (1987). The effect of real-time laboratory graphing on learning graphic representations of distance and velocity. *Journal of Research in Science Teaching*, 24(4), 385-395.

COMLAB Project (2012). http://comblab.eu. *Average speed control -how to detect the speed of a moving car?* http://www.comblab.eu/sites/default/files/011_phy_body_motion_stud_low_eng.pdf

Guitart, J., Stratilová-Urvalkovà, E. Smejkal, P., & Tortosa, M. (2014). Analysis of students' questionnaires after implementation of research-based activities on the acquisition of science competencies using sensors to real classrooms. In C. P. Constantinou, et al. (Ed.), *Proceedings of the ESERA conference (Part 4)*. Nicosia, Cyprus. 855-863.

IBM Corp. (2010). IBM SPSS Statistics for Windows (Version 19.0). Armonk, NY: IBM Corp.

Pintó, R. Couso, D. & Hernández, M. (2010) An inquiry-oriented approach for making the best use of ICT in the classroom. eLearning Papers 13(20) 1887-1542.

Skorsepa, M. & Tortosa, M. (2014). What do pre-service and in-service teachers think of education in computer-based-lab? In Bilek, M. (Ed.) *Science and Technology Education for 21st cent*ury. 183-195.

Tortosa Moreno, M. (2012). The use of microcomputer based laboratories in chemistry secondary education: Present state of the art and ideas for research-based practice. *Chemistry Educ. Research and Practice*, 13(3), 161-171.

Tortosa Moreno, M., Skorsepa, M., Guitart, J., Urban-Woldron, H., Aksela, M., Tolvanen, S., Stratilova-Urvalkova, E., & Smejkal, P. (2013). Desing of research-based lab sheets for the aquisition of science competencias using ICT real-time experiments. Do students get the point of what they are doing? In C. P. Constantinou, et al. (Ed.), *Proceedings of the ESERA conference (Part 4)*. Nicosia, Cyprus. 695-703.

Urban-Woldron, H., Tortosa, M., & Skoršepa, M. (2013). Implementing learning with sensors in science education: Students' motivational orientations toward using MBL. In C. P. Constantinou, et al. (Eds), *Proceedings of the ESERA conference (Part 4)*. Nicosia, Cyprus, 848-854.

White, R., & Gunstone, R. (2014). *Probing understanding*. Routledge.

Ye, J., Lu, S., & Bi, H. (2019). The effects of microcomputer-based laboratories on students' macro, micro, and symbolic representations when learning about net ionic reactions. *Chemistry Education Research and Practice, 20(1)*, 288-301.

EXPLORING VIEWS OF SPANISH MIDDLE, HIGH SCHOOL STUDENTS AND PRE-SERVICE SCIENCE TEACHERS ABOUT SCIENTIFIC INQUIRY

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The aim of this study is to analyze and compare views of Spanish elementary, middle school students and pre-service science teachers about scientific inquiry (SI). A total of 159 elementary school students, 121 middle school students and 100 pre-service teachers from Spain participated in the study. The Views about Scientific Inquiry [VASI] (Lederman et al., 2014) was used to assess participants' scientific inquiry views. The baseline data will provide, on the one hand, information on what students learn about inquiry in middle and high school and, on the other hand, information on what future science teachers know about inquiry when they start with a science method course in the primary education degree

Keywords: Scientific inquiry, Initial Teachers Training, Middle School Students

STATEMENT OF THE PROBLEM

Scientific inquiry (SI) has been a perennial focus of science education for the past century and it generally refers to the combination of general science process skills with traditional science content, creativity, and critical thinking to develop scientific knowledge (Lederman, 2009). At the same time, recent reform documents have emphasized that students should develop the abilities necessary to *do* inquiry as well as have an *understanding* about inquiry (e.g., *Benchmarks for Science Literacy*, AAAS, 1993; *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas*, National Research Council [NRC], 2011; NGSS; Achieve, Inc., 2013).

In Spain, the Royal Decree 1105/2014, of December 26, regulates the basic curriculum from 7th grade to 12th grade and, for the 11th and 12th grade, this Royal Decree emphasizes the importance of applying the necessary skills for scientific inquiry such as, raising questions, identifying problems, collecting data, designing problem-solving strategies, using models and laws, reviewing the process and obtaining solutions. However, in the classroom few spaces are left to the exploration of phenomena and to the investigation, since teacher performances reflect that teaching is factual and based on the reproduction of concepts (Solbes, Monserrat, & Furió, 2007; Sánchez Cumplido, & Viejo Montesinos, 2012).

On the other hand, scientific inquiry has been introduced in the classroom and in the curriculum through different programs in teacher training and in-service teachers. However, there is no evidence whether, in fact, the students achieve an adequate understanding of the scientific inquiry. The aim of the study was to analyze and compare pre-service teachers and 7th and 12th-grade students' understandings of scientific Inquiry.

SAMPLE, METHOD, DATA COLLECTION AND ANALYSIS

The sample for the middle (MS) and high schools (HS) came from three public middle and high schools in Andalusia and they purposely selected to participate in the international VASI study (two schools from Seville and the other from Granada, Spain provide). The participant sample has been selected keeping in mind its socio-economic level (high, medium and low) and its population representativeness (students from rural, urban and marginal areas). We have contacted teachers who work in schools that present these characteristics by requesting their help on a voluntary basis. The first school is located in a neighborhood next to Seville. The second school from Seville is located in the Eastern District of the city. Finally, the third school from Granada is situated in a rural area halfway between the capital and the coast of Granada. Therefore, we carry out a purposeful sampling that allows us to provide rich and relevant information about the Spanish 7th and 12th-grade students (Patton, 2002). The sample consists of 159 seventh-grade students, 121 twelfth-grade students, and 100 pre-service teachers. The majority were Spanish with, also, students belonging to minority ethnic groups of Gypsies and Muslims. Female and male students were represented is similar proportions in this study. On the other hand, the sample from pre-service teachers (PST) came from a cohort of student teachers from the University of Seville. One hundred preservice teachers consented to participate in the study. The future teachers have a background in science that is a mandatory requirement to become a science teacher in Spain.

The VASI questionnaire was administrated in its paper and pencil version. Most of the students had no difficulties answering the VASI questionnaire. All students had no difficulty in reading, understanding and answering the VASI questions during a period of 60 minutes. After that, two researchers participated during the coding process. Each researcher analyzed each answer in each questionnaire independently and scored each response as naïve (N), mixed (M), and information (I). Blank responses were coded as no- answer (NA). The expected reliability for the VASI study was 80% of the inter-rater coding agreement for each aspect because we were measuring cognitive outcomes and also by typical international convention. After discussing the differences, the values achieve the overall reliability of 90%. Finally, as part of the research protocol, 20% of students were interviewed in order to verify coherency between written answers and thought, and also to confirm that the answers have not been affected by time or other conditions. However, no significant changes were observed.

RESULTS

In general, most of the Spanish students and future teachers show a Naïve or Mixed knowledge of the aspects of Scientific Inquiry (Figure 1). Then, the results are presented describing each aspect of understanding scientific inquiry.

Related, to **Begin with, a Question.** Most of the students 65.4% (MS) and 50.4% (HS) show a naive view about the importance of the questions to begin a scientific investigation and only

12.6% and 17,4% of students show an informed view of this aspect. Some students mentioned that the questions are not important because scientific research can begin with the observation of a phenomenon, problem, experimentation or even testing. 17.6% (MS) and 25.6% (HS) have a mixed view about this aspect and 4.4% (MS) and 6.6% (HS) of students did not answer the question. On the other hand, 30% of the science future teachers (PST) do not mention that the questions are an important aspect to begin an investigation (naive view), 14% expressed a mixed answer about this issue and 54% have an informed view for thi s aspect.

No Single Method: 83.6% of middle school students think that there is just a single scientific method and only 15.7% expressed a mixed response about it. No student expresses that scientists can use more than one method to do science. It seems that students have a reductionist view of the scientific method. Only 0.6% did not answer the question and 84.3% of high school students showed a naïve view for this aspect. In the same way, most future teachers (70%) have a naïve view about this issue, they do not explain the existence of more than one method to do science. 18% have a mixed response and only 12% have an informed view.

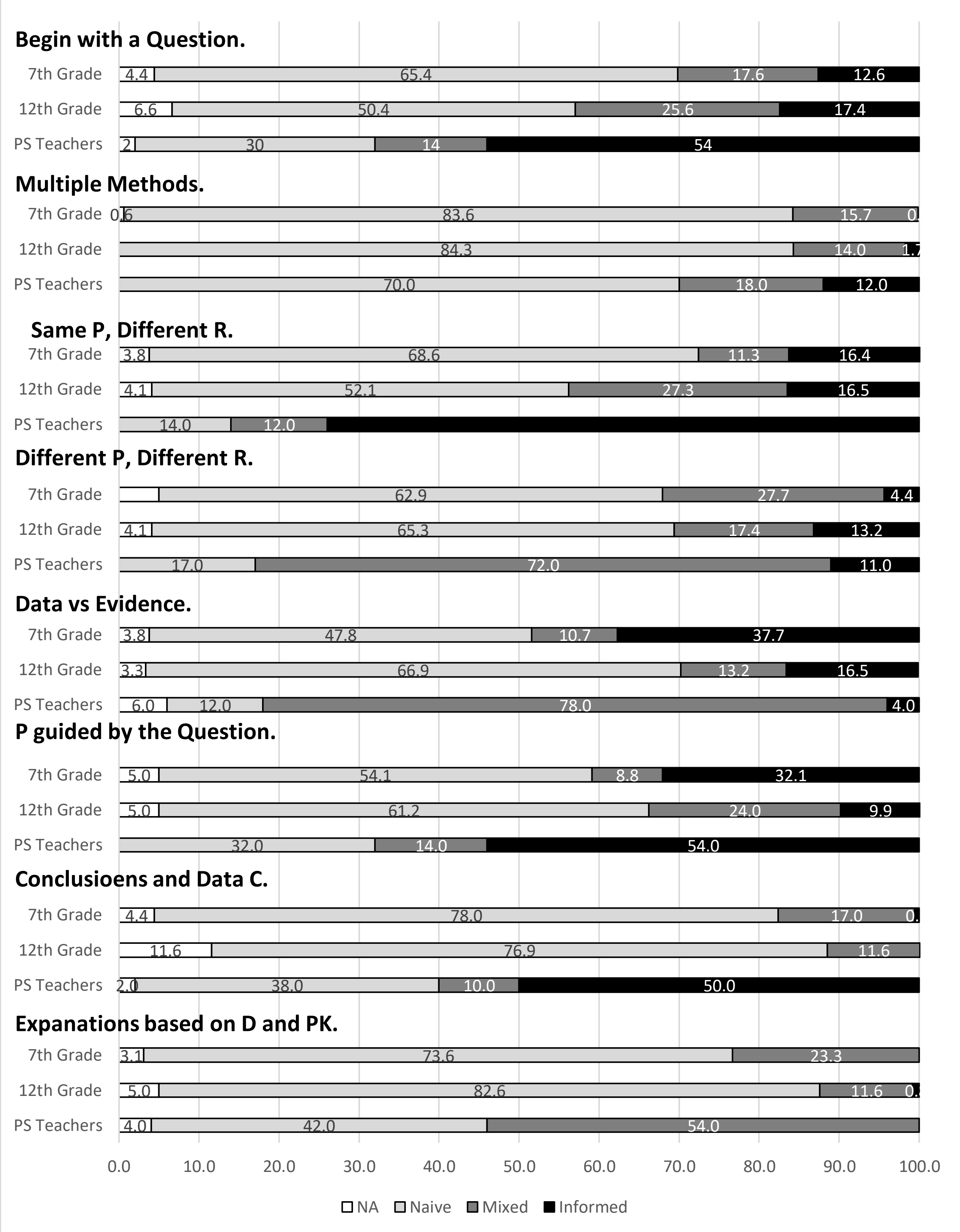

Figure 1. Comparison of Knowledge of SI among 7th grade, 12th grade, and Pre-Service Science Teachers

Procedure guided by Question: 32.1% of the middle school students show an informed view related to procedures are guided by the question asked. On the other hand, 54.1% of the students have a naïve idea about the procedures are designed to answer a question and 8.8% of students showed mixed ideas. Only 5% did not answer this question. Only 9.9% of high school students showed an informed view of this aspect vs 61.2% who showed a naïve view. On the other hand, 54% of future teachers have an informed response about this aspect, 32% have a naïve idea and only 14% express a mixed answer.

Same Procedure, different Results: Only 16.4% of the middle school students think that in from to the same procedures, the researchers can interpret the conclusions differently and get different results because of subjectivity and previous knowledge. On the other hand, 68.6% of the students think that when scientists do the same, they have to get the same results. 11.3% of the students have a mixed view for this aspect and only 3.8% did not answer. For high school students, only 16.5% showed informed views about this aspect and 52.1% exhibited naïve views. Instead, 74% of the future teachers have an informed view about this aspect, 14% a naïve response and 12% a mixed answer.

A different procedure, different results: Only 4% of middle school students showed informed views for this aspect and 62.9% showed naïve views. In high school students, the results are not different, only 13.4% expressed an informed view vs 65.3% with naïve views. Preservice science teachers have similar results than middle and high school students, only 11% of future science teachers are able to show understanding of this aspect and 72% showed mixed views.

Conclusions consistent with Data: 37.7% of the middle school students present an informed answer to this question. However, more than 47.8% still shows a naïve answer. Also, 10.7% show a mixed answer and 3.8% did not answer. This could show little ability of students to critically interpret tables and graphics. On the other hand, most of the high school students showed naïve views for this aspect (76.9%). For the future science teachers, 50% of the future teachers show an informed view, 38% a naïve view, 10% a mixed response. Only 2% did not answer.

Data differ from Evidence: 78% of the middle school students are not able to explain the difference between data and evidence. Showing that, for most of them, data and evidence are the same. 17% have problems to define one or another term. Only one student (0.6%) explain correctly the difference between them, and 4.4% did not answer. In high school students, the panorama is not different, only 16.5% of students showed an informed view and 66.9% showed naïve views for the aspect. In the same line, 78% of the future teachers show a mixed view, 12% a naïve response. Only 4% have an informed view. 6% did not answer.

Explanations developed from Data and existing Knowledge: None middle school students were able to provide an informed answer to this question. Again, more of the half of the students show a naïve answer for this aspect and 74.6% and 23.3% showed a mixed answer for this aspect. Only 3.1% did not answer. Similar to the category Conclusions consistent with data collected, students have difficulty interpreting the information in charts as well as having a naive conception of it. Similar results were obtained for high school students were only one student showed an informed view vs 82.6% who showed naïve views. Finally, 54% of the future teachers have a mixed view, 42% have a naïve response and 4% did not answer.

CONCLUSIONS

More than 50% of high school and high school students show naive responses to all aspects of scientific research. In the case of future teachers, it is distributed among naive, mixed and informed. The analysis of the aspects reveals for the three educational levels the idea that there is a single method for doing science (Lederman, Lederman, & Antik, 2013), the difficulty of differentiating between data and evidence and that the explanations and conclusions are developed from of data and pre-existing knowledge.
It seems that the results emphasize the presence of a positivist perspective of science, conceived as an absolute and true knowledge that is generated and validated whenever we faithfully follow the sequence of steps characteristic of the scientific method (Windschitl, Thompson, & Braaten, 2008; Lederman, Lederman, & Antik, 2013).

The lack of opportunities in the classroom for exploration, the reflection of phenomena and the conduct of research (Sánchez Cumplido & Viejo Montesinos, 2012), the complex and theoretical curriculum and the excessive use of books Text from an early age, maybe reasons that explain the distorted vision of students and future teachers about the aspects analyzed (Senler, 2015).

Developing research activities does not necessarily entail obtaining a sophisticated understanding of the nature of its aspects (Trumbull, Bonney and Grudens-Schuck, 2005). The results obtained provide evidence to the educators of these stages to reflect on the need to explicitly teach the aspects analyzed (Abd-El-Khalick and Lederman, 2000b) and on the strategies that facilitate it.

IMPLICATIONS AND FUTURE RESEARCH

The goal of science education is to develop scientific literacy in every citizen. In order to reach this goal, the citizens need to be able to understand what science is, the process involved in the development of scientific knowledge and also a comprehension of the characteristics of scientific knowledge or nature of science in order to solve daily life problems that have a scientific basis.

Scientific inquiry refers to the process of how science is developed and involved different methods and the development of science skills, but also it is needed to understand the characteristics of scientific inquiry. For that, students, from an early age, must be involved in simple scientific researches that allow them to get an understanding of how science works.

Teachers at schools should include the practice of doing research in the classroom and also help the students to develop an understanding of the aspects of scientific inquiry. Teacher educators should provide a set of strategies and methods to the future teachers that they can apply in their classroom in the future, but also teachers' trainers must provide activities to promote understanding of scientific inquiry. In-service teachers need to modify their current practice at the classrooms from center teacher approaches to student-centered approaches in order that students can show autonomy and be able to carry scientific investigation that allow them to reach an understanding of scientific inquiry.

Finally, this study provide a brief and not generalizable overview about the state of understanding scientific inquiry in Spain classrooms in three levels, middle school, high school, and preservice teacher programs that allows to take some actions in order to improve teaching practices and also promote more active ways of teaching in the classrooms focusing not only in "doing" scientific inquiry but also "understanding" scientific inquiry.

REFERENCES

Abd-El-Khalick, F., & Lederman, N. G. (2000b). The influence of the history of science courses on students' views of nature of science. *Journal of Research in Science Teaching*, *37*(10), 1057-1095.

American Association for the Advancement of Science. (1993). *Benchmarks for science literacy*. New York, NY: Oxford University Press.

Escrivà-Colomar, I., y Rivero, A. (2017).Progresión de las ideas de los futuros maestros sobre la construcción del conocimiento científico a través de mapas generados en una secuencia de actividades. *Revista Eureka sobre Enseñanza y Divulgación de las Ciencias*, 14(1),199-214.

Fernández Palop, M.P. & Caballero García, P.A.(2017). El libro de texto como objeto de estudio y recurso didáctico para el aprendizaje: fortalezas y debilidades. *Revista Electrónica Interuniversitaria de Formación del Profesorado*, 20 (1), 201-217.

Lederman, J. S. (2009). *Teaching scientific inquiry: Exploration, directed, guided, and opened-ended levels.* In National geographic science: Best practices and research base (pp. 8–20). Hapton-Brown Publishers.

Lederman, J. S., Lederman, N. G., Bartos, S. A., Bartels, S. L., Meyer, A. A., & Schwartz, R. S. (2014). Meaningful assessment of learners' understandings about scientific inquiry- The views about scientific inquiry (VASI) questionnaire. *Journal of Research in Science Teaching*, *51*(1), 65-83.

Lederman, N.G., Lederman, J.S., & Antink, A. (2013). Nature of science and scientific inquiry as contexts for the learning of science and achievement of scientific literacy. *International Journal of Education in Mathematics, Science and Technology, 1*(3), 138-147.

National Research Council [NRC]. (2011). *A framework for K-12 science education: Practices, crosscutting concepts, and core ideas*. Washington, D.C.: National Academy Press.

Pozo, J. I., Gómez, M.A. (2010). Por qué los alumnos no comprenden la ciencia que aprenden. *Alambique, Didáctica de las Ciencias Experimentales*, 73-79.

Sánchez Cumplido, Consuelo; Viejo Montesinos, José Luis (2012). Investigando antes de la Universidad: La investigación en los niveles educativos preuniversitarios. *Encuentros Multidisciplinares,* 42, 1-10.

Sanmartí, N., Burgoa, B., Nuño, T. (2011) ¿Por qué el alumnado tiene dificultad para utilizar sus conocimientos científicos escolares en situaciones cotidianas? *Alambique, Didáctica de las Ciencias Experimentales*, 67, 62-69.

Senler, R. (2015). Middle School Students' Views of Scientific Inquiry: An International Comparative Study, *Science Education International,* 26 (2) 2015, 166-179.

Solbes, J, Montserrat, R. Y Furió, C. (2007). El desinterés del alumnado hacia el aprendizaje de la ciencia: implicaciones en su enseñanza. *Didáctica de las Ciencias Experimentales y Sociales*, 21, 91-117.

Trumbull, D. J., Bonney, R., & Grudens-Schuck, N. (2005). Developing materials to promote inquiry: Lessons learned. *Science Education, 89*, 879-900.

Vazquez A., Manassero A. (2012). La selección de contenidos para enseñar naturaleza de la ciencia y tecnología (parte 1): Una revisión de las aportaciones de la investigación didáctica. *Revista Eureka sobre Enseñanza y Divulgación de las Ciencias*, 9(1), 2–31.

Windschitl, M., Thompson, J., & Braaten, M. (2008). Beyond the scientific method: Model based inquiry as a new paradigm of preference for school science investigations, *Science Education*, 92(5), 941-967.

REFLECTION AND INQUIRY-BASED TEACHING: EXPLORING REFLECTIVE PRACTICES IN BEGINNING SECONDARY SCIENCE TEACHERS

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Science teachers' reflections can be used as an opportunity to improve teaching through inquiry-based instruction (White, Frederiksen, & Collins, 2009), especially during their first years as teachers. Yet more work is still needed to support the development of beginning teachers' reflective practices (Russell & Martin, 2014). The purpose of this exploratory multi-methods study was to describe: (a) beginning secondary science teachers' reflective practices up to 4 years after completing their teacher education program, (b) the factors that might have an effect on these practices for participants, and (c) the connection (if any) between their inquiry-based instruction and reflective practices. We used open-ended interviews to describe the participants' reflective practices, applying Cartwright (2011) levels of reflection, and to determine factors that could support or limit their reflective practices. Additionally, we analyzed classroom observations coded using EQUIP to understand the teachers' inquiry-based teaching. We found that novice teachers can develop all levels of reflection, but they tended to be more unconscious when they teach a new course or teach out-of-field. Teaching experience, collaboration among teachers, and whole-school professional development can support science teachers to engage in higher levels of reflective practices. Finally, higher levels of reflection seemed to have a connection to more proficient use of inquiry-based instruction.

Keywords: Reflection, teacher induction, secondary school

INTRODUCTION AND RATIONALE

Secondary science teachers' reflection could support the process of learning how to teach science using inquiry-based instruction (White, Frederiksen, & Collins, 2009), especially in their first years as teachers (i.e., induction phase). Reflection, in the context of teaching, means to "look back" or "think back" at actions and teaching strategies, being able to assess these strategies for improvement and develop expertise focusing attention on certain elements teachers want to develop (Korthagen & Vasalos, 2005; McGregor, 2011; Marzano, Boogren, Heflebower, Kanold-McIntyre & Pickering, 2012). Moreover, reflection as part of a learning process, has a social component (Lovett, 2013). This is, it might start as an individual internalization, but it is enhanced when it is done in communication with others, such as peers or supervisors.

The purpose of this exploratory multi-methods study was to describe beginning secondary science teachers' reflective practices up to 4 years after completing their teacher preparation program. The research questions for this study were: What are beginning science teachers' reflective practices after finishing their teacher preparation program? What factors may affect beginning science teachers' reflective practices? And, what is the relationship (if any) between reflective practices and inquiry-based instruction?

Theoretical framework

Teachers' first years are full of new experiences and learning. New science teachers come to their classrooms with a set experiences inside (e.g., as students, student teachers) and outside (e.g., personal interests) the school, content and pedagogical knowledge, and many expectations and hopes. As novice science teachers gather new experiences within the specific context of their science classrooms, teachers' reflection may support their process of meaning making (Duffy, Miller, Parsons & Meloth, 2009; Rusell & Martin, 2014). Applying the conceptual change framework, after a higher order cognitive task, such as teaching science as inquiry, teachers' reflection supports the process of accommodation and assimilation of new ideas and experiences (Russell & Martin, 2014). Moreover, teachers' reflection should involve a process of high levels of metacognitive thinking to transform teachers' cognitive conflicts and alternative conceptions into new learning (Duffy et al., 2009). In other words, reflection can enhance, modify, or adapt teachers' initial knowledge about science teaching, into new knowledge to improve their practice. Yet, more work is needed to support and understand beginning science teachers' reflective practices (Russel & Martin, 2014), especially when using high stakes science standards (e.g., NGSS) and inquiry-based instruction.

Teachers' reflection is a broad and complex construct that might involve several elements about science teaching. For example, reflection might involve thinking about teacher's mission, identity, beliefs, competencies, or behaviors (Korthagen & Vasalos, 2005). Therefore, to gain a better understanding of beginning teachers' differences on thinking about and capacity to use reflective practices, some scholars have suggested levels of reflection. Although Collin, Karsenti, and Komis, (2013) stated that reflective practices in all levels could be useful for teaching improvement, depending on the pedagogical circumstances, we found Cartwright's (2011) levels of reflection as a helpful analytic lens to view reflective practices (Table 2) and gain a better understanding of the qualities of reflection and possible connections to inquiry-based teaching.

RESEARCH METHOD AND DESING

We used an multi-methods exploratory research approach to conduct this study about beginning science teachers' reflective practices. We followed the requirements of the university's Institutional Review Board. For this study, the participants were beginning science teachers (0 to 4 years of experience), alumni from a university-based, secondary science education program in a Midwestern city in the United States during August 2016-May 2017. We contacted 64 alumni who graduated from the masters level (MAT) or undergraduate (UG) programs between 2013 - 2017. Fifteen teachers agreed to participate (10 females and 5 males; 12 of Western European descent, one Latino, one African American, and one Middle Eastern; two participants came from the UG, while thirteen from the MAT) (Table 1); all of them were participating or participated in some point in a larger longitudinal study about inquiry-based instruction.

Table 1. Summary of Interviewed Participants.

	Gender		Level			School	
	Male	Female	HS	MS	Both	High SES	Low SES
MAT	5	8	9	3	1	7	6
UG	0	2	2	0	0	1	1
Total	5	10	11	3	1	8	7

We conducted open-ended interviews (average of 50 minutes) from August 2016 to March 2017, and included questions to generate reflection about their concept of effective science teaching and factors that might affect their reflective practices, using a grounded theory approach. This is, the data collection and analysis occurred simultaneously using in-process and analytical memos. We transcribed all the interviews for analysis. For teachers participating in the longitudinal study, we observed their instruction at least four times during the school year 2016-2017, wrote detailed field notes, and coded (after a process of calibration) them using the EQUIP instrument (Marshall, Horton, Smart, & Llewellyn, 2008). This tool (EQUIP) analyzes four specific areas of inquiry-based teaching (i.e., instructional, discourse, assessment, and curriculum factors) in a scale 1 to 4, where 1 is labeled as "pre-inquiry" and 4 as "exemplary inquiry". We used 64 coded lessons from 11 participants.

Table 2. Levels of Reflective Practice Indicators for beginning teachers (Cartwright, 2011).

Unconscious Reflection (UR)	Conscious Informed Reflection (CIR)	Conscious Critical Reflection (CCR)
1. Learning as "transmitter of knowledge."	1. Seeks support from different sources (e.g., readings, colleagues).	1. Recognize different ways of approaching a problem.
2. Trial and error. Getting things done for now.	2. Recognizes his/her own feelings.	2. Use different learning strategies.
3. Little evidence, but the lesson appeared to run "smoothly."	3. Evaluates his/her own practice and modifies instruction.	3. Using theory to inform teaching.
4. Accepting intuition to assess effectiveness.	4. Using data to support teaching.	4. Taking risks, but willing to evaluate the results.
5. Considering only his/her feelings.	5. Experience informs teaching.	5. Comparing with other teachers or ideas.
6. Using generalizations or unsubstantiated statements.	6. Using experience as student with meaning as a teacher.	6. Open to other's ideas and criticism.

To identify the level of reflection used by the participants during the interviews, we analyzed them using protocol coding (Miles, Huberman & Saldana, 2014). In MAXQDA, we identified the descriptors listed by Cartwright (2011) (Table 2) in the interview segments. We tallied the number of descriptors found to classify the interview trending as uncounsious (UR), conscious informed (CIR), or conscious critical reflection (CCR). Because all the participants had coded segments in the three levels, we decided to use the level with the most segments. To find out factors that affected teachers' reflective practices, we used an interactive model (Miles et al., 2014); in MAXQDA first we used open coding to condense the data and then, with the themes that emerged, focused coding to reach conclusions. For trustworthy purposes, we used the classroom observations we conducted from the longitudinal study to confirm our emerging themes. We hypothesized that years of teacher experience might have an influence on the level of reflection used by participants.

To find connections between the levels of reflection and inquiry-based instruction, we used the participants' EQUIP coded lessons. Because EQUIP uses an ordinal scale, we calculated the total mode for each participant, grouping the four tool's inquiry areas. We compared these modes with the level of inquiry practices.

ANALYSIS AND FINDINGS

We used the descriptors developed by Cartwright (2011) to identify segments and tallied these descriptors to identify trends (Table 3). Due to space limitations we provide a few examples of the range of teachers' use of reflective thinking practices.

Table 3. Example of coded segments of Unconscious (UR), Conscious Informed (CIR), and Conscious Critical Reflection (CCR).

Descriptor	Participant	Example of coded segments
Learning as "transmitter of knowledge" (UR-1)	David	*I like to bring something to kids that you can use as an example or applied when, in some point, you would have to lecture or explain things. You know, it's like... I like to have like a concrete example to bring…* (12/03/2016, line 50)
Using data to support teaching (CIR-4)	Frank	*I'll look at the grades and that indicates to me either those skills are or aren't being met.* (11/29/2016, line 27)
Using different learning strategies (CCR-2)	Betty	*I think it should be engaging as far as the kids are asking questions and the kids are trying to gather, collect data, generate data, the kids are doing the thinking where they're figuring out how to solve a problem but also they're talking with each other, they're discussing…* (12/01/2016, line 66)

The coded data showed that almost all of the 2nd-year teachers, the largest group in this study, tended to use CIR or CCR (Table 4). This is, teachers with more than one year of experience demonstrated more conscious reflection. Nevertheless, we found teachers with three and four years of experience using UR as well (e.g., Mary and David). Therefore, it seemed years of teaching experience might have an influence but be insufficient to explain the development or lack of change in how teachers engaged with reflective practices.

After each interview, we had a general sense of some participants' overall level of reflection. These teachers' interview analysis showed a strong trend in their number coded segments in one level of reflection. For example, Frank, a 2nd-year teacher, had 77% of his coded segments as CIR; or Jean, a 5th-year teacher, had 72% as CCR. Therefore, we could identify or have a general sense of the level of reflection most used by these participants, even before coding the interview or before tallying the coded segments. But, for other participants, it was difficult to predict their level of reflection after our conversation and analysis, and before tallying their coded segments. We noticed that for these participants the coded segments' trends were not that clear or dominant. In our tally and analysis, at least half (or close) of the coded segments were one level of reflection and half were between the other two (we bolded these participants in Table 3). For instance, Paula, a first-year teacher, had 45% of her segments as UR and 55% between CCR and CIR. Although she had a largest percentage of coded segments as UR, more than half of her interview reflection was in a more conscious level of reflection. Or Betty, with 49% of segments coded as CCR, but 51% in the other two levels (40% as CIR and 11% as UR) (we added an arrow to show where the trend of the second half of the coded segments were). It was interesting to observe that second-year teachers identified as CIR, the biggest group of participants, two of the participants tended toward UR and two toward CCR. Again, reflection is a complex construct. It was clear that experience might help to deepen the level of reflection, but there were other actors that might have an effect in teachers' reflective practices.

Table 4. Participants' Levels of Reflection and Teaching Experience. Participants were categorized based on the highest number of coded segments in that level of reflection (% of coded segments).

Years of teaching experience	Unconscious reflection (% UR)	Conscious informed reflection (% CIR)	Conscious critical reflection (% CCR)
0	**Paula (45)** →		
1	←	**Steve (54)/Gina (48)/** Frank (77)/ **Kate (57) Pam (57)** →	Lucy (75)/Elsa (79)
2	**Henry (52)** →		
3	David (80)		Emma (67)
4	**Mary (58)** →	←	**Betty (49)**/Jean (72)/ Matt (60)

**Bolded names show a not clear classification after analyzing coded segments. The arrows show the trend of the other coded segments.*

Analyzing the context and the participants' answers, we concluded that other factors such as teaching out-of-field or teaching for the first time a science content, independently of the number of years of teaching experience, could have an impact in teachers' level of reflection. For instance, Betty, a 5th-year biology teacher, had coded segments as CCR, such as: "*Well, obviously, I want them to learn science concepts, that's important for scientific literacy. But, I also want them to be able to like think and do critical thinking and be able to analyze things and I want them to be able to organize data and be able to come up with conclusions and arguments and back up what they're saying with evidence.* (CCR-3, 12/01/2016; line 72)". However, she used UR in segments where she described her chemistry course, a new course she was teaching, out of her original biology endorsement. Betty described her chemistry course as "getting things done for now" (UR-2): "*I mean, I really, for chemistry, I'm just taking it day-by-day because I have no idea what I'm doing and I'm just going.* (UR-2, 12/01/2016; line 128). Even though Betty was an experienced teacher using CCR in most of her interview, she applied UR when talked about the courses she was teaching out-of-field (a course different from her original endorsement area). Consequently, these also happened to Paula, the first-year participant. All the other participants classified as CIR were teaching in-field (in their original endorsement area) courses.

Also, collaboration seemed to be a factor that influence participants' level of reflection. Teachers' used CCR when they were involved in whole-school professional development (e.g., "*We had staff meeting yesterday, my principal and I did a… an activity with the rest of the staff of… for this Danielson [model of instruction] and… he hands it out different scenarios and they had to identify which part of the model, the teaching model where they came from, and so… and what we're going to go forward with that is okay would this person be ranked as basic, or proficient, or distinguished, or unsatisfactory or how would we do it. And so, things like that, I think the whole school is kind of on a transition to being much more reflective and… in that way"* [Henry's interview, 09/21/2016; line 90]) and reflected with other teachers (e.g., "*One of the new teachers at the school, me and her actually graduated on the same year of high school, so… We talked quite a bit about things like that. I guess that's probably more like extracurricular talk too, and [we] talk about like well this, we did this yesterday and this didn't work. Then, I'll kind of give her ideas too about like lots of like classic, like last year this is what I ran into and stuff like that so... [Kate's interview,11/10/2016; line 5]*), also confirming the social component of reflection. On the other hand, teachers isolated or being the only teacher of a course in the school (e.g., Mary, the only teacher in her private school teaching science and biology) used a lower level of reflection.

Finally, our findings suggest that teachers tend to use more CIR when they have the habit of documenting their lessons to plan or assess their teaching (e.g., "*And I have for that particular lesson like 5 or 6 okay let's make these macro changes on this particular lesson cause that would help next year's class. And I go say having iterative class and that I take the feedback at each year of what didn't and did work and then updated and change it for next year's class cause if you keep doing that eventually it'll be semi-decent, right?* (Frank's interview, 11/29/2016; line 87), and reflect after assessment practices (e.g., "*I look at the quiz x, usually the kids that struggle, you know, they come and retake it the next Monday, and I do a short re-teaching session* [Emma's interview, 11/02/2016; line 29]).

Table 5. Participants' Levels of Reflection and Inquiry-Based Instruction (EQUIP mode).

Years of teaching experience	Unconscious reflection (Mode)	Conscious informed reflection (Mode)	Conscious critical reflection (Mode)
0	Paula (2)		
1		Steve (1)/ Frank (3)/ Kate (2) Pam (2)	Lucy (3)
2	Henry (2)		
3			Emma (3)
4	Mary (2)		Betty (3)/Matt (2)

Similarly, and according to the participants, the themes that emerged as the mediating factors that teachers perceived as assisting their use of reflective practices were collaboration among teachers (from science or other disciplines) (76% of the participants mentioned this theme), setting goals at the beginning of the school year and follow up meetings with science supervisors, mentors, or first-year teachers' institutes (60% of participants), and whole-school professional development and administrators' involvement (27% of participants). Also, teachers with an open attitude toward change and improvement appeared to use these opportunities more often to think about their teaching (20%). As limitations, 33% mentioned that setting goals at the beginning of the school year without a supervisor's follow up becomes busy-work and does not promote reflective thinking; new teachers (or teaching out-of-field) found difficulties reflecting upon their teaching when they were busy preparing new materials or working on several different activities at the same time that required their attention (47% of participants).

After analyzing the EQUIP coded classroom observations (from the larger study) to identify a level of inquiry instruction and related them to the participants' level of reflection (Table 5), we found that the most common level of inquiry based on EQUIP was "developing" inquiry teaching (i.e., 2). Therefore, we found "developing inquiry" in all levels of reflection. However, CCR participants tended to have a higher level of inquiry instruction (i.e., 3, "proficient inquiry") compared with UR (i.e., 2, "developing inquiry").

DISCUSSION AND CONCLUSIONS

Reflection has been considered for teacher preparation programs and schools as a necessary practice for new teachers and a tool for learning how to teach science (McGregor, 2011). For this study, we had three questions about teachers' reflective practices: (1) What are beginning science teachers' reflective practices after finishing their teacher preparation program? (2) What factors may affect beginning science teachers' reflective practices? And, (3) what is the relationship (if any) between reflective practices and inquiry-based instruction? Based on our findings we will try to answer them.

Beginning science teachers' reflective practices (research question 1)

Analyzing the level of the participants' reflection based on Cartwright (2011), we found that we coded segments using the three levels of reflection for almost all participants. Larrivee (2008b), who developed similar levels of reflection to Cartwright (2011), explained that a reflective practitioner incorporates all levels of reflection. Therefore, it is common to find all levels when a teacher reflects about a teaching event.

Although there were all levels of reflection in participants with the same amount of years of teaching experience, in general, we found that beginning teachers require experience to deepen their level of reflection. Participants teaching in-field and with more than one year of teaching experience tended to use CIR and CCR. This is, teachers use their past experiences to inform their teaching and make instructional decisions. For example, Betty, a fifth-year biology teacher teaching for the first time a chemistry course, tended to use CCR in the interview. However, she used UR when she referred to her chemistry classroom. In the case of Paula, the first-year teacher, her reflection during the interview was dominated by UR segments. Cartwright (2011) explained that teachers learn from their own and others' experiences. Reflection on past experiences and learning strategies can develop teachers' self-efficacy and understanding of themselves as learners (Mycroft & Gurton, 2011). Therefore, experiences can help teachers develop deeper reflection about their strategies. Conversely, a lack of experience might promote superficial reflections that do not lead to improvement.

Factors affecting reflective practices (question 2)

Teachers' reflective practices are complex and not static. Teaching experience can support teachers' deeper reflection but there are other factors, such as the context where the reflections are made, the collaboration with others, and an opened attitude toward change, that might have an influence as well. Malthouse, Roffey-Barentsen, & Watts (2014) defined context as the physical surroundings, social setting, and individual dispositions contributing to the quality of reflection. Therefore, all the later elements might have affected the participants' level of reflection. For instance, busy teachers might tend toward more superficial reflections than those who have more time to stop and think about the past. Also, isolated teachers tend to more unconscious reflection compared to those teachers who have peers or mentors to think about their goals, challenges, and expertise development.

York-Barr, Sommers, Ghere and Montie (2006) viewed reflective teaching as related to collaboration and practice. They came up with the idea that reflection can be performed in four interconnected levels of a spiral that includes individual reflection, reflection with partners (e.g., another teacher, a mentor), reflection in a small group or team, and finally, school-level reflection practice that can result in a "cumulative effect on school wide practices and learning" (p. 21). Our findings support that the outer levels of this spiral (i.e., school and group reflection) will support deeper levels of reflection. The later might be because these outer levels of the spiral create a supportive environment for teachers to grow and adopt a specific practice.

Moreover, other researchers have also supported the importance of the context in which reflection takes place. Edwards and Thomas (2010) insisted that educators should be concerned with developing supportive contexts to enhance reflection as part of social conduct. They argued that the context in which teachers solve problems will have a significant impact in their decisions. Collin et al. (2013) agreed that context might influence teachers' ability to reflect. Supportive school environments can provide opportunities to reflect that will enhance teachers' reflective abilities and metacognition. Larrivee (2008a) explained that "even novice teachers can deepen their level of reflection with powerful facilitation and mediation within an emotionally supportive learning climate" (p. 346). Therefore, a supportive environment in schools where teachers, administrators and the community are involved in teaching science as inquiry will be more effective supporting teachers' deeper levels of reflection.

Relationship between reflective practices and inquiry-based instruction (question 3)

There is a general agreement that reflective practices can improve teaching and learning in the classroom (e.g., Belvis, Pineda, Armengol, & Moreno, 2013). We agree that any level of reflection can help teachers improve their practice (Cartwright, 2011) and that no difference exists between "good" or "bad" reflection (Collin et al., 2013). The effectiveness of reflection depends on multiple factors, such as the purpose, teachers' goals, etc. However, McGregor (2011) found that deepening the level of reflection can make it more meaningful and support teaching improvement and creativity more effectively than lower levels of reflection. The later aligns to our preliminary findings, after analyzing the EQUIP coded lessons. In general, participants in CCR tended to have better inquiry rates than teachers mostly using unconscious reflection.

Conclusions

Some of the lessons learned after this study rely on the idea that beginning teachers' reflective practices are complex and not static. Teaching experience can support teachers' deeper reflection (CCR) but there are other factors (e.g., teaching out-of-field, collaboration, whole-school professional development) that might have an influence as well. Therefore, we conclude that TEPs, schools and learning communities need to promote collaborative reflective environments to prepare teachers to become deeper critical thinkers about their professional careers and their proficiency applying inquiry-based strategies.

Moreover, we acknowledge that the participants' level of reflection during our conversations did not represent the way they reflected all the time and that our bias could have affected our coding of their statements. Instead, our purpose was to understand some of the differences in their reflective practices, as part of their conceptual change as beginning science teachers. We found Cartwright's (2011) levels of reflection adequate to analyze reflective practices and their descriptors as a good tool to promote deeper reflection in TPP or schools. Additionally, understanding some factors that might have an influence teachers' reflection could support the understanding of this skill and its social dimension. Therefore, Cartwright's (2011) levels of reflection could be used as a tool to promote/support/analyze more conscious critical reflection and apply a higher level of inquiry instruction for science teachers during their induction phase.

Finally, applying the descriptors used by Cartwright (2011) and additionally to our findings, we noticed a lack of explicit concern about equity issues in the tool and the participants' comments during these interviews. This was despite the fact that during their student teaching experiences they were largely placed in highly diverse school settings during their teaching preparation program and many of them were teaching at high-needs schools. Our suggestion would be to include descriptors connected to teaching for all students as part of a critical reflection.

ACKNOWLEDGEMENT

We would like to thank to the research group involved in the larger longitudinal study: Lyrica Lucas, Amy Tankersley and Aaron Musson.

REFERENCES

Belvis, E., Pineda, P., Armengol, C., & Moreno, V. (2013). Evaluation of reflective practice in teacher education. *European Journal of Teacher Education*, 36(3), 279–292.

Cartwright, L. (2011). How consciously reflective you are? In D. McGregor & L. Cartwright (Eds.) *Developing Reflective Practice* (pp. 55-68). New York, NY: McGraw Hill Open University Press.

Collin, S., Karsenti, T., & Komis, V. (2013). Reflective practice in initial teacher training: Critiques and perspectives. *Reflective Practice*, 14(1), 104–117.

Duffy, G. G., Miller, S., Parsons, S., & Meloth, M. (2009). Teachers as metacognitive professionals. In D. J. Hacker, J. Dunlosky, & A. C. Graesser (Eds.), *Handbook of Metacognition in Education* (pp. 240–256). New York: Routledge.

Edwards, G., & Thomas, G. (2010). Can reflective practice be taught? *Educational Studies*, 36(4), 403–414.

Korthagen, F., & Vasalos, A. (2005). Levels in reflection: Core reflection as a means to enhance professional growth. *Teachers and Teaching: Theory and Practice*, 11(1), 47–71.

Larrivee, B. (2008a). Development of a tool to assess teachers' level of reflective practice. *Reflective Practice*, 9(3), 341–360.

Larrivee, B. (2008b). Meeting the challenge of preparing reflective practitioners. *The New Educator*, 4(2), 87–106.

Malthouse, R., Roffey-Barentsen, J., & Watts, M. (2014). Reflectivity, reflexivity and situated reflective practice. *Professional Development in Education*, 5257(August 2014), 1–13.

Marshall, J.C., Horton, B., Smart, J, & Llewellyn, D. (2008). *EQUIP: Electronic Quality of Inquiry Protocol:* Reviewed from Clemson University's Inquiry in Motion Institute, https://www.clemson.edu/education/research/centers-institutes/inquiry-in-motion/research-evaluation/equip.html

Marzano R.J., Boogren, T., Heflebower, T., Kanold-McIntyre, J., & Pickering, D. (2012). *Becoming a Reflective Teacher.* Bloomington, IN: Marzano Research.

McGregor, D. (2011). What can reflective practice mean for you… and why should you engage in it? In D. McGregor & L. Cartwright (Eds.), *Developing reflective practice* (pp. 1-19). New York, NY: McGraw Hill Open University Press.

Miles, M.B., Huberman, A.M., & Saldana, J. (2014). *Qualitative Data Analysis: A Methods Sourcebook* (3rd ed.). Washington, DC: SAGE.

Mycroft, L., & Gurton, P. (2011). How can you use reflection to develop creativity in your classroom? In D. McGregor & L. Cartwright (Eds.), *Developing reflective practice* (pp. 107-125). New York, NY: McGraw Hill Open University Press.

Parker, J., & Heywood, D. (2013). Exploring how engaging with reflection on learning generates pedagogical insight in science teacher education. *Science Education*, 97(3), 410–441. doi:10.1002/sce.21049

Russell T., & Martin, A. (2014). Learning to teach science. In N.G. Lederman & S.K. Abell (Eds.). *Handbook of Research on Science Education* (pp. 871-888). New York, NY: Routledge Taylor & Francis Group.

White, B., Frederiksen, J., & Collins, A. (2009). The interplay of scientific inquiry and metacognition: More than a marriage for convenience. In D.J. Hacker, J. Dunlosky, & A.C. Graesser (Eds.), *Handbook of Metacognition in Education* (175–205). New York, NY: Routledge Taylor & Francis Group.

York-Barr, J., Sommers, W. A., Ghere, G. S., & Montie, J. (2006). *Reflective Practice to Improve Schools: An Action Guide for Educators* (2nd ed.). Thousand Oaks, CA: Corwin Press.

ANALYSIS OF LEARNING WITH DYNAMIC MODELS AND EXPERIMENTS IN OPTICS

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Modelling is an essential step in acquiring scientific knowledge, serving as the basis for experimenting and interpreting collected data. The teaching and research project presented in this paper used an online learning environment to prepare students for experiments in optics, implementing dynamic models created with GeoGebra to encourage virtual exploration. The results support the idea that the learning environment enables model-based hypothesis formation. In this mixed-methods study, screen recordings, videos and questionnaires were used to explore how learning with dynamic models and experiments works.

Keywords: Dynamic Visualisation Tools, Video Analysis, Inquiry-based teaching

INTRODUCTION

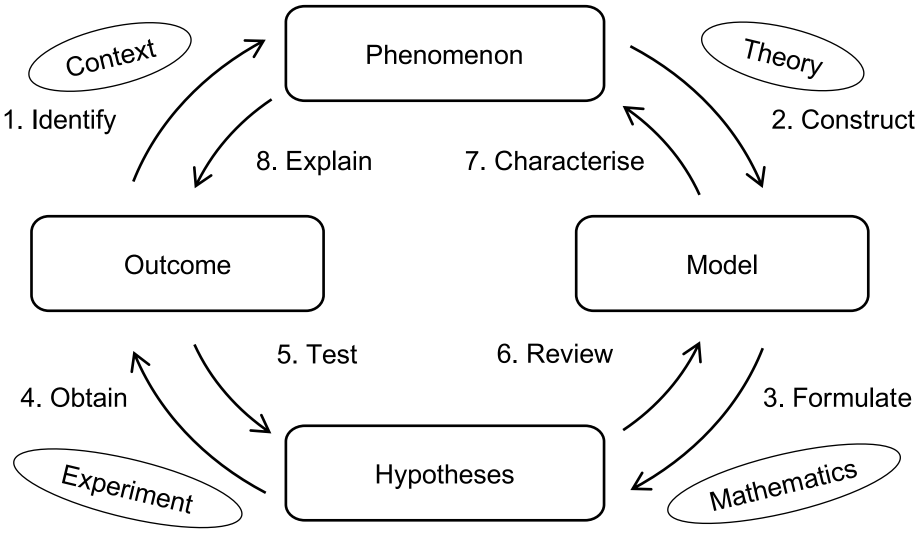
Experimentation is considered the central process of scientific knowledge acquisition in classrooms. However, it is not possible to obtain knowledge from an experiment if subject-specific knowledge and theoretical assumptions are not well presented. One possible way to improve results, explored here, is for students to engage with dynamic models of the phenomenon under instruction.

Scientific knowledge acquisition with dynamic models

Working with models is considered a key capability for research and learning processes (Bailer-Jones, 2009; Thiele et al., 2005). Structural models for scientific thinking or experimental competence aim to depict knowledge acquisition as a problem-solving process with several steps (Mayer, 2007). In general, these are steps to plan, carry out and analyse experiments (Nawrath et al., 2011; Theyßen et al., 2016). However, a model that combines modelling and experimentation in a united problem-solving process would be more appropriate. As a design aid for learning environments, we constructed the cycle of knowledge acquisition shown in Figure 1 (Teichrew & Erb, 2018). The components include four topics (rounded rectangles), which are developed in several steps (arrows) with suitable tools (ovals).

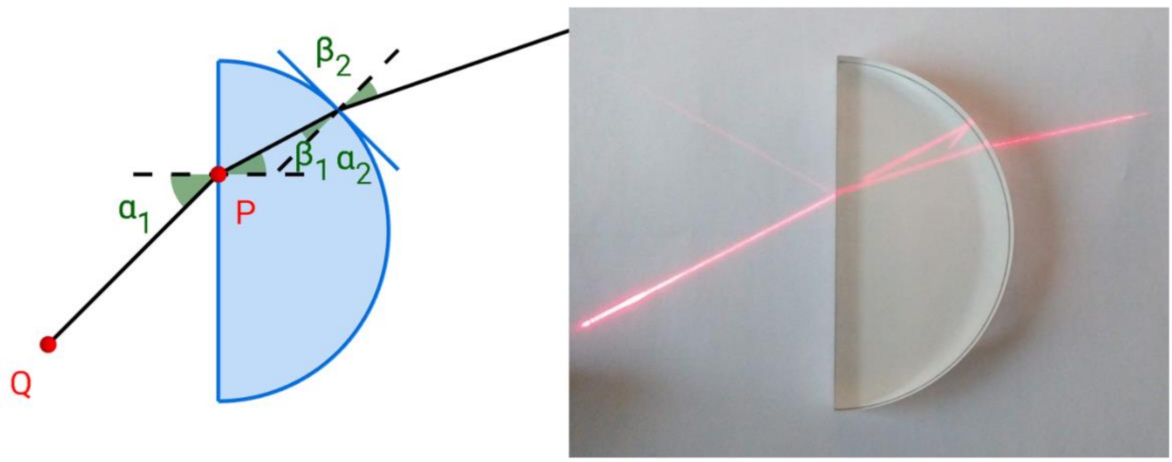
In the first steps, students learn that in order to understand something unknown, they must construct a model for the phenomenon, learn how their model behaves and build their hypotheses from it. The hypotheses are then used to get an experimental outcome. In each of the first four steps, they need input from the learning environment, such as context of the investigation, a scientific theory, mathematics and experimental material. The later steps encourage reflection on the process. Students are directed to test their hypotheses, review their model and identify the limits of it. Finally, they should be able to characterise the phenomenon based on the model and explain new observations with their knowledge of different phenomena.

Figure 1. Cycle of knowledge acquisition with modelling and experimentation.



With dynamic geometry software like GeoGebra, learners can create or work with interactive models, while directly observing the result (Erb, 2016). In this way, they use dynamic representations to construct their own understanding (also referred to as mental models, see Schnotz & Bannert, 2003). At the same time, this exploratory learning activity should produce hypotheses that can be tested experimentally. In this study a dynamic model of refraction of light through a semi-circular disc was used (Fig. 2, left). It contains several variables, principally the entry angle and entry point can be varied in order to analyse different light paths. The instructional materials for the corresponding "real" experiment direct students to produce different paths of light through the disc and the task is to compare observations with the results of the model (Fig. 2, right). At first glance, it is apparent that reality is more complicated and differs from the model. Some reflections distract from the subject under investigation, the refraction of light through the disc.

Figure 2. Example of a dynamic model (left) and the corresponding experiment (right).



Teaching and research project

In order to answer the general research question of the influence on learning outcomes through the interaction with dynamic models and experiments, it is necessary to clarify how to characterise students' approaches. Therefore, we pursued in a mixed-methods study three exploratory research questions:

Q1: How do students interact with dynamic models and experiments in an open learning environment?

Q2: How does hypothesis formation based on a dynamic model work?

Q3: Do cognitive or affective factors have an influence on this learning process and if so which?

Overall, 41 students participated in all parts of the study and answered several questionnaires. Using an online learning environment at home throughout the semester students took part in several lessons on light propagation, reflection and refraction. The core of each lesson was a dynamic model that encourages free exploration and formulation of hypotheses followed by practical work on optical experiments during contact hours at the university. However, research focus was on learning activities related to refraction. First, the participants interaction with the model in Figure 2 on a tablet screen was recorded. After writing down their hypotheses and answering questions about their impressions of the modelling process, the experimentation process with the refraction lab equipment was also recorded.

METHODS

In order to answer the research questions, an integration of qualitative and quantitative data shown in Table 1 was produced. On the one hand, videos were used to measure time on task during modelling and experimentation, adding up the time to read the instructions and modify the model (or work with the equipment). On the other hand, a deductive content-coding, based on the usage possibilities in the model or experiment was carried out. In this case, 12 goals can be achieved in the model and the experiment, whereby following interactions have been counted: Whether a variable was varied (moving one part of the model or the experiment), whether extreme cases were explored (wide variation of a variable), whether relevant settings were found (setting several variables to a certain value).

To answer the second question, hypotheses formulated by the students after their work with the model were inductively coded and divided into three levels with five categories each (111 or 2.8 statements per student in total). Declarative statements about refraction that are probably known from the previous lecture are assigned to Level 1 (55 statements). More complicated hypotheses that included relevant settings for the experiment based on the model are at Level 3 (32 statements). A level in between contains other ideas and observations (24 statements).

In addition, questionnaires were integrated into the learning environment to measure various types of perceived self-efficacy (PSE) such as mathematics, computer use or experimentation (according to Bescherer, 2004; Spannagel & Bescherer, 2009; Körner & Ihringer, 2016). Besides that, various dimensions of intrinsic motivation were measured immediately after interacting with the model (according to Wilde et al., 2009). In this way, influence of different factors can be analysed, such as enjoyment, perceived competence, perceived choice or external pressure. The internal consistency of most factors is satisfying. Furthermore, the students have previously passed a subject knowledge test containing 18 Rasch-calibrated items on the topic of refraction from an item pool from previous studies (Weber et al., 2017). The results were used to estimate prior knowledge using the maximum likelihood method based on item response theory.

Table 1. Mean values and standard deviations of the analysed data.

Constructs and measurements	*n*	*M*	*SD*	*No. of items*	*α*	*Scale*
Modelling time (modtim)	37	358	160	1	-	in s
Experimentation time (exptim)	39	208	161	1	-	in s
Modelling goals (modgoa)	41	6.41	2.93	1	-	from 0 to 12 goals
Experimentation goals (expgoa)	41	5.68	2.56	1	-	from 0 to 12 goals
Number of Hypotheses						from 0 to 5 statements
→ Level 1 (hyplv1)	41	1.34	1.13	1	-	
→ Level 2 (hyplv2)	40	0.53	0.68	1	-	
→ Level 3 (hyplv3)	40	0.73	0.75	1	-	
Subject knowledge ability value (subkno)	41	4.81	1.86	1	-	from 0.96 for 7 of 18 answers to 8.86 for 17 of 18 answers
Perceived self-efficacy						Likert from 1 to 5
→ Mathematics (mse)	41	3.96	0.56	9	.89	
→ Computer use (cse)	40	3.76	0.74	7	.91	
→ Experimentation (ese)	35	3.81	0.32	8	.88	
Intrinsic motivation						Likert from 1 to 5
→ Enjoyment (enj)	39	3.68	0.54	3	.82	
→ Perceived competence (com)	41	3.07	0.74	3	.84	
→ Perceived choice (cho)	39	3.62	0.50	3	.69	
→ External pressure (pre)	41	2.96	0.93	3	.83	reversed

Annotations: N = 41. Adjusted sample sizes result from the omission of outliers.

RESULTS

The interaction with the dynamic model and the corresponding experiment was very heterogeneous in terms of time and goals achieved. That is the consequence of an open learning environment in which no precise learning steps are specified. On average, students spent significantly more time on the model than on experimental verification of it (asymptotic Wilcoxon test: $z = -3.62$, $p < .001$, $n = 35$, $r = .61$), but achieved about the same amount of goals ($z = -.90$, $p = .369$, $n = 41$). The correlation matrix in Table 2 shows that goals correlate stronger with time than with other factors. This result replicates the known connection between time on task and learning outcomes.

Nevertheless, the interaction with the model allowed all learners to formulate their observations as hypotheses. However, the majority were simple statements that had no relation to the special geometry of the refraction medium (Level 1 and 2), but there is a correlation between successful work with the model and the number of Level 3 hypotheses. Overall, the number of formulated hypotheses had no measurable influence on the experimentation process (time and goals).

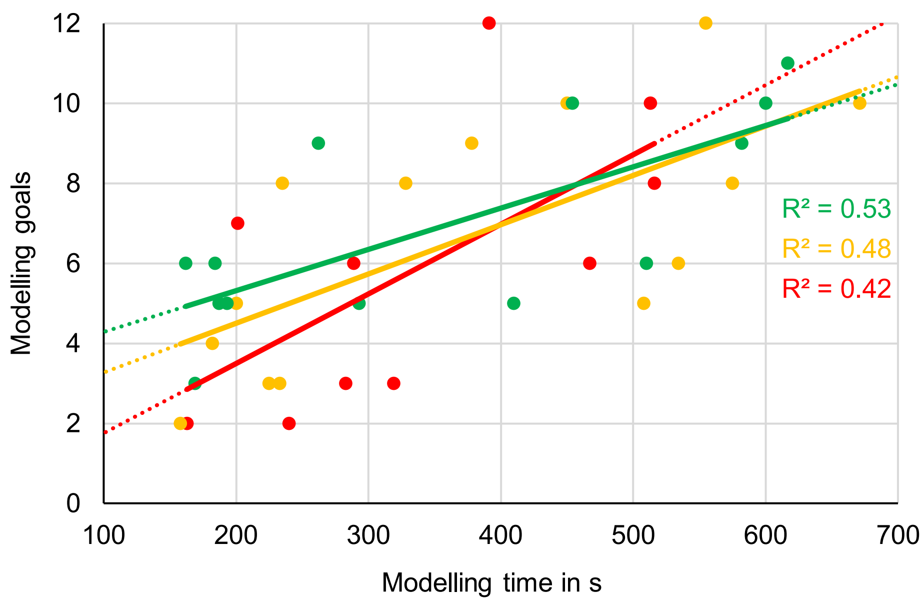
Furthermore, the correlation matrix shows that PSE in mathematics qualifies as a predictor for successful work with the model, in contrast to PSE in computer use and experimentation. In addition to PSE in computer use, it also appears to be helpful for a variety of Level 3 hypotheses. Besides that, motivational factors such as a high level of perceived competence and the absence of external pressure in the modelling process had a positive effect. The correlation matrix also shows that more experimentation goals were achieved by students reported enjoying the modelling phase.

Table 2. Shortened correlation matrix of constructs and measurements.

	modtim	exptim	modgoa	expgoa	hyplv1	hyplv2	hyplv3
modtim	1						
exptim	.	1					
modgoa	.672**	.	1				
expgoa	.	.616**	.	1			
hyplv1	.	.	.	.	1		
hyplv2	.	.	.	.	.	1	
hyplv3	.	.	.386*	.	.	-.309	1
subkno	.	.	.	.	-.448**	.	.432**
mse	.	.	.346*	.	.	.	.406**
cse	.	.	.	.	.	.	.320*
ese	.	.	.	.	.	.	.
enj	.	.	.	.406*	.	.	.
com	.	.	.	.	.	.	.389*
cho	.	.	.	.	.	.	.
pre	.	.	.	.	.	.	.429**

Annotations: Values between -.300 and .300 are hidden. The correlation is significant at the level of *0.05 or **0.01 (2-sided).

Figure 3. Scatter plot of modelling time and goals divided into tertiles based on prior knowledge.



Annotations: Low prior knowledge group in red (n = 10), medium in orange (n = 14) and high in green (n = 13).

Finally, prior knowledge only has a negative correlation with the number of Level 1 hypotheses and therefore a positive correlation with Level 3. On the one hand, this confirms the validity of the content analysis. On the other hand, it seems that the developed learning environment enables a successful interaction with dynamic models and experiments in optics, regardless of the amount of prior knowledge. This impression is confirmed by the graphic analysis of the scatter plot in Figure 3. The low knowledge group achieves less on average in a short time than the high knowledge group, but the students who invest more time can also achieve many of the modelling goals.

DISCUSSION AND CONCLUSIONS

The exploratory research questions were aimed at generating data-based hypotheses about learning with dynamic models and experiments. The study shows that not all students reach their modelling goals in an open learning environment. However, none of the dimensions of intrinsic motivation were measurably responsible for this. The number of modelling or experimentation goals strongly depends on the time invested. At the same time, it was found that the better the prior knowledge, the faster goals can be achieved. As for the formulated hypotheses, more subject knowledge results in a higher quality, but more modelling goals also occur with more Level 3 hypotheses. Based on the results, we expect that using a good learning environment, advanced hypotheses can be formulated based on a dynamic model without much prior knowledge, given enough time. Furthermore, an improved instructional design could help more students to find all the relevant settings for the model and to formulate functional hypotheses. We suggest that this would lead to a purposeful experimentation process and a better understanding of the physics, which will be examined in subsequent studies.

ACKNOWLEDGEMENT

This research was supported by Joachim Herz Foundation. We thank Julian Weide, Laura Sührig and Jelka Weber for assistance with video content analysis.

REFERENCES

Bailer-Jones, D. (2009). *Scientific models in philosophy of science*. University of Pittsburgh Press.

Bescherer, C. (2004). *Selbsteinschätzung mathematischer Studierfähigkeit bei Studienanfängerinnen und -anfängern. Empirische Untersuchung und praktische Konsequenz.* [PhD Thesis]. http://nbn-resolving.de/urn:nbn:de:bsz:93-opus-16269

Erb, R. (2016). *Optik mit GeoGebra*. De Gruyter.

Körner, H.-D., & Ihringer, S. (2016). Selbstwirksamkeit beim Experimentieren – Mädchen und Jungen in den Naturwissenschaften. In C. Wiepcke & M. Kampshoff (Eds.), *Vielfalt geschlechtergerechten Unterrichts: Ideen und konkrete Umsetzungsbeispiele für die Sekundarstufen* (1st ed., pp. 106–140). epubli.

Mayer, J. (2007). Erkenntnisgewinnung als wissenschaftliches Problemlösen. In D. Krüger & H. Vogt (Eds.), *Theorien in der biologiedidaktischen Forschung* (pp. 177–186). Springer.

Nawrath, D., Maiseyenka, V., & Schecker, H. (2011). Experimentelle Kompetenz. Ein Modell für die Unterrichtspraxis. *PdN Physik in Der Schule*, *60*(6), 42–49.

Schnotz, W., & Bannert, M. (2003). Construction and interference in learning from multiple representation. *Learning and Instruction*, *13*(2), 141–156.

Spannagel, C., & Bescherer, C. (2009). Computerbezogene Selbstwirksamkeitserwartung in Lehrveranstaltungen mit Computernutzung. *Notes on Educational Informatics - Section A: Concepts and Techniques, 5(1)*, 23–43.

Teichrew, A., & Erb, R. (2018). Implementierung modellbildender Lernangebote in das physikalische Praktikum. *PhyDid B - Didaktik Der Physik - Beiträge Zur DPG-Frühjahrstagung*.

Theyßen, H., Schecker, H., Neumann, K., Eickhorst, B., & Dickmann, M. (2016). Messung experimenteller Kompetenz. Ein computergestützter Experimentiertest. *PhyDid A - Physik Und Didaktik in Schule Und Hochschule*, *15*(1), 26–48.

Thiele, M., Mikelskis-Seifert, S., & Wünscher, T. (2005). Modellieren. Schlüsselfähigkeit für physikalische Forschungs- und Lernprozesse. *PhyDid A - Physik und Didaktik in Schule und Hochschule*, *1*(4), 30–46.

Weber, J., Winkelmann, J., Erb, R., Wenzel, F., Ullrich, M., & Holger, H. (2017). Ein Fachwissenstest zur geometrischen Optik. In C. Maurer (Ed.), *Implementation fachdidaktischer Innovation im Spiegel von Forschung und Praxis* (p. 107). Gesellschaft für Didaktik der Chemie und Physik, Jahrestagung in Zürich 2016.

Wilde, M., Bätz, K., Kovaleva, A., & Urhahne, D. (2009). Überprüfung einer Kurzskala intrinsischer Motivation (KIM). *Zeitschrift für Didaktik der Naturwissenschaften*, *15*.

COMPARISON OF COMPUTER-AIDED AND HANDS-ON TEACHING APPROACHES ON STUDENTS' ANXIETY TOWARDS SCIENCE

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The present study was conducted to explore the effect of the use of computer-aided and hands-on teaching approaches on 7th grade students' anxiety towards science. The research was carried out in the spring semester of 2016-2017 academic year with the participation of 70 students from two classes of a middle school in Kayseri, Turkey. The pre-test and post-test quasi-experimental design without a control group was used. Within the scope of the study, "Reflection in the Mirrors and Absorption of the Light" unit was taught through computer-aided instruction in experimental-1 group, and hands-on science in experimental-2 group by developing suitable activities for each approach. In the study, data were collected through Science Anxiety Scale. The data were analyzed through paired sample and independent samples t-tests. According to the results, although both two approaches had positive effects on science anxiety levels, it was seen that computer-aided instruction was more effective. In terms of five sub-dimensions of the scale, there is a significant difference between two groups of students' post-test scores in favour of experimental-2 group.

Keywords: Science education, computer-aided instruction, hands-on science

INTRODUCTION

The middle school years are a critical time for learning science. In addition to cognitive characteristics, affective features such as attitude, anxiety and motivation also affect the learning process. There is a close relationship between anxiety and learning (Cüceloğlu, 2015). Anxiety is defined as the feeling that occurs when situations threaten the ability to meet basic human needs such as competence, control, self-esteem (Fiske, Morling, & Stevens, 1996). Although a certain amount of anxiety is usually beneficial for learning, an advanced level of anxiety prevents learning (Cüceloğlu, 2015).

The science anxiety is defined as the total of experiences such as fail to solve a science problem or understand a scientific concept, or failing a science exam (Mallow, 1986). A high level of science anxiety leads to a decrease in students' success and attitude towards science, and discourage them from entering science-related professions (Udo, Ramsey, & Mallow, 2004). The teaching methods used by teachers have important effects on students' science anxiety (Jegede, 2007).

In the literature, it was emphasized that physical phenomena such as light and mirrors are not sufficiently related to daily life and remain abstract, therefore they cannot be understood clearly and cause science anxiety (Colin & Viennot, 2001; Galili & Hazan, 2000). It is thought that active student participation in the science course will enhance students' self-confidence and lower their science anxiety levels (Kaya & Yıldırım, 2014), and enable concretization of the scientific concepts and link them with daily life (Zacharia, 2003). At this point, computer-aided instruction (CAI) and hands-on science (HOS), which play an important role in the concretization of abstract concepts by addressing many sense organs, come to the fore. Computers play an important role in doing dangerous experiments, obtaining and processing data quickly, and providing immediate feedback. It was revealed in several studies that the computer reduces anxiety when it is used for educational purposes (Newhouse, 2002; Rutten, van Joolingen, & van der Veen, 2012). HOS is defined as laboratory activities that allow the students to handle, observe and manipulate a scientific process (Lumpe & Oliver, 1991). In HOS, students work as scientists to learn the scientific concepts permanently- i.e. they conduct experiments, make observations, and collect data. “Reflection in the Mirrors and Absorption of the Light” unit in science curriculum is well suited for teaching through both CAI and HOS approaches, and there is no accessible study comparing the effects of these two approaches on students’ anxiety levels. Therefore, the research question of the current study was determined as “Is there a statistically significant difference between science anxiety levels of the 7th grade students who taught “Reflection in the Mirrors and Absorption of the Light” unit through CAI and HOS?” Within the scope of this research question, the following sub-problems were searched:

1. Is there a statistically significant difference between pre-test and post-test scores of the students in the experimental groups?

2. Is there a statistically significant difference between the post-test scores of experimental groups in terms of entire scale, and in terms of sub-dimensions of the scale?

3. Is there a statistically significant difference between pre-test and post-test scores of the students with respect to the gender?

METHOD

Research Design

In the study, the pre-test and post-test quasi-experimental design without a control group was used. In order to assess the efficacy of each activity the same scale was administered two times, before and after the five-weeks implementation.

Sample

The sample, which was selected through convenience sampling method, consisted of 70 (34 girls, 36 boys) 7th grade students from two classes of a middle school in Kayseri, Turkey in the spring semester of 2016-2017 academic year. While one class including 34 students (17 girls, 17 boys) was assigned to be the experimental group-1 (E1), one class including 36 students (17 girls, 19 boys) was assigned to be the experimental group-2 (E2).

Instrument

Science Anxiety Scale developed by Uluçınar Sağır (2014) was used to determine the students’ anxiety levels towards science in the study. This 5-point Likert scale has 25 items and five sub-dimensions namely; (1) focusing on class, (2) lack of self-confidence, (3) studying and anxiety for the exams, (4) disturbance, (5) interest. These five factors include seven, six, six, four and two items, respectively. While higher total scores obtained from the scale indicate high science anxiety level, lower total scores indicate low science anxiety level.

In addition to the anxiety scale; after a comprehensive review of the scientific literature was conducted, the teacher and student evaluation rubrics were developed by the researchers to be used for classroom observations.

Implementation

"Reflection in the Mirrors and Absorption of the Light" unit in Turkish science curriculum has six main subjects: (1) Mirrors and their usage, (2) image formation in mirrors, (3) interaction of light with matter, (4) white light contains all colors, (5) reflection and absorption of light, (6) the importance of solar energy.

During five weeks (four hours a week), the unit was taught to E1 through CAI, and E2 through HOS. In E1 group, subjects were taught using smartboard, computers through digital images, videos, animations, simulations (i.e. Algodoo), interactive tests, while in E2 group, activities were done with simple, inexpensive materials. In order to ensure validity and reliability, all the courses of each group were systematically observed by two observers, a researcher and a science teacher, using teacher and student evaluation rubrics which were developed by the researchers.

Data Analysis

In order to examine the first, second and third sub-problems, paired-sample t-test and independent samples t-test were conducted using SPSS (Statistical Package for the Social Sciences) version 24.0.

RESULTS

Firstly, according to the independent samples t-test results, no significant difference was found between E1 (M=58.00, SD=10.354) and E2 group (M=57.08, SD=17.130) students' pre-test scores [$t(68)$=0.273, p>.05]. Similarly, no significant difference was found between two groups' pre-test scores in terms of sub-dimensions (p>.05).

Secondly, according to the paired-sample t-test results, for E1 group, there was a significant difference between pre-test (M=58.00, SD=10.354) and post-test mean scores (M=42.68, SD=9.524) in favour of pre-test scores ($t(68)$ =6.006, p<.05). Eta-squared was found as 0.35, suggesting a large effect size (Cohen, 1988). Similarly, for E2 group, there was a significant difference between pre-test (M=57.08, SD=8.145) and post-test mean scores (M=48.36, SD=16.162) in favour of pre-test scores [$t(68)$ =3.989, p<.05]. Eta-squared was found as 0.19, suggesting a large effect size (Cohen, 1988). In other words, CAI activities in E1 group and HOS activities in E2 group significantly reduced the anxiety levels of the students.

According to independent samples t-test results, there is a significant difference between E1 (M=42.68, SD=9.524) and E2 group (M=48.36, SD=16.162) students' post-test scores in favour of E2 group [$t(68)$= -3.392, p<.05]. Eta-squared was found as 0.15, suggesting a large effect size (Cohen, 1988). The results also indicated that there is a significant difference between E1 and E2 groups for all the five sub-dimensions in favour of E2 (p<.05) (Table 1). For focusing on class, lack of self-confidence, studying and anxiety for the exams, disturbance and interest sub-dimensions, eta-squared values were found 0.08, 0.13, 0.06, 0.08 and 0.05, respectively. While 0.05 indicates a small effect, other values indicate moderate effects (Cohen, 1988).

Table 1. Independent samples t-test results according to the average total scores for Science Anxiety Scale sub-dimensions

Sub-dimensions	Group	N	Min.	Max.	M	SD	t-test		
							t	SD	p
Focusing on class	D1	34	7	19	10.18	3.371	-2.487	3.37	0.016
	D2	36	7	27	11.72	5.069		5.07	
Lack of self-confidence	D1	34	6	19	10.94	3.550	-3.153	3.55	0.003
	D2	36	6	29	12.56	5.828		5.83	
Studying and anxiety for the exams	D1	34	6	18	10.00	3.153	-2.127	3.15	0.037
	D2	36	4	12	11.05	4.804		4.80	
Disturbance	D1	34	4	12	7.88	2.332	-2.371	2.33	0.021
	D2	36	4	17	8.67	3.825		3.83	
İnterest	D1	34	2	7	3.68	1.273	-1.896	1.27	0.062
	D2	36	2	7	4.36	1.726		1.73	

In Figure 1, a line chart regarding the pre and post-test mean scores of the E1 for the five sub-dimensions was given. According to the chart, students' mean scores in all sub-dimensions were increased in post-test dramatically.

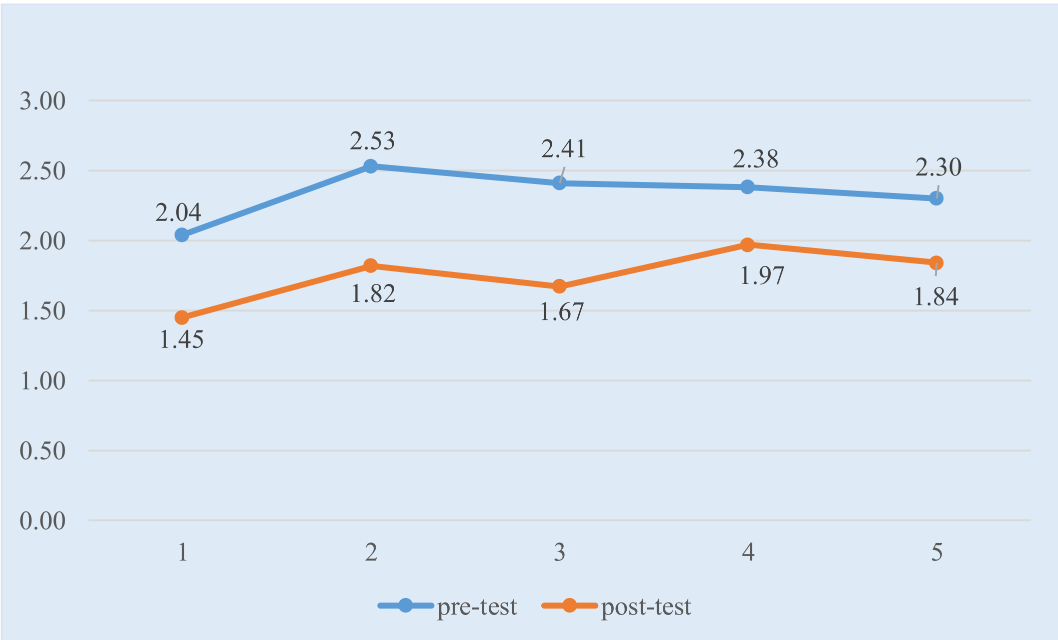

Figure 1. Line chart for the comparison of E1's pre and post-test mean scores regarding the five sub dimensions.

In Figure 2, a line chart regarding the pre and post-test mean scores of the E2 for the five sub-dimensions was given. According to the chart, students' mean scores in all sub-dimensions were increased, but not as much as the students' scores in E1.

Figure 2. Line chart for the comparison of E2's pre and post-test mean scores regarding the five sub dimensions.

Lastly, in order to examine whether there is a statistically significant difference between pre-test and post-test scores of the students with respect to the gender or not, independent samples t-test was conducted. The analysis results indicated that no significant difference was found between both the pre-test mean scores of girls (M=58.40, SD=14.369) and boys (M=57.06, SD=13.219), [$t(68)=-0.435$, $p>.05$], and the post-test mean scores of girls (M=45.02 SD=11.739) and boys (M=46.02, SD=11.756), [$t(68)=-0.375$, $p>.05$].

DISCUSSION OF FINDINGS AND IMPLICATIONS

The research findings revealed that while both teaching approaches decreased students' anxiety towards science, CAI is much more effective than HOS. Unlike HOS, which usually involves collaborative activities, since students usually work individually and feedback is given directly to the student in CAI, the student does not worry about being criticized by his/her teacher or friends when s/he make a mistake. This situation encourages students to participate in the course (Sevim, 2015). It is thought that the use of computer, which the students frequently use in daily life, in the learning process actively makes the students feel more comfortable and decreases their anxiety levels (Newhouse, 2002; Rutten, van Joolingen, & van der Veen, 2012).

The current study is limited to the selected sample and teaching approaches. Thus, it is recommended that future studies be conducted to validate the findings of the current study by incorporating- a larger sample size, different grade groups, a longer period of time, and different teaching approaches.

ACKNOWLEDGEMENT

This research was financially supported by Erciyes University Scientific Research Project Unit, contract no: SDK-2017-7115. The authors are grateful to Erciyes University Scientific Research Project Unit.

REFERENCES

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences*. Mahwah, NJ: Lawrence Erlbaum.

Colin, P. & Viennot, L. (2001). Using two models in optics: Students' difficulties and suggestions for teaching. *American Journal of Physics, 69*(1), 36-44.

Cüceloğlu, D. (2015). *İnsan ve davranışı*. Remzi Kitabevi.

Fiske, S. T., Morling, B., & Stevens, L. E. (1996). Controlling self and others: A theory of anxiety, mental control, and social control. *Personality and Social Psychology Bulletin, 22*(2), 115-123.

Galili, I. & Hazan, A. (2000). Learners' knowledge in optics: Interpretation, structure and analysis. *International Journal of Science Education, 22*(1), 57-88.

Jegede, S. A. (2007). Students' anxiety towards the learning of chemistry in some Nigerian secondary schools. *Educational Research and Review, 2*(7), 193-197.

Kaya, E. & Yıldırım, A. (2014). Science anxiety among failing students. *İlköğretim Online, 13*(2), 518-525.

Lumpe, A. T. & Oliver, J. S. (1991). Dimensions of hands-on science. American Biology Teacher, 53(6), 345-348.

Mallow, J. V. (1986). *Science anxiety: Fear of science and how to overcome it*. Florida: H & H Publishing Company.

Newhouse, P. (2002). *Literature review: The impact of ICT on learning and teaching*. Perth, Western Australia.

Rutten, N., van Joolingen, W. R., & van der Veen, J. T. (2012). The learning effects of computer simulations in science education. *Computers and Education, 58*(1), 136-153.

Sevim, O. (2015). *Kuramdan uygulamaya bilgisayar destekli öğretim materyali geliştirme (Türkçe eğitimi uygulama örnekleri).* Ankara: Nobel Yayıncılık.

Udo, M. K., Ramsey, G. P., & Mallow, J. V. (2004). Science anxiety and gender in students taking general education science courses. *Journal of Science Education and Technology, 13*(4), 435-446.

Uluçınar Sağır, Ş. (2014). İlköğretim öğrencilerine yönelik fen kaygı ölçeği. *Buca Eğitim Fakültesi Dergisi, 37*, 1-20.

Zacharia, Z. (2003). Beliefs, attitudes, and intentions of science teachers regarding the educational use of computer simulations and inquiry-based experiments in physics. *Journal of Research in Science Teaching, 40*(8), 792-823.

DIAGNOSIS OF DIFFICULTY-GENERATING CHARACTERISTICS IN PHYSICAL PROBLEMS

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In general, physics is seen as one of the less favourite school subjects, which has been widely examined in the past. The lessons are perceived as difficult by many pupils, resulting in a deficient number of them choosing physics as an advanced course, or A Levels exam subject. Explaining the difficulty of physics lessons, essential features of physics are often suspected, such as experimental work, thinking in models, mathematization, dealing with different forms of representation, or just the scientific language. Although these individual features have been empirically referenced, their impact on pupils' perception of the difficulty has not been examined sufficiently. Based on four main categories established by Merzyn (2008), this project examined pupils' problems while solving physical tasks, each with an increased share of scientific language, mathematization, modelling or a lack of reference to everyday life. While solving the tasks, the method of thinking aloud was used to answer the following questions: What characteristics make physical problems difficult for pupils while solving a task? How do pupils perceive the problem's level of difficulty? Can pupils articulate a particular difficulty-generating characteristic to ask for targeted support? In an ensuing interview, the pupils were asked to rank the problems according to their level of difficulty and to reflect on the difficulties and individual hurdles during the solving process.

Keywords: Physics, Problem-solving, Task difficulty

THEORETICAL BACKGROUND

As so many pupils see physics as their least-liked school subject (Williams et al., 2003; Bennett & Hogarth, 2006; Fruböse, 2010; Caglar-Öztürk, 2015), it is interesting to explore the main reasons for this unpopularity. Especially its widely perceived difficulty has been stated many times (Ford, 1989; Angell et al., 2004; Ornek et al., 2008). This is also reflected in the alarming results of the PISA survey (OECD, 2016) which are worthy of improvement and brought problem-solving to public attention, as experts feared after those results, that pupils would not learn to deal with real problems in everyday life (Kühn, 2011). Daily and physical problems, as well as the problem-solving competence, will be explained hereafter.

In a previous work (Fareed & Winkelmann, 2019), several factors that are believed to make physics difficult have been examined. Most frequently mentioned, by both male and female pupils, are the following difficulty-generating characteristics: lack of relevance in the daily life, need of personal effort, use of technical terms, modelling and idealisation of physical problems. These factors coincide with the main categories by Merzyn (2008) and will be further explained in the following.

(Physical) Problems and Problem-solving

Although the two terms "problem" and "task" are mostly used synonymously, it is helpful to define them, as well as the process of problem-solving in cognitive psychology. While a task predominantly describes one single (part) of an exercise or question, a problem serves more as a collective term, from which related terms like problem-solving derive (cf. Brandenburger, 2016). Dörner (1976) defines a situation as a problem if a person strives to turn an unpleasant initial state into an opposite final state. A barrier in between prevents the person from doing so, which might be a lack of methods or the final state not being defined properly. Following Smith (1991), every item that needs analyses and conclusions (concluding knowledge of the relevant domain) is defined as a problem. In order to reach the desired final state, a person must make use of problem-solving strategies. Problem-solving is an essential condition to act in simple daily situations, in scientific questions, or in complex socially relevant political and economic problems (cf. Reif, 2008; Brandenburger, 2016). In school, problems need to be solved daily. The ability to do so is called problem-solving competence, which is defined as "an individual's capacity to engage in cognitive processing to understand and resolve problem situations where a method of solution is not immediately obvious […] in order to achieve one's potential as a constructive and reflective citizen" (OECD, 2014). In school, it is also a key competence necessary in all subjects and fields (cf. Brandenburger, 2016) and required in national educational standards and curricula. Therefore, the focus of our research is on the problem-solving competence, which enables students to deal with the presented physical problems successfully. Those problems result from reality; in order to process them appropriately for pupils, they are represented by means of idealization and simplification. Physical models depict those phenomena of everyday life professionally in the form of representations, which are to be solved with mathematical tools. Thus, multiple characteristics are faced, which can generate difficulties during the problem-solving process.

Difficulty-generating Characteristics in Physical Problems

As mentioned at the beginning, Merzyn (2008) collected pupils' impressions of difficulty and sorted them into four prominent categories. These are a) the technical jargon, b) the use of mathematics and quantitative calculations, c) physical statements that are inconsistent with expectations from everyday life, and d) a high degree of abstractness and modelling. These four main categories are difficult to separate in school, as they overlap a lot. They served as a basis for this study, which was conducted to examine the impact of the characteristics on task difficulty.

In school, it is useful to include everyday life phenomena as a context for solving physical problems. Those contexts also help in training scientific literacy (cf. Dorschu, 2013). By applying knowledge to other contexts, it is linked and transferred more strongly, as learning never happens in an isolated way. In this way, physics gets closer to the pupils' lives and more problem-oriented, so authentic problems are needed in class. Furthermore, the higher motivation which comes with it helps create a better attitude of the pupils towards physics lessons (cf. Merzyn, 2008). The ideas of everyday life phenomena are retrievable like previous knowledge (cf. Lehner, 2012), whereas incorrect ideas and preconceptions need to be corrected.

Physics has a high level of abstract words which are used in a technical way (cf. Fruböse, 2010). This results in a contrast between physical language and everyday language (cf. Merzyn, 2008), and is especially difficult when terms are used in both domains with different meanings.

Mathematics plays an essential role in physics. On the one hand, it acts as a helpful tool for capturing physical correlations quantitatively. On the other hand, it helps with formulating precise statements about physics, making it a medium for communication (cf. Pospiech et al., 2015). Furthermore, numerous fundamental physical concepts consist of mathematical operators, making mathematics and physics closely linked and hard to separate. Moreover, mathematics is used for modelling, in order to predict and simplify phenomena (cf. Trump & Borowski, 2012). But transferring mathematical knowledge to physics is often problematic for pupils (cf. Taşar, 2010), as they cannot apply the right knowledge flexibly to physical problems and therefore use mathematical strategies which are inconsistent with the problem (cf. Uhden, 2012).

Scientific models are distinguished through two essential features. The illustrating feature means that a model is the projection of an object, while the reducing feature means that a model includes only a subset of all attributes of an object (cf. Kircher, 2010). Therefore, there are elements of an object which are not part of the model, resulting from the method of idealizing. Idealization means neglecting aspects of reality in a theoretical model which would complicate it (cf. Lehner, 2012). Furthermore, models are always linked to an issue and a purpose, thus they include the opinion of a person or a certain intention for formulating and analysing hypotheses about experiences (cf. Krüger et al., 2018). Another argument in favour of including models in physics class is the fact that they are a way of treating physical subjects like in real scientific research, which can be motivating for pupils (cf. Leisen, 1999).

STUDY DESIGN

Research Questions

In this project, based on the presented background, the following research questions are addressed:

1. Do pupils articulate the difficulty-generating characteristics suspected in the referred literature while trying to solve physical problems?

2. Can pupils use the detected characteristics to overcome difficulties in the solving process by purposefully asking for support?

Preliminary Study

In the preliminary study, experts (n = 25) on creating lesson material (active and retired teachers, scientific assistants, and university professors) were to evaluate, based on the problems we have created, what constitutes the difficulty-generating characteristic which is deliberately built into the task by us. Here, the experts were not required to solve the tasks, but only to find out what is the hurdle that makes the task difficult. The difficulty-generating characteristics that were incorporated are those mentioned before in the theoretical background and have been worked out by Fareed & Winkelmann (2019). This preliminary study was conducted as a validity check of whether experts can recognize the difficulty-generating characteristics in the problem.

Main Study

In the main study, a two-stage qualitative case study, two types of testing were performed. First, our group of pupils (n = 9), was presented with physical problems on four different worksheets. The group consisted of high school (Gymnasium) pupils in the German E-Phase (pre-A levels, year 10, or 11). All the problems dealt with the issue of freefall, which is part of the curriculum of that year. The pupils were asked to articulate their method of solving the freefall situations on each worksheet. Every single problem was designed consisting of a certain built-in characteristic that made the task difficult (cf. preliminary study, above). The pupils' statements were recorded, and they were supervised by one of the study leaders while solving the problems within a time span of 45 minutes, each pupil on his or her own. In their attempt to solve the tasks, they were motivated to use the method of thinking aloud (cf. measuring instruments, below) to explain their solving techniques.

At the end of the thinking aloud phase (second stage), the pupils were to reflect on what was difficult in the individual tasks, and the resulting interviews were then used to check whether the statements match our assumptions. A guideline-based interview supported the pupils' reflection on identifying individual hurdles in the different given problems. First, they had to rate the four worksheets with regard to the level of difficulty. Secondly, every worksheet was discussed regarding each intended characteristic, and the pupils were asked what exactly made the solving process difficult or impossible. In the end, the pupils' half-term marks in physics and their satisfaction with the subject were recorded.

The objectivity of the study was ensured by working with an observation sheet that provided a pre-structured guide to the analysis of the recordings, including keywords which point to the individual characteristics. The recordings were transcribed in order to analyse them qualitatively, according to Mayring (2015).

Measuring Instruments

1. Physical Problems and Rating Sheet

In the preliminary study, the experts received four different worksheets, each of which contained a physical problem with one individual difficulty-generating characteristic. By the experts, this characteristic only needed to be recognized and named without having to solve the problem. For this purpose, the experts received an additional rating sheet to help them to identify the corresponding difficulty-generating feature. Using a five-point rating system, they had to evaluate which feature occurs to what extent in the task. Additionally, we checked the inter-rater reliability.

In addition to the worksheet covering the technical jargon, an alternative one was prepared for the pupils to compare them in the reflection phase. On the alternative version, all technical terms were wiped out, and physical phenomena were explained in simple words.

2. Recordings of the Thinking Aloud Phase

In the main study, the pupils were given the worksheets with the built-in difficulty-generating characteristics, and they were then encouraged to solve them. Successful solving was not required, which the pupils were told beforehand. While solving the problems, the pupils were asked to formulate their thoughts out loud, which was recorded via voice recorder. The voice recordings of the thinking aloud phase were transcribed and served for further analyses.

Qualitative research formed the approach of the study since the openness and flexibility of the qualitative method make it possible to freely and exploratively analyse the pupils' way of solving the tasks and generating hypotheses. Furthermore, the method of thinking aloud is used to capture insights into the mental part of the problem-solving process, which is very complex and sometimes unobservable. Thinking aloud always happens parallelly to the primary task (cf. Völzke, 2012).

3. Guideline-based Interview

The observations from the problem-solving phase were used to ask what the personal difficulty was specifically for each pupil. Also, all difficulty-generating characteristics were addressed, so that the pupils could connect each general difficulty with a concrete problem situation and sort these according to the perceived difficulty.

RESULTS

In the preliminary study, the validity of the material was checked. Unfortunately, only two of the expert questionnaires were sent back to the institute in time to analyse them for this study, so there cannot be drawn adequate conclusions. Moreover, there could be seen a big inter-rater discrepancy between those two questionnaires, so that the preliminary results were not used for the final evaluation.

The main study enabled in-depth structural analyses of problem situations. The pupils' statements during the thinking aloud phase and in the reflective interview suggest that they have issues formulating concrete difficulties and are not able to ask for targeted support concerning the difficulty.

Furthermore, the study should give a brief insight into the pupils' ability to solve physical problems in the sense of identifying the difficulty of the individual problem. Different difficulties can dominate different problems. The identification of those individual hurdles could help the pupils to solve the problem.

Regarding the four examined difficulty-generating characteristics, especially the modelling and idealising, get into the focus. The pupils agreed that exercises with models are rarely used in class. While solving the modelling worksheet, the pupils found it rather motivating that they did not have to calculate at first. They tended to idealize the wrong details, though, in order to approach their model. For example, some pupils thought about the constitution of the landing ground while modelling a suitable parachute situation.

Before pupils have to use advanced mathematics in a problem like the presented one (here: using the reduced quadratic equation), the sense of the problem has to be understood by modelling it. Most of the pupils already failed in this situation, which confirms earlier studies (cf. Angell et al., 2004).

Technical jargon in physical problems was perceived as both an advantage and a disadvantage. On the one hand, new physical terms first sounded difficult and confusing, but on a closer look, they helped in founding the right formula. In the reflection interview, the pupils had to compare it to the alternative version without the technical terms. They perceived that version as childish and not helpful in solving the problem. Last, the pupils expressed the wish for a higher level of everyday life references in all the worksheets.

SUMMARY & OUTLOOK

The results of the study show that it seems worthwhile to focus more on modelling in physics class. On the one hand, pupils express more interest in this kind of exercises, and on the other hand, they show big difficulties in solving the problems.

Almost all pupils complained that they were not able to solve the problems due to the lack of important formulas. The reason for this might be the long period between learning the subject in class and the study, as the issue of free fall had been discovered in the first half term of that year and thus had been a few weeks earlier. The required formulas could have been repeated in preparation for the study, but it would have distorted the results.

Contrary to the literature, the characteristic of the technical jargon was often not perceived as hindering, but as helpful for deriving the necessary formulas. Nonetheless, in future studies, the material should be designed more clearly and unambiguously with the required formulas given, in order to focus more strongly on the actual difficulty-generating characteristics.

Regarding the second research question, if pupils can use the detected characteristics to ask for targeted support, we can see that they were not able to do so. In conclusion, pupils should be sensitized more in class for difficulty-generating characteristics, to facilitate the search for support. One possibility might be the reflection about individual hurdles while trying to solve physical problems.

ACKNOWLEDGEMENT

We thank the Equal Opportunities Council of the physics department at Goethe University in Frankfurt, which supported the presentation of this project at the ESERA 2019 conference financially.

REFERENCES

Angell, C., Guttersrud, Ø., Henriksen, E. K., & Isnes, A. (2004). Physics: Frightful, But Fun. Pupils' and Teachers' Views of Physics and Physics Teaching. *Wiley Periodicals Sci Ed, 88*, 683–706.

Brandenburger, M. (2016). *Was beeinflusst den Erfolg beim Problemlösen in der Physik? Eine Untersuchung mit Studierenden*. Berlin: Logos.

Bennett, J. & Hogarth, S. (2009). Would YOU Want to Talk to a Scientist at a Party? High School Students' Attitudes to School Science and to Science. *Science Education, 31,* 1975–1998.

Caglar-Öztürk, Y. (2015). Interessenforschung – Werden Naturwissenschaften und Mathematik immer unbeliebter? *Delta Phi B*, 1–9.

Dörner, D. (1976). *Problemlösen als Informationsverarbeitung*. Stuttgart: Kohlhammer.

Dorschu, A. (2013). *Die Wirkung von Kontexten in Physikkompetenztestaufgaben.* Berlin: Logos.

Fareed, B. & Winkelmann, J. (2019). Schülerwahrnehmung von Schwierigkeit des Physikunterrichts und der kognitiven Aktivierung durch die Lehrkraft. In H. Grötzebauch & V. Nordmeier (Hrsg.). *PhyDid B – Didaktik der Physik, Beiträge zur DPG-Frühjahrstagung des Fachverbands Didaktik der Physik in Aachen 2019*. Beitrag DD. 02.11.

Ford, K. W. (1989). Is physics difficult? *American Journal of Physics, 57*, 871–872.

Fruböse, C. (2010). Der ungeliebte Physikunterricht. Ein Blick in die Fachliteratur und einige Anmerkungen aus der Praxis. *Der mathematische und naturwissenschaftliche Unterricht, 63*(7), 388–392.

Kircher, E. (2010). Modellbegriff und Modellbildung in der Physikdidaktik. In: Kircher, E., Girwidz, R. & Häußler, P. (Hrsg.). *Physikdidaktik. Theorie und Praxis*. 2. Aufl. Berlin, Heidelberg: Springer, 735–762.
Krüger, D., Kauertz, A. & Upmeier zu Belzen, A. (2018). Modelle und das Modellieren in den Naturwissenschaften. In: Krüger, D., Parchmann, I. & Schecker, H. (Hrsg.). *Theorien in der naturwissenschaftsdidaktischen Forschung*. Berlin: Springer, 141–157.
Kühn, S. M. (2011). Weiterentwicklung der Aufgabenkultur im naturwissenschaftlichen Unterricht der gymnasialen Oberstufe und im Abitur. *Zeitschrift für Didaktik der Naturwissenschaften, 17*, 35–55.
Lehner, M. (2012). *Didaktische Reduktion*. Bern: Haupt.
Leisen, J. (1999). Modellbildungssysteme. Didaktische und methodische Aspekte. *Praxis der Naturwissenschaften Physik, 48*(2), 1–3.
Mayring, P. (2015). *Qualitative Inhaltsanalyse. Grundlagen und Techniken.* 12., überarb. Aufl. Weinheim, Basel: Beltz.
Merzyn, G. (2008). *Naturwissenschaften, Mathematik, Technik – immer unbeliebter? Die Konkurrenz von Schulfächern um das Interesse der Jugend im Spiegel vielfältiger Untersuchungen*. Baltmannsweiler: Schneider Verlag Hohengehren, 5–96.
OECD (2014). *PISA 2012 Results (Volume V). Creative Problem Solving: Students' Skills in Tackling Real-Life Problems*. Paris: OECD Publishing.
OECD (2016). *PISA 2015 Results (Volume I). Excellence and Equity in Education*. Paris: OECD Publishing.
Ornek, F., Robinson, W. R., & Haugan, M. P. (2008). What makes physics difficult? *International Journal of Environmental & Science Education, 3*, 30–34.
Pospiech, G., Uhden, O. & Geyer, M.-A. (2015). Modell der mathematischen Modellierung in der Physik. In: Bernholt, S. (Hrsg.). *Heterogenität und Diversität – Vielfalt der Voraussetzungen im naturwissenschaftlichen Unterricht*. Gesellschaft für Didaktik der Chemie und Physik, Jahrestagung in Bremen 2014. Kiel: IPN, 199–201.
Reif, F. (2008). *Applying cognitive science to education: Thinking and learning in scientific or other domains*. MIT, Cambridge MA.
Smith, M. U. (1991). *Toward a unified theory of problem solving: Views from the content domains*. Lawrence Erlbaum Associates, Hillsdale NJ.
Taşar, M. F. (2010). What part of the concept of acceleration is difficult to understand: the mathematics, the physics, or both? *ZDM Mathematics Education, 42,* 469–482.
Trump, S. & Borowski, A. (2012). Mathematikkompetenz beim Lösen von Physikaufgaben. Evaluierung und Elaboration eines Kompetenzmodells der Mathematik für die Physik der Sekundarstufe II. *phydid B Beiträge zur DPG-Frühjahrstagung*.
Uhden, O. (2012). *Mathematisches Denken im Physikunterricht. Theorieentwicklung und Problemanalyse*. Dissertation, Universität Dresden.
Völzke, K. (2012). *Lautes Denken bei kompetenzorientierten Diagnoseaufgaben zur naturwissenschaftlichen Erkenntnisgewinnung*. Kassel: kassel university press.
Williams, C., Stanisstreet, M., Spall, K., & Boyes, E. (2003). Why aren't secondary students interested in physics? *Physics Education*, 38, 324–329.

ENHANCING SECONDARY SCHOOL STUDENTS' LEARNING AND INTEREST FOR ENERGY: RESULTS FROM THE IMPLEMENTATION OF AN INTERVENTION

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In the present paper we briefly describe an intervention aiming at enhancing secondary students' interest and academic achievement for the topic of energy and present the results of its implementation. The intervention was implemented in the introductory physics course in the second year of the Greek High school. The total number of the participants was N=110 for the experimental group and N= 96 for the control group. The learning activities were delivered in real classroom settings. The intervention included experimental hands on activities, outdoor activities, problem solving situations and use of a software specifically designed for the purpose of our study. The control group was taught about the same topics of energy in a traditional way of teaching. We investigated whether there is a relationship between level of engagement, interest and learning outcomes. The results showed that there are significant positive correlations between, interest, academic achievement and level of engagement. This highlights that enhancing interest could lead to better learning outcomes.

Keywords: energy, interest, engagement

INTRODUCTION

The unifying role of energy in all fields of science which makes it a concept that enables the explanation of many phenomena, confirms its multidimensional importance for education. It is recognized as a major learning objective of school science as it is significant for the students' understanding of other concepts and phenomena in school physics. The teaching of energy has been the subject of many studies in the field of education (e.g. Papadouris and Constantinou, 2016) as it is a concept that students find difficult to understand and for which they hold many alternative conceptions. The above diminish the students' interest for the subject making energy an unattractive topic for the students. Given all the above, we consider important to find appropriate teaching approaches to attract and enhance the interest of students and improve their learning outcomes.

Researchers (e.g. Hidi & Renninger 2006, Harackiewicz, J. M., Smith, J. L., & Priniski, S. J. 2016) have highlighted the role of interest as it creates motivation and guarantees the engagement of a person in content-specific activities. It is a powerful motivational factor that energizes and increases learning, and is essential to academic success (Pressley et al., 1992). Interest is both a psychological state characterized by increased attention, effort, and affect, experienced in a particular moment (situational interest), as well as an enduring predisposition to reengage with a particular object or topic over time (individual interest) (Hidi & Renninger, 2006). Situational interest appears to be especially important in catching students' attention, whereas personal interest may be more important in holding it (Hidi and Baird, 1986, Mitchell, 1993). According to Renninger and Hidi (2016) interest is always motivating and engaging and the presence of interest ensures active and meaningful engagement in science classes which is a key contributing to academic success and better learning outcomes (Wang & Degol, 2014b).

Regarding engagement-strongly related to student performance (e.g. Darling-Hammond, et al. (2008)-according to Wang & Degol (2014b), incorporates four dimensions: behavioral, emotional, cognitive, and social engagement. These four components of student engagement are dynamically embedded within the individual and operate at multiple levels. Behavioral engagement is defined in terms of involvement in academic and class-based activities, presence of positive conduct, and absence of disruptive behavior (Fredricks et al., 2004). Emotional engagement is conceptualized as the presence of positive emotional reactions to teachers, peers, and classroom activities, as well as valuing learning and having interest in the learning content (Voelkl, 1997). Cognitive engagement is defined in terms of self-regulated learning, using deep learning strategies, and exerting the necessary cognitive strategies for the comprehension of complex ideas (Zimmerman,1990). Social engagement includes the quality of social interactions with peers and adults, as well as the willingness to invest in the formation and maintenance of relationships while learning (Fredricks et al., 2016). Since there is an alarming decline on students' interest from elementary to high school (Frenzel, Pekrun, Dicke, & Goetz, 2012) educators should take into account the beneficial synergy between interest and engagement in order to design and create appropriate learning environments that enhance these two important components.

In a metanalytic review (Lazowski & Hulleman,2016) there are 74 interventions that highlight the important role of interest in all subjects. In their metanalytic review Rosenzweigh and Wigfield, (2016), found that there are 53 interventions aiming at creating motivation in math and science in general. We found no intervention that targets in enhancing students' situational interest and engagement, concerning the specific topic of energy and the concepts related (mechanical work, kinetic and potential energy), in the secondary education. Based on the above, we designed and implemented in the secondary education an intervention aiming at enhancing students' situational interest, engagement and learning in the topic of energy. In the present paper we briefly describe the intervention and present the results of students' academic achievements and development of their situational interest and their engagement.

METHODOLOGY

The intervention: design and implementation

In order to design an appropriate intervention, we considered Hidi and Renninger's (2006) interest model. According to four-phase model of interest development it is assumed that in the first phase (triggered situational interest), it is necessary that the materials attract a student's attention and lead to momentary enjoyment. In the second phase (maintained situational interest) external factors sustain a learner's attention, such as value (usefulness and importance) of the content. The last two phases include emerging individual interest (Phase 3) and well-developed individual interest (Phase 4). Since our target is to increase situational interest, we are dealing only with the two first phases.

Before designing the intervention, students were asked about themes from every-day life that trigger their interest. Their answers were grouped into categories related to the topics of the energy units (e.g sports, nutrition, space). Furthermore, to investigate students' prior knowledge, a questionnaire composed of questions related to the topic of energy was administered to the students ahead of the implementation of the intervention. A sample of the questions is presented in Appendix A.

Our intervention included experimental hands on activities, outdoor activities, problem solving situations and use of a software specifically designed by the authors for the purpose of our study. The structure of the intervention is presented in Figure 1.

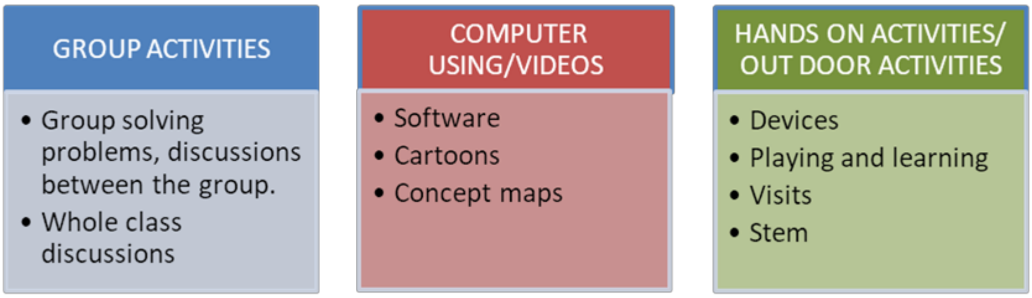


Figure 1. The teaching and learning activities of the intervention

The software was in Java script and included 3D animated experiments. These animations helped students understand easily all the related to energy concepts such as mechanical work, potential and kinetic energy. For example, in order to calculate the work done by constant forces, students had the chance to carry out the same experiment as many times as needed, for various displacements and realize that the work done by a constant force increases with the displacement. Also, they could change the mass of a moving with constant speed object and understand that kinetic energy increases with mass and they could also change the speed of a moving object and understand that it is proportional to the speed's square. Students could furthermore examine how potential energy depends on the distance of an object from the ground (height), its mass and the acceleration of gravity. They also could understand that potential energy is independent of the path a moving body takes. All students, work in small groups and had the chance to use the software. The software was accompanied by worksheets distributed to all students participating in each group. This helped them stay focused during the lesson.

To maintain students' interest their involvement and engagement were considered crucial. Thus, they participated in pleasant activities they could easily deal with which assisted them to comprehend the lesson. To this contributed the fact that all the students were given active roles during the course designing and performing simple experiments on their own and had the opportunity to make constructions as well. They also watched short funny cartoon videos and came into conclusions about energy transformations after whole class discussions. Furthermore, in order to understand energy transformations, they participated in STEM activities, where they constructed a windmill, a solar car etc. Apart from this they had the chance to make connections between the concept of energy and their everyday life and develop a sense of the new content's value at the same time. A large number of the students of the experimental group worked voluntarily and found information concerning various topics like atomic bomb, nuclear energy and also accidents that happened in nuclear factories etc.

The study (which was carried out in a public school in Greece) involved an experimental and a control group. Both groups were taught the units concerning the topic of energy were according to the National Curriculum: mechanical work, kinetic and potential energy, mechanical energy and its conservation. In the experimental group our intervention was implemented while in the control group we used the traditional teacher-centered teaching approach. This involved lectures and students' individual work. The intervention took place during the scheduled Physics course, twice a week, for two separate hours. in the second year of high school (students aged 14). There were two implementations of the intervention during two consequent school years (2016-17, 2017-18), from January until May, where the total number of the participants for both years was N=110 for the experimental group and N= 96 for the control group.

Data collection

Data for students' interest, academic achievement and level of engagement were collected from both experimental and control groups. The data were used to investigate:

a) whether there is a positive correlation between situational interest, level of engagement and learning outcomes for both groups

b) whether there are higher levels of the above factors in the experimental group.

Students' situational interest during the physics class was assessed by a self-report questionnaire with thirteen items, seven items for triggered and six items for maintained interest. The questionnaire was based on Mitchell's (1993) scale and on Linnenbrink-Garcia et al., (2010) scale after appropriate statements' adaptation to the concept of energy. The items for measuring triggered interest and those used for measuring maintained interest are presented in Table 1.:

Table 1. Questionnaire items used to measure interest

Triggered interest	**Maintained interest**
1) The lesson for energy fascinates me and thus it is very easy for me to pay attention during the class.	1) I believe that the field of energy is very interesting in general.
2) I find the lesson about energy interesting.	2) Studying about energy fascinates me.
3) The lessons for energy is so boring that it seems to me that drags on forever.	

To assess the level of students' engagement we adapted for the concept of energy "The Math and Science Engagement Scale" (Fredricks & Wang, 2016) consisting of 14 items. Five for assessing cognitive engagement, 3 for assessing behavioral engagement and 2 for assessing social engagement. A sample of these items are presented in Table 2.

Table 2. Sample of items for assessing students' engagement

Cognitive engagement:
1. I was trying to understand my mistakes concerning the topic of energy
2. When I was confronting a difficult problem, I tried to work hard, and never give up easily
3. I was always trying to connect my new knowledge with my prior knowledge.
Behavioral engagement:
1. I was trying really hard and I was seeking for help when it was necessary during classes concerning the topic of energy
2. I stayed focused during classes concerning the topic of energy
3. I participated during the learning activities.
Social engagement:
1. I liked cooperating with my fellow students
2. I was sharing my ideas during classes.
Emotional engagement:
1. I was feeling joy during classes
2. The lesson was not at all boring because I was actively engaged.

In both questionnaires students rated the extent to which they agree with each item on a four-point Likert -type scale ranging from 1 (totally disagree) to 4 (totally agree).

To assess academic achievement according to the learning goals, a test was administered to both experimental and control groups. The test consisted of 27 items with open-ended questions and with different levels of difficulty. We examined whether our students could apply the new knowledge they were taught in solving various problems concerning the topic of energy and the concepts related to it, according to our learning goals. For example, we examined whether students:

- Could calculate the work done by a constant force when the force and the displacement have the same or the opposite direction and in all other cases.
- Did not confuse the definition of work with everyday notion of work and understand the scientific conception of work.
- Understood that weight is a special case of force and that work can be calculated with another way apart from the conventional
- Understood that kinetic energy is a form of energy and is the energy possessed by an object due to its motion.
- Could calculate the kinetic energy of a moving object and solve more complex problems.
- Understood that kinetic energy has only magnitude and no direction.
- Understood that kinetic energy of an object increases with its speed.

- Can make calculations and solve complex problems using conservation of mechanical energy and be aware of the fact that in case energy is transformed, the total energy remains unchanged.

A sample of items that were used to asses learning outcomes are presented in Appendix B.

Data analysis and results

Initially we calculated the percentages of all the answers that students gave in both questionnaires, using SPSS. In Figure 3 we present an example of the percentages concerning situational interest and specifically from the item: *I find the lesson about energy interesting*. In Figure 4 we present an example of the percentages concerning engagement and specifically from the item: *I was trying hard and I was seeking for help when it was necessary during classes concerning the topic of energy*. As we can see there is a significant difference between the two groups. We had similar findings for all items in both questionnaires which is very encouraging.

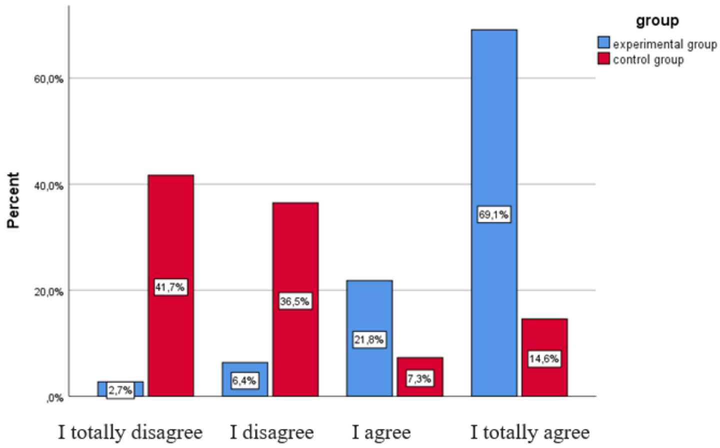


Figure 3. Percentages of students' answers concerning situational interest.

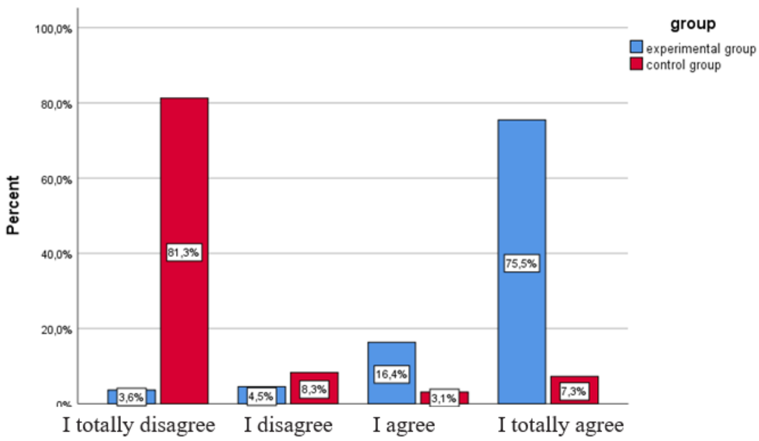


Figure 4. Percentages of students' answers concerning engagement.

Then we calculated the average of the students' answers to the questionnaires for each of the variables interest, academic achievement and level of engagement, using conventional methods. Value 1 was assigned to the lowest levels of each of the three variables and 4 to the highest. We found that the values of the three variables are significantly higher in the experimental group (see Figure 3). Questionnaire data were coded, categorized and statistically analyzed using SPSS. Cronbach's was calculated 0,879 for the interest and 0,866 for the level of engagement. To indicate correlations between the variables Pearson r was calculated. For the experimental group: between interest and level of engagement was 0,867, between interest and academic achievement was 0,757 and between level of engagement and academic achievements was 0,809. For the control group the corresponding values were 0,862, 0,876, 0,905.

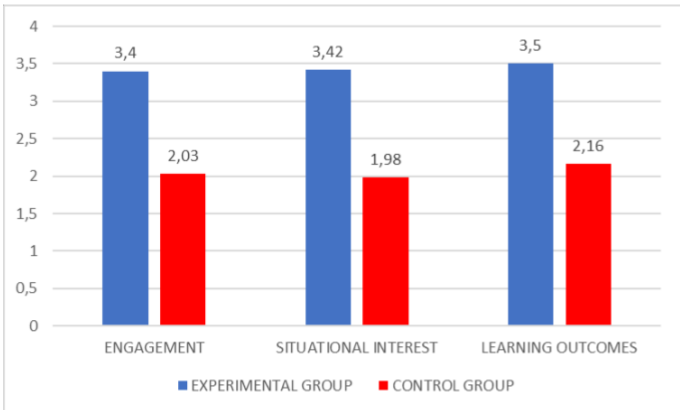


Figure 5. Levels of interest, engagement and learning outcomes for the experimental and control groups.

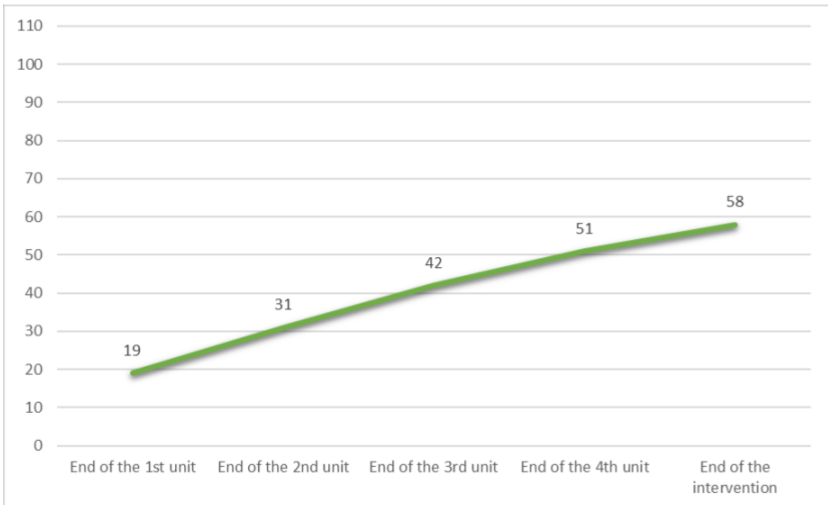


Figure 6. Number of students of the experimental group that work voluntarily during the intervention.

As we mentioned earlier, many students of the experimental group worked voluntarily during the intervention, something that proves that they reengaged with the new content they learned, and situational interest was maintained.

CONCLUSIONS

The results of the statistical analysis coupled with the findings reported in Figure 4, indicate that there is a strong positive correlation between high levels of interest, levels of engagement and academic achievement (experimental group). They also indicate that low levels of interest and engagement is positively correlated with low academic achievement (control group). The results are very encouraging indicating that students' interest is of great importance since it can lead to better learning outcomes and academic achievement. Our intervention seems to be fruitful in enhancing and maintaining the interest of the students of the class in which it was implemented. This can be due on the one hand to the materials used among which the software specifically designed to be simple in use which assisted students' understanding of difficult ideas introduced in the specific intervention, and on the other, to the approach used and most importantly in relating the topic of energy to the students' interests coming from every-day life, the hands on activities, the outdoor activities and the problem solving situations. Also, we consider that having students design and perform simple experiments on their own as well as giving them the opportunity to make constructions engaged them fruitfully in their own learning.

REFERENCES

Darling-Hammond, L., Barron, B., Pearson, D. P., et al. (2008). *Powerful learning: What we know about teaching for understanding.* San Francisco, CA: Jossey-Bass.

Fredricks, J. A., Blumenfeld, P. C., & Paris, A. H. (2004). School engagement: potentialof the concept, state of the evidence. Review of Educational Research, 74, 59e109.

Fredricks, J. A., Wang, M. T., Schall Linn, J., Hofkens, T. L., Sung, H. C., Parr, A. K., & Allerton, J. J. (2016). Using qualitative methods to develop a survey measure of math and science engagement. Learning and Instruction.

Frenzel, A. C., Pekrun, R., Dicke, A.-L., & Goetz, T. (2012). Beyond quantitative decline: Conceptual shifts in adolescents' development of interest in mathematics. Developmental Psychology, 48, 1069–1082. doi:10.1037/a00268.

Hidi, S., and Baird, W. (1986). Interestingness—A neglected variable in discourse processing. Cognitive Sci. 10: 179–194.

Hidi, S., & Renninger, K. A. (2006). The fourphase model of interest development. Educational Psychologist, 41, 111–127.

Harackiewicz, J. M., Smith, J. L., & Priniski, S. J. (2016). Interest matters: The importance of promoting interest in education, 3, 220–227. Policy Insights from the Behavioral and Brain Sciences. doi:10.1177/2372732216655542.

Lazowski, R. A., & Hulleman, C. S. (2016). Motivation interventions in education: A meta-analytic review. *Review of Educational Research 86*(2), 602-640.

Linnenbrink-Garcia, L., Durik, A. M., Conley, A. M., Barron, K. E., Tauer, J. M., Karabenick, S.A., et al. (2010). Measuring situational interest in academic domains. Educational and Psychological Measurement, 70 (4), 647–671.

Mitchell, M. (1993). Situational Interest: Its multifaceted structure in the secondary school mathematics classroom. J. Educ. Psychol. 85: 424–436.

Papadouris, N., & Constantinou, C. (2016). Investigating middle school students' ability to develop energy as a framework for analyzing simple physical phenomena. Journal of Research in Science Teaching, 53(1), 119–145.

Pressley, M., El-Dinary, P. B., Marks, M. B., Brown, R., and Stein, S. (1992). Good strategy instruction is motivating and interesting. In Renninger, A., Hidi, S., and Krapp, A. (eds.), *The Role of Interest in Learning and Development*, Erlbaum, Hillsdale, NJ, pp. 333–357.

Renninger K.A, Hidi S. (2016). The power of interest for motivation and engagement. New York, NY: Routledge.

Voelkl, K. E. (1997). Identification with school. American Journal of Education, 105, 204e319.

Wang, M. T., & Degol, J. (2014b). Staying engaged: knowledge and research needs in student engagement. Child Development Perspectives, 8, 137e143.

Rosenzweig, E., & Wigfield, A. (2016). STEM Motivation Interventions for Adolescents: A Promising Start, but Further to Go. *Educational Psychologist, 51*(2), 1-18.

Zimmerman, B. J. (1990). Self-regulated learning and academic achievement: an overview. Educational Psychologist, 21, 3e17.

Appendix A

Pretest questions

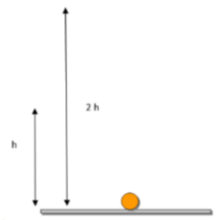
Why do you think the sheep feels tired even if he stays still?

Why do you think the big stone sitting on the rock becomes dangerous if it falls off the rock?

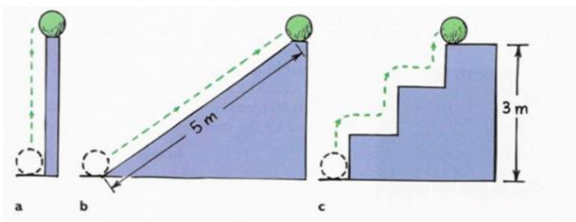
Appendix B

Questions used to asses learning outcomes

1. We lift an object of a mass m, at two different heights h and 2h from the ground. Can you calculate the analogy between its potential energy in these two different heights?



2. The same ball follows three different paths, as presented below. According to your opinion in which path the ball possesses higher potential energy and why?



3. We throw a ball from the ground with a speed equal to uo=40m/sec. What is the maximum height from the ground that the ball reaches? In what height from the ground the potential energy is equal to kinetic energy? (g=10m/sec2). Consider that there are no frictions or other forces from the air.

USING CLASSROOM MANAGEMENT TO SUPPORT INCLUSIVE CHEMISTRY LEARNING

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In light of the increasing heterogeneity and diversity of today's secondary school students, it is important to consider innovative developments in science education research. Teachers face challenges on a daily basis as they try to address students' needs adequately in order to provide good-quality education for every student. Particularly chemistry teachers face challenges when teaching in very heterogeneous classroom settings as chemistry is not only taught theoretically but also calls for practical experiments. To cope with these challenges, it is reasonable to use strategies for inclusive chemistry education which have been identified as successful to promote students' learning. Classroom management is a proven approach to promote learning for all students. As the concept of classroom management offers a range of different strategies, it is necessary to identify those strategies most effective and relevant for inclusive science education and chemistry education in particular.

Therefore, this research project aims at identifying effective strategies of classroom management which support students' chemistry learning in heterogeneous and diverse learning groups focussing on the requirements of practical experiments. A qualitative research design was developed to explore major challenges of experimenting in the inclusive classroom and elicit respective strategies of classroom management. Interviews and questionnaires done with chemistry teachers were used as research methods. The successful completion of student experiments in a safe and supportive environment appears to be one of the major concerns in the inclusive classroom. On the basis of this prerequisite the preliminary study found out that learning of all students is best supported in an environment where there are clear procedures and routines, rules and consequences as well as clarity and structure of content. The results of the preliminary study are the starting point for investigating some strategies of classroom management in more detail, especially with respect to experimenting in the inclusive chemistry classroom.

Keywords: Inclusion, Science Education, Teaching Practices

THEORETICAL FRAMEWORK

> *„In addition, chemistry and science teachers are challenged by growing heterogeneity and diversity. This development challenges both the practice of science teaching and science education research development." (Markic, Eilks, Di Fuccia & Ralle, 2012, p.1)*

Following the ratification of the Convention on the Rights of Persons with Disabilities (CRPD) in 2006 and due to the increasing heterogeneity of secondary school students, it is necessary to think about new developments in science education research. Especially in Germany, the

CRPD raised many questions and posed challenges to teachers. Such an in-depth systemic change implies that chemistry teaching is faced with increasing student diversity and, consequently, chemistry teachers have to acquire appropriate strategies to deal with students' needs adequately and to provide high-quality education for all students in mainstream settings (Soriano, Watkins & Ebersold, 2017, p. 6). However, to cope with these challenges, it is useful to return to validated concepts and strategies which have been identified to be successful in promoting students' learning and providing high-quality education for all students. Nevertheless, these concepts must be considered in the subject-specific context of inclusive learning settings. Literature provides several framework concepts (e.g. UDL: Schlüter & Melle, 2017) and pedagogical-methodical approaches (diagnosis, differentiation and individual learning: e.g. Abels, 2015; Menthe & Hoffmann, 2015) to the design of chemistry-specific learning in diverse and heterogeneous learning groups. All of them focus on individual access and pay less attention to the general conditions of learning, like the atmosphere or learning environment. Classroom management is one promising concept.

Why does Classroom Management appear to be a promising approach?

Classroom management is a concept that provides strategies effective for creating a positive teaching and learning environment. This includes general strategies like rules, consequences, instructions, routines, procedures, managing student work and monitoring student behaviour (Bear, 2015; Emmer & Evertson, 2013). Several meta analyses showed the relevance of these strategies for learning in heterogeneous learning groups (Korpershoek, Harms, de Boer, van Kuijk & Doolaard, 2016; Helmke, 2014; Hattie, 2012). Classroom management may seem to be contradictory to concepts of dealing with heterogeneity and diversity initially, as it has a strong focus on routines, procedures and rules, but Seiz et al. (2016) were able to show various positive effects for heterogeneous classes. In general, it is very important for heterogeneous and diverse learning groups to have clear guidelines when learning (Claßen, 2013; Lotan, 2006; Soodak & McCarthy, 2006; Polirstok, 2015). Furthermore, they pointed out that underachieving students benefited greatly from classroom management. Ferreira González et al. (2019) also observed positive effects on learning and working behaviour in inclusive biology lessons. The strategies of classroom management address the general conditions of learning and facilitate students' learning. The concept of classroom management is one possible way to support students' learning successfully (Emmer & Sabornie, 2015; Fricke, 2016; Borich, 2014; Hattie, 2009; Kounin, 1970). One central aim of classroom management is to establish and sustain a structured academic environment which allows all students to participate in learning (Evertson & Weinstein, 2013, p.4).

The theoretical framework is based on three main aspects (see fig.1). Firstly, the concept of classroom management is outlined and the challenges of heterogeneity and diverse learning groups are discussed. The aspect of the project focuses on a distinctly subject-specific issue, the student experiment.

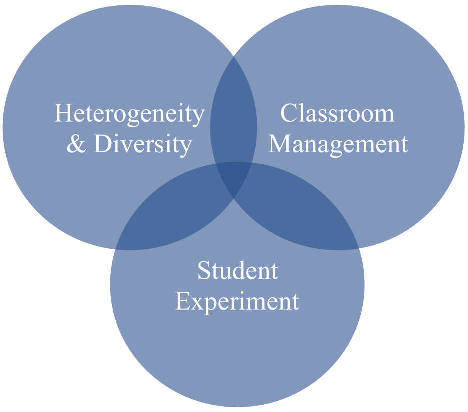

Figure 1. Theoretical Aspects of the Research Project.

The student experiment is a central component of chemistry education. However, experimenting in inclusive learning groups can be very challenging (Reiners & Adesokan, 2017; Menthe & Hoffmann, 2015), as there are several factors that have to be considered: supportive conditions have to be created for students' subject-related learning while ensuring safety, which is both important and demanding in a highly heterogeneous setting. Successful classroom management includes organizational and instructional strategies to ensure a safe and supportive environment so that all students can experiment and learn together in chemistry classes.

A variety of general classroom management strategies are available. But as classroom management is a comprehensive approach to promote learning for all students, it is necessary to identify strategies relevant for chemistry education in general and the student experiment in particular. Therefore, this research project aims at finding out which subject-specific classroom management strategies support students experimenting in inclusive chemistry classes.

METHODOLOGY

In order to be able to identify chemistry-specific classroom management strategies for student experiments in diverse and heterogenous learning groups, this project was divided into five stages (see Fig. 2).

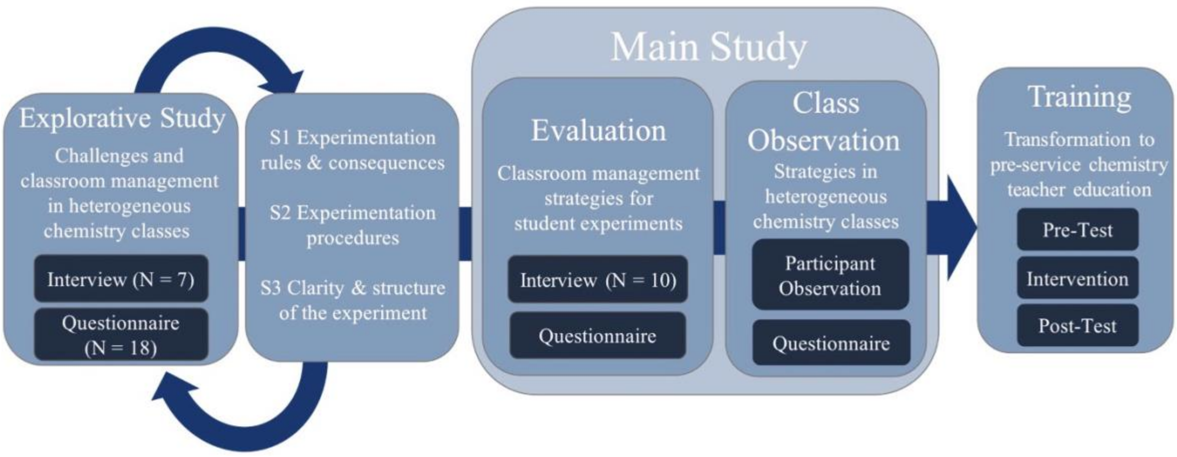

Figure 2. Overview of the project.

The first step of the explorative preliminary study aimed at analysing the particular challenges of inclusive chemistry classes and examining subject-specific classroom management strategies. In order to explore chemistry teachers' experiences and attitudes towards the use of strategies of classroom management in inclusive chemistry classes, a qualitative research approach was chosen. Therefore, semi-structured interviews (*N*=7) and semi-structured questionnaires with other chemistry teachers (*N*=18) were conducted. The questions in the thematic framework for the interview and the surveys dealt with the practice of inclusive chemistry teaching and are based on the theory of classroom management as it has been elaborated in literature (Emmer & Evertson, 2013; Evertson & Weinstein, 2013; Kounin, 1970). The data was analysed by means of qualitative content analysis by Mayring (2014) in which the specific qualitative techniques of summary and inductive category formation were applied. Six main categories were formed in order to identify and structure conditions that promote learning (see Pawlak & Groß, 2019). The data analysis was an iterative process, combining the results of the preliminary study with findings from additional literature research.

This article discusses these findings of the explorative study in order to identify and develop strategies of the classroom management. The three identified strategies and various sub-strategies were analysed and evaluated in the main study by means of interviews with heads of the Centres for Teacher Training at Schools. These are experts on the second phase of teacher training in Germany, they have considerable experience in teaching chemistry as well as teacher training and they also have practical teaching experience with heterogeneous chemistry classes. The qualitative research design was used to evaluate the strategies, the school practical background and make possible suggestions for improvement. As a second step, the lessons and consequently the teaching methods of the interviewed chemistry teachers were observed. Finally, the results were transferred to chemistry teacher education in order to enable pre-service chemistry teachers to face the identified challenges adequately by using strategies of classroom management.

RESULTS AND DISCUSSION

Within the preliminary study, the major challenges of conducting experiments in inclusive chemistry lessons have been identified. It can be said that safety is a central concern for chemistry teachers when carrying out student experiments: "[…] as a chemistry teacher, you have to ensure students' safety, because you have to take the blame for it yourself" (I1). Classroom management offers various strategies for establishing and ensuring safety during student experiments, such as the acquisition of a "laboratory license", where students must demonstrate safe behaviour. Observing these rules of laboratory safety must be practiced by the students continually. The results of the study show that establishing rules and defining consequences for unsuitable behaviour are among the most important strategies of classroom management in the context of safety (*N*=10): "[…], student behaviour is of course influenced by the need to define clear rules for experimenting in chemistry lessons from the very beginning" (I3).

Establishing routines and sticking to procedures can also be regarded as key strategies (*N*=12): "Strategies which limit disruption and conflict are crucial factors for successful chemistry lessons. As the kids carry out experiments by themselves, I hand over control […] therefore they need rules and routines, which are clear. Only if [they] are familiar with certain procedures, experimental chemistry teaching works out” (I5). An example for the practice of experimental procedures is the gas burner driving license, where the students practice the handling of the gas burners.

Experimenting itself does not necessarily promote students’ learning. The understanding for the content of the experiment must also be given. Emphasizing clarity of content and structure of the experiment can help here: "I always think that works quite well, and what is important, is the presence of instructions… and classroom management. What do I have planned for today? I want to make the aim of the lessons and the way how to reach it clear. Be it with symbols or simply explained: ‘We'll do that today, then we'll do the experiment and then we are doing that.’ This is often important for the children, because these long phases with the difficulty of listening are something they have all learned to bear and then they take little of the lecture that the teacher still likes to give. It also happens to me that I talk too much” (I4).

The interviews explicitly emphasised that classroom management was important for successful learning: “Well, I need good classroom management strategies in order to be able to teach in an inclusive chemistry classroom safely. And it is also beneficial for the students. If the class is loud […] it is more difficult for an inclusive student […] he/she already has a handicap. And if the class cannot work silently, it is twice as hard for an inclusive student. A normal student can even work if the classroom management is just average, but for an inclusive student this is probably not enough, I would say” (I3).

The results so far indicate the importance of classroom management, but also highlight the challenges teachers face with? when conducting student experiments in inclusive chemistry classes. In the next step the results of the preliminary study were transferred to three specific strategies relevant when experimenting with students.

Identification and development of chemistry-specific strategies

The identification and development steps were conducted as an iterative process. Therefore, the results of the explorative study and an additional literature analysis were combined. This led to the identification of three chemistry-specific strategies of classroom management and various sub-strategies (S1, S2 & S3, see Tab. 1). The literature analysis triangulated literature on practical chemistry teaching, literature on chemistry didactics and pedagogy as well as research on classroom management strategies for teaching and learning. On the basis of this systematic connection, three chemistry-specific strategies were developed:

Table 1. Specific strategies of classroom management.

S1 EXPERIMENTAL RULES & CONSEQUENCES
Behavioural standards that organize experimentation and form the framework for student behaviour in the classroom. Behaviour must be built up in a targeted manner and, especially in the context of student experiments, inadequate behaviour must be penalized whereas favourable, safe behaviour needs to be fostered. This can be done setting positive and negative consequences.
S1.1 General rules of experimentation
General standards of behaviour which are intended to regulate student behaviour when conducting experiments and ensure safety during preparing, conducting and cleaning up the experiment.

S1.2 Specific experimental rules
Specific behavioural standards that ensure the particular requirements of each experiment and can modified according to the situation.
S1.2.1 Substance specific
Symbols, pictograms, etc are used when handling chemicals considering hazards, safety measures, disposal, special procedures.
S1.2.2 Device-specific
Procedures and safety measures which are characteristic for each device. The device-specific rules are linked to the device routines (see S2.3).
S1.3 Strict realisation
Development of behaviour by supporting desirable behaviour and sanctioning non-compliant behaviour. Consequences are possible intervening measures to react to the obedience and/or disobedience of the experimental rules. Appropriate handling of disturbance and rule violation plays an important role.
S1.3.1 Positive consequences
Set of measures applied when observing experimental rules (e.g. praise)
S1.3.2 Negative consequences
Set of measures applied in case of disregard of experimental rules (e.g. warning)
S2 EXPERIMENT ROUTINES AND PROCEDURES
Specific behaviour and patterns of action for recurring situations during experimentation. Routines and procedures must be introduced and practiced in order to reduce the time and effort required for student experiments and to increase safety during experiments. In contrast to routines, rules are much more explicit and must be recorded in writing.
S2.1 General experimental routines
General behaviour and patterns of action for recurring situations during experimentation.
S2.2 Organisation and mobility routines
Organisation and mobility routines organise experimentation and support the processes during experimentation (e.g. experimental roles, distribution of tasks, movement in the specialist room).
S2.3 Device routines
The device routines include the practice of fixed action scripts (routines) in handling chemical-specific devices such as the Bunsen burner.
S3 CLARITY OF CONTENT & STRUCTURE OF THE EXPERIMENT
The clarity of content and structure aims at a thematically plausible, comprehensible and clear structure of planning, preparation, execution and evaluation of an experiment for the students. The aim is to ensure comprehensibility and linguistic clarity, which can be achieved by means of simplicity, brevity as well as structure, and can be supported by visualisation.

Based on the qualitative study design and the literature analysis, the three key strategies above could be identified. These strategies and their sub-strategies offer a promising approach for establishing safe and supportive learning conditions when conducting student experiments in inclusive learning environments.

CONCLUSION

In summary, the results of the explorative study show that ensuring safety for all students in inclusive chemistry classes pose real challenges for teachers when conducting student experiments. Based on these findings, it can be claimed that establishing rules and routines with respective consequences is an appropriate strategy to ensure safety in an inclusive experimental classroom. As safety is a major concern, strategies that ensure safety offer all students the opportunity to take part actively in practical inclusive chemistry lessons and conduct in experiments themselves. In addition to safety as a basic requirement, the understanding of the experiment must also be supported. For this purpose, further sub-strategies for clarity of content and structure of experiments are needed to be investigated in the following steps.

In the main study, the identified strategies will be qualitatively evaluated and analysed by means of expert interviews and class observation. This should provide further insights into the use of the strategies in inclusive chemistry classes. The interviews will be conducted to investigate the research questions: In what way can the specific strategies of classroom management contribute the safety of student experiments? In what way can the specific classroom management strategies support learning through experiments? Interviews and questionnaires are only one way to examine the views of chemistry teachers and trainers. Therefore, it is also necessary to analyse chemistry teaching practices. For this reason, the chemistry lessons of the interviewed teachers will be observed. The aim is to focus on the use of the strategies in practice. Finally, the findings of the main study will be implemented in university teacher training.

REFERENCES

Abels, S. (2015). Scaffolding inquiry-based science and chemistry education in inclusive classrooms. In: N.L. Yates (Ed.). *New Developments in Science Education Research*. Hauppauge: Nova science, 77-95.

Claßen, A. (2013). *Classroom-Management im inklusiven Klassenzimmer: Verhaltensauffälligkeiten: vorbeugen und angemessen reagieren*. Mülheim an der Ruhr: Verl. an der Ruhr.

Bear, G. G. (2015). Preventive and classroom-based strategies. In E. T. Emmer & E. J. Sabornie (Eds.), *Handbook of classroom management* (Second edition, p.15-39). New York: Routledge, Taylor & Francis Group.

Borich, G. D. (2014). *Effective teaching methods: Research-based practice* (Eight Edition). Pearson Education.

Emmer, E. T., & Evertson, C. M. (2013). *Classroom management for middle and high school teachers*. Boston: Pearson.

Emmer, E. T., & Sabornie, E. J. (Eds.). (2015). *Handbook of classroom management* (Second edition). New York: Routledge, Taylor & Francis Group.

Evertson, C. M., & Weinstein, C. S. (Eds.). (2013). *Handbook of Classroom Management: Research, Practice, and Contemporary Issues.* Hoboken: Taylor and Francis.

Ferreira González, L., Hövel, D. C., Hennemann, T., Schlüter, K., & The impact of classroom management strategies on at-risk students' behavior in biology class. A case study. (2019). Auswirkungen des gezielten Einsatzes von Classroom-Management-Strategien im inklusiven Fachunterricht Biologie auf das Unterrichtsverhalten von Schülern unter erhöhten Risiken aus Perspektive der Lehrperson. Eine Einzelfallstudie. *Empirische Sonderpädagogik*, *11*(1), 53–70.

Fricke, K. (2016). *Classroom management and its impact on lesson outcomes in physics: a multi-perspective comparison of teaching practices in primary and secondary schools.* Berlin: Logos Verlag Berlin GmbH.

Hattie, J. (2009). *Visible learning: a synthesis of over 800 meta-analyses relating to achievement.* London; New York: Routledge.

Helmke, A. (2014). *Unterrichtsqualität und Lehrerprofessionalität: Diagnose, Evaluation und Verbesserung des Unterrichts* (5. Auflage). Seelze-Velber: Klett/Kallmeyer.

Korpershoek, H., Harms, T., de Boer, H., van Kuijk, M., & Doolaard, S. (2016). A Meta-Analysis of the Effects of Classroom Management Strategies and Classroom Management Programs on Students' Academic, Behavioral, Emotional, and Motivational Outcomes. *Review of Educational Research*, *86*(3), 643–680.

Kounin, J. S. (1970). *Discipline and group management in classrooms.* New York: Holt, Rinehart and Winston.

Lotan, R. A. (2006). Managing Groupwork in Heterogeneous Classroom. In C. M. Evertson & C. S. Weinstein (Eds.), *Handbook of Classroom Management: Research, Practice, and Contemporary Issues*, 525–540.

Markic, S., Eilks, I., Di Fuccia, D., & Ralle, B. (Hrsg.). (2012). *Issues of heterogeneity and cultural diversity in science education and science education research: a collection of invited papers inspired by the 21st Symposium on Chemical and Science Education* held at the University of Dortmund, May 17-19, 2012. Aachen: Shaker Verlag.

Mayring, P. (2014). *Qualitative content analysis: theoretical foundation, basic procedures and software solution.* Klagenfurt.

Menthe, J., & Hoffmann, T. (2015). Inklusiver Chemieunterricht: Chance und Herausforderung. In O. Musenberg & J. Riegert (Hrsg.), *Inklusiver Fachunterricht in der Sekundarstufe*. Stuttgart: Verlag W. Kohlhammer, 131–141.

Pawlak, F., & Groß, K. (2019). Classroom-Management im inklusiven Chemieunterricht. In C. Maurer (Hrsg.), *Naturwissenschaftliche Bildung als Grundlage für berufliche und gesellschaftliche Teilhabe*. Universität Regensburg, 125-128.

Polirstok, S. (2015). Classroom Management Strategies for Inclusive Classrooms. *Creative Education*, 06(10), 927–933.

Reiners, Ch. S., & Adesokan, A. (2017). Inklusion im Chemieunterricht. In *Chemie vermitteln: Fachdidaktische Grundlagen und Implikationen.* Springer Spektrum, 167-177.

Seiz, J., Decristan, J., Kunter, M., & Baumert, J. (2016). Differenzielle Effekte von Klassenführung und Unterstützung fürSchülerinnen und Schüler mit Migrationshintergrund. *Zeitschrift für Pädagogische Psychologie*, *30*(4), 237–249.

Schlüter, A.-K., & Melle, I. (2017). Luft ist komprimierbar. Beispiele für die Umsetzung des Universal Design for Learning. *Naturwissenschaften im Unterricht Chemie*, (162), 36–39.

Soodak, L. C., & McCarthy, M. R. (2006). Classroom Management in Inclusive Settings. In C. M. Evertson & C. S. Weinstein (Hrsg.), *Handbook of Classroom Management: Research, Practice, and Contemporary Issues*, 461–490.

Soriano, V., Watkins, A., & Ebersold, S. (2017). European Parliament, Directorate-General for Internal Policies, Policy Department C: Citizens' Rights and Constitutional Affairs. European Agency for Special Needs and Inclusive Education. *Inclusive education for learners with disabilities: study.*

The United Nations. (2006). Convention on the Rights of Persons with Disabilities (CRPD). *Treaty Series*, *2515*, 3.

EXPLORING PRACTICING AND PRE-SERVICE TEACHERS' PROCEDURAL METACOGNITIVE KNOWLEDGE: INITIAL FINDINGS AND POTENTIAL IMPLICATIONS

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Metacognition is a key factor influencing science learning endeavours. While research has been undertaken into science students' metacognition and means to develop and enhance their metacognition, little research has explored practicing or prospective science teachers' metacognition, which includes what they know about how they themselves learn science, i.e., their procedural metacognitive knowledge. This exploratory study aims to help fill this gap. Sixteen science teachers and twelve pre-service science teachers where interviewed within two distinct hermeneutic dialectic circles regarding, (a) their science learning strategies, (b) the extent to which they considered it important to teach explicitly such strategy knowledge to students, and why, and, (c) the extent to which they had been asked to consider such matters previously. Both practicing and pre-service teachers reported a range of responses regarding (a) – (c). Some were able to describe in detail their science learning strategies. Others were less able to do so. Substantial variation was evident regarding the extent to which both populations considered it important to teach explicitly about such strategic knowledge to students and regarding if, how, and why they might do so. Participants reported that they had not been asked to consider such matters before. This study, shortcomings of which are identified, provides a platform for future research that might inform teacher education and professional development.

Keywords: Metacognition, Teacher Thinking, Learning to Learn.

INTRODUCTION: THEORETICAL FRAMEWORK AND STUDY PURPOSE

Over the past 30 years there have been many suggestions for how to improve science education, particularly as such improvement could relate potentially to improving students' conceptual understanding. Prominent and persistent amongst suggestions is the view that developing and enhancing students' metacognition is necessary to effect improved science learning (White, 1988; Georghiades, 2004; Thomas, 2012a; Zohar and Barzilai, 2013). Metacognition is an important factor influencing self-regulation and learning success (e.g., Ertmer & Newby, 1996), and the view in the science education literature is that enhancing students' metacognition does lead to improvements in their science learning (Avargil, Lavi, & Dori, 2018; Georghiades, 2004; Thomas, 2013). Metacognition is defined as an individual's knowledge, control, and awareness of their thinking and learning strategies (e.g., Flavell; 1979, Gunstone, 1994; Thomas, 2012a). Metacognitive knowledge can be categorized as, (1) declarative – related to beliefs and propositions about thinking and learning, (2) procedural – related to the strategies used to think and learn, & (3) conditional – related to when and why to apply procedural metacognitive knowledge to achieve specific, contextually relevant learning goals.

Teachers' knowledge of metacognition, including their own metacognitive knowledge, is an important factor influencing the teaching of the strategic, higher order thinking that is central to science education, e.g., conceptual development, argumentation, and scientific inquiry (Avargil et al., 2018; 2017; Thomas & Anderson, 2014). Research by Thomas (2013, 2017) and Thomas and Anderson (2014) clearly supports the contention that when teachers (a) become more knowledgeable of their often tacit knowledge of science learning processes, including their own, and (b) they are able to articulate explicitly these processes to students, that However, as far back as 1999, Zohar reported that science teachers' metacognitive knowledge as "unsatisfactory for the purpose of teaching higher order thinking skills in science classrooms" (p. 413), and Zohar and Barzilai (2013) and Thomas (2012b) proposed that science teacher metacognition should be given increased attention in science education research. This is because, while substantial research has been conducted into science students' metacognition, research into teachers' metacognition is not prominent in the science education literature, or in the education literature in general (Duffy, Miller, Parsons and Meloth, 2009 Thomas, 2012a,b). Despite these calls, little if any research in any field has been reported that investigated the metacognition of practicing teachers, and to this author's knowledge no research at all has been reported that explores the metacognition of pre-service science teachers.

This study aims to help fill this gap in science education research and stimulate further consideration of this understudied area . Accordingly, this study investigated practicing and pre-service science teachers' self-reports of, (a) their personal procedural metacognitive knowledge related to their science learning strategies, (b) the extent to which they considered it important to teach explicitly about such knowledge to students, and their reasons for their views and, (c) the extent to which they had been asked to consider such matters previously.

METHODOLOGY

An interpretive methodology underpinned by a social constructivist epistemology was chosen for this study. Interpretive research takes into account social action and thought that is "locally distinct and situationally contingent" (Erickson, 1998, p. 1155). Such a stance acknowledges that variation between participants is expected because each of them has constructed individually their metacognitive procedural knowledge on the basis of their personal experiences within their specific social contexts. Therefore any generalizations from this study to other contexts should be made prudently. The participants were a convenience sample of, (a) sixteen teachers from two high schools located on the outskirts of a large metropolitan Canadian city who were all teaching science in grades ten through twelve, and (b) twelve pre-service science teachers who were in the third year (of four) of their teacher preparation programme at a large comprehensive university in the same city. In that teacher preparation programme all students took the same science education courses and their specialist science area, or major, was not a consideration guiding their recruitment for this study. The practicing teachers varied in teaching experience from two to thirty-five years and were teaching across all science subject areas. All participants gave informed consent and all names in this paper are pseudonyms. The data collection involved semi-structured interviews, with each interview taking between twenty and thirty minutes. Practicing teachers were interviewed prior to those of the pre-service teachers. The interviews with each group of participants (practicing or pre-service teachers) took the form of separate hermeneutic dialectic circles (Guba & Lincoln, 1989) in which the tentative assertions generated from initial interviews were used as the basis for seeking data to confirm or disconfirm those assertions for each group in subsequent interviews. A key function of the hermeneutic dialectic circle is to seek consensus; consensus being achieved when no new information arises as the sequence of interviews proceeds. The data from the two sets of interviews were analyzed using a three-stage process of descriptive coding, interpretive coding, and deriving overarching themes, as suggested by King and Horrocks (2010), and consistent with the processes suggested by Braun and Clarke (2006) and Langridge (2004). Results are presented as three assertions. These assertions reflect the overarching themes common to both sets of participants that were derived from the analysis, and that attend to the aforementioned research purposes. Data from the interviews supporting those assertions, and variations between and within practicing teachers (PT) and pre-service teachers (PST), are presented to support the claims made.

RESULTS

Assertion 1: *All participants reported behavioral elements and procedural metacognitive knowledge elements, both being intertwined in relation to their personal science learning strategies.* Participants provided coherent information, varying in detail between them, regarding how they considered they learned science. Reading, memorization and connecting information elements were key elements of the metacognitive procedural knowledge reported by both groups of participants. For example, Steve (PT) reported, “I take an academic article, read it, glean the pieces that I feel are relevant, and meld that into (my) current knowledge, past experience, and beliefs and put that together. I look at it as a puzzle and [ask], “How do I put the pieces together?” I can see how patterns go together and, if I have a problem in front of me, I am going to try to see which of these puzzle pieces that I have stored is going to help me solve that problem.” Brian (PT) claimed, “I’ve got to read it, I’ve got to see it, and I’ve got to do it. You’ve got to read it at the very fundamental level. Information is transferred mainly by the written word. I think I’m a good memorizer, but I need to do some problems and examples to really learn and understand it. I can get a shallow understanding just by reading over it. Inside my head, I think new, uncomfortable connections in the brain become comfortable after repetition. The first time you do something is always the hardest because you’re out of your comfort zone and making new connections, whatever the topic. The more repetition, the easier it gets. The ‘pathways’ (sic) become second nature.” “Alex (PT) suggested, “I really rely on the textbook a lot for reading and reading and re-reading and studying. I try, through just simple repetition to remember the vocabulary and the facts. I was conscious of the etymology of the words a lot to help me remember and I would try to visualize to help me remember a little bit as well.” Erica (PST) suggested, “There’s a lot of memorization. It starts with how engaged I am in class; am I paying attention? But, in the end it comes down to repetition. There’s different ways to do repetition like reading out aloud, writing cue cards, drawing diagrams, or going over the manual…but it all comes back to repetition.” Mitch (PST) explained his procedural metacognitive knowledge in relation to memorization, stating, “Memorization is important. Biology is mostly memorization. Associating a strange memory with whatever you’re learning, just like you have a number system of your flashcards or whatever you have printed out, and then you associate those numbers with your flashcards and the specific word or phrase or whatever you're supposed to memorize, and then associate it with something that rhymes with it or something weird that stands out, and you always remember it. That's how I usually memorize. Rhymes usually help a lot. Also, there's just looking over and over [the material] again." Frank (PST), however, held a different view about the role of memorization for his learning of stating "I suck (sic) at memorizing and I'm pretty good at it [learning]. I love graphic organizers, like making mind maps of everything…If I can make a connection, I say I know it… if you understand it, you make that connection."

Assertion 2: *Participants considered it important to teach explicitly such strategies to students but varied regarding how and the extent to which this might happen and the reasons for their views*. The practicing teachers were all generally supportive of the idea of teaching students about how to employ the strategies that they had reported. However they also identified barriers to this occurring in class. Some of the barriers were to do with personal matters, while others arose from their views about the nature of the students they taught. For example, Dan (PT) proposed, "Yes, it would be useful, but I don't know if students necessarily want to be taught that. I find that high school students' approaches are focused on getting good marks. It might help student achievement if they did [know this], but they might not see the value of it." Marg (PT) suggested, "I don't think I know enough of a language of thinking or learning to be able to teach students about what it means to think and learn." Alex (PT) was of the view that, "There's definite value to be had there [with this idea]. Putting more responsibility on students for their own learning, if they have the tools to do so is a great idea. But I'm not sure if there's time [for me to do this]. They need to find something that works for them. Also, when you're fifteen [years old] it's tough to find that motivation, that commitment, or even that time." The pre-service teachers, without the hindsight of full-time experience as practicing teachers were more enthusiastic about the possibilities of sharing their metacognitive procedural knowledge with their future students. Justine (PST) asserted, "I think is important for you to explain to students how you work through problems in your mind so that you would model that type of thinking." Lincoln (PST) articulated how he might explicitly teach the strategies he used, stating, "I think it's 100% important. If I'm trying to help students, I might do a 'think aloud.' I'll go through the dialogue that's going on in my head...you can show them your thinking process, which can be very useful." Mike (PST), like other pre-service science teachers, identified a lack of attention to such matters in his teacher preparation programme, adding, "I think it's a good idea to teach our students how to memorize; how to learn effectively. I've never thought of that before. Why don't our classes tell us to [think about that].

Assertion 3: *Participants reported that they had never previously been asked to consider the matters that they were asked about in the interviews*. For example, Corrine (PT) stated, "It's never crossed my mind. I've never thought about it. You're so focused on the information, the [science] material. I never thought about what's going on in my head when I'm learning and thinking." Paul (PT) added, "I don't think about what I do; I just do it," while Dan (PT) noted, "I've never thought of this before." Garry (PST) exemplified pre-service teacher replies, stating, "I've never been asked these types of questions before; you can probably tell." Max (PST) added to this them when suggesting that what was valued in his schooling might have influenced his experience; "I've never been asked before. Nobody cares about how you get the results, as long as you get them. As long as you get that eighty or ninety percent, you're good."

DISCUSSION AND IMPLICATIONS

In this preliminary, exploratory study variations were evident in practicing and pre-service science teachers' reports of their metacognitive procedural knowledge, the extent to which they considered it important to teach explicitly such strategies to students and why, and whether they had been asked to think previously about such matters. Because the data were drawn from two convenience samples, generalizations across populations should be undertaken with caution. Also, the affordances and constraints of using self-reports for exploring metacognition have long been discussed with varying levels of support as to their validity and reliability (e.g., Veenman et al, 2006). These factors notwithstanding, the variation identified within and between the groups of participants warrants considered attention and raises matters that might be addressed in future research.

It was clear from the data analysis that reading was a key activity identified by almost all participants as being an essential element of their science learning processes. Some gave substantial detail on how they attended cognitively to the information they accessed when and through reading; for example, looking for relevance (Steve) and being aware of the etymology of vocabulary (Alex). The importance of memorization was a common theme and participants were also able to provide insights into how they performed this mental operation. Notably, the notion of connecting and inter-relating ideas and concepts and the importance of one's existing, prior knowledge was common amongst participants of both groups. This metacognitive procedural knowledge is consistent with and reflects foundational tenets of constructivist learning theory, even if none of the participants verbalized their thoughts in such a specific language. As such, if the participants were able to articulate such views to their students, it might be that students would be provided with a view of science learning that is well supported in the science education literature. This is certainly a pedagogical possibility and, as reported by Thomas (2013, 2017) and Thomas and Anderson (2014), when teachers communicate views of what it means to learn science that reflect the nature of the subject they are teaching it is possible to develop and enhance students' metacognition.

It is generally acknowledged that reflection on the processes of learning is a key component influencing the development of metacognition. Therefore, given the aforementioned importance of teachers' knowledge of metacognition, including their own metacognitive knowledge, opportunities should be provided for facilitating such reflection by practicing and pre-service teachers so that they might consider using their metacognitive knowledge as a basis for teaching students about the strategies and cognition that are important for science learning. In this study the interview processes stimulated such reflection and constituted a metacognitive experience (Flavell, 1979; Thomas 2012a) for all participants. Metacognitive experiences are those in which individuals focus their attention on their cognition and the products of that cognition, and evaluate both. As Flavell notes "metacognitive experiences can affect your metacognitive knowledge base by adding to it, deleting from it, or revising it" (p. 908). Teacher professional development activities that explicitly aim to stimulate metacognitive experiences might prove valuable in assisting teachers to become more conscious of their metacognitive procedural of their science learning processes, and the possibility of framing that knowledge as information that can be taught to students. In undergraduate science teacher education, when students can see potential advantages of teaching students about how to learn science effectively, there is the opportunity stimulate metacognitive experiences so that students can begin to articulate those processes to themselves and others, with a long-term view of being able to teach their future students about them. Doing so in undergraduate teacher education might also be an appropriate time to do so, before these future teachers encounter the often harsh contextual realities of teachers' lives in schools.

Future research might build on this study and use multiple methods and purposive sampling to develop assertions across science teacher populations taking into account factors such as the specific science subjects that teachers teach and teachers' years of teaching experience. Such research could lead to valuable suggestions for science teacher education, teachers' pedagogy, and professional development.

ACKNOWLEDGEMENT

This research was supported with financial and logistical assistance from the Centre for Mathematics, Science and Technology Education (CMASTE), located in the Faculty of Education at the University of Alberta, Edmonton, Canada.

REFERENCES

Avargil, S., Lavi. R., & Dori, J. (2018). Students' metacognition and metacognitive strategies in the classroom. In Dori, J., Mevarech, Z., & Baker, D. (Eds.). *Cognition, metacognition and culture in STEM education* (pp. 33-64). Dordrecht: Springer.

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology, 3,* 77-101.

Duffy, G. G., Miller, S., Parsons, S., & Meloth, M. (2009). Teachers as metacognitive professionals. In D. J. Hacker, J. Dunlosky & A. C. Graesser (Eds.), *Handbook of metacognition in education* (pp. 240 – 256). NY: Routledge.

Erickson, F. (1998). Qualitative research methods for science education. In B. J. Fraser & K. G. Tobin (Eds.), *International handbook of science education* (pp. 1155–1173). Dordrecht, The Netherlands: Kluwer.

Ertmer, P. A., & Newby, T. J. (1996). The expert learner: Strategic, self-regulated, and reflective. *Instructional Science, 24*, 1-24.

Flavell, J. H. (1979). Metacognition and cognitive monitoring: A new area of cognitive-developmental inquiry. *American Psychologist, 34,* 906-911.

Georghiades, P. (2004). From the general to the situated: Three decades of metacognition. *International Journal of Science Education, 26*(3), 365-384.

Guba, E. G., & Lincoln, Y. S. (1989). *Fourth generation evaluation.* Newbury Park, Ca: Sage.

Gunstone, R. F. (1994). The importance of specific science content in the enhancement of metacognition. In P. Fensham, R. F. Gunstone & R. T. White, (Eds.), *The content of science: A constructivist approach to its learning and teaching* (pp. 131-146). London: Falmer Press.

King, N., & Horrocks, C. (2010). *Interviews in qualitative research*. London, UK: Sage.

Langridge, D. (2004). *Introduction to research methods and data analysis in psychology.* Harlow: Pearson Education.

Thomas, G. P. (2017). "Triangulation:" An expression for stimulating metacognitive reflection regarding the use of 'triplet' representations for chemistry learning. *Chemistry Education Research and Practice, 18*(4), 533-548.

Thomas, G. P. (2013). Changing the metacognitive orientation of a classroom learning environment to stimulate metacognitive reflection regarding the nature of physics learning. *International Journal of Science Education, 35*(7), 1183-1207.

Thomas, G. P. (2012a). Metacognition in Science Education: Past, present and future considerations. In B. J. Fraser, K. G. Tobin, and C. J. McRobbie (Eds.), *Second International Handbook of Science Education* (pp. 131-144). Dordrecht: Springer.

Thomas, G. P. (2012b). The Metacognitive Science Teacher: A statement for enhanced teacher cognition and pedagogy. In F. Ornek and I. Saleh (Eds.), *Contemporary Science Teaching Approaches: Promoting Conceptual Understanding in Science* (pp. 29-53). Charlotte, NC: Information Age Publishing.

Thomas, G. P., & Anderson, D. (2014). Changing the Metacognitive Orientation of a Classroom Environment to Enhance Students' Metacognition Regarding Chemistry Learning. *Learning Environments Research, 17*(1), 139-155.

Veenman, M., Vam Hout-Wolters, B., & Afflerbach, P. (2006). Metacognition and learning: Conceptual and methodological issues. *Metacognition and Learning, 1,* 3-14.

White, R. T. (1988). Decisions and problems in research on metacognition. In B. J. Fraser and K. G. Tobin (Eds.), *International handbook of science education* (pp. 1207-1212). Dordrecht, The Netherlands: Kluwer Academic Publishers.

Zohar, A. (1999). Teachers' metacognitive knowledge and instruction of higher-order thinking. *Teaching and Teachers' Education, 15,* 413-429.

Zohar, A., & Barzilai, S. (2013). A review of research on metacognition in science education: Current and future directions. *Studies in Science Education, 49*(2), 121-169.

HOW CAN EARTHQUAKES GET INTO A 5TH GRADE CLASSROOM?

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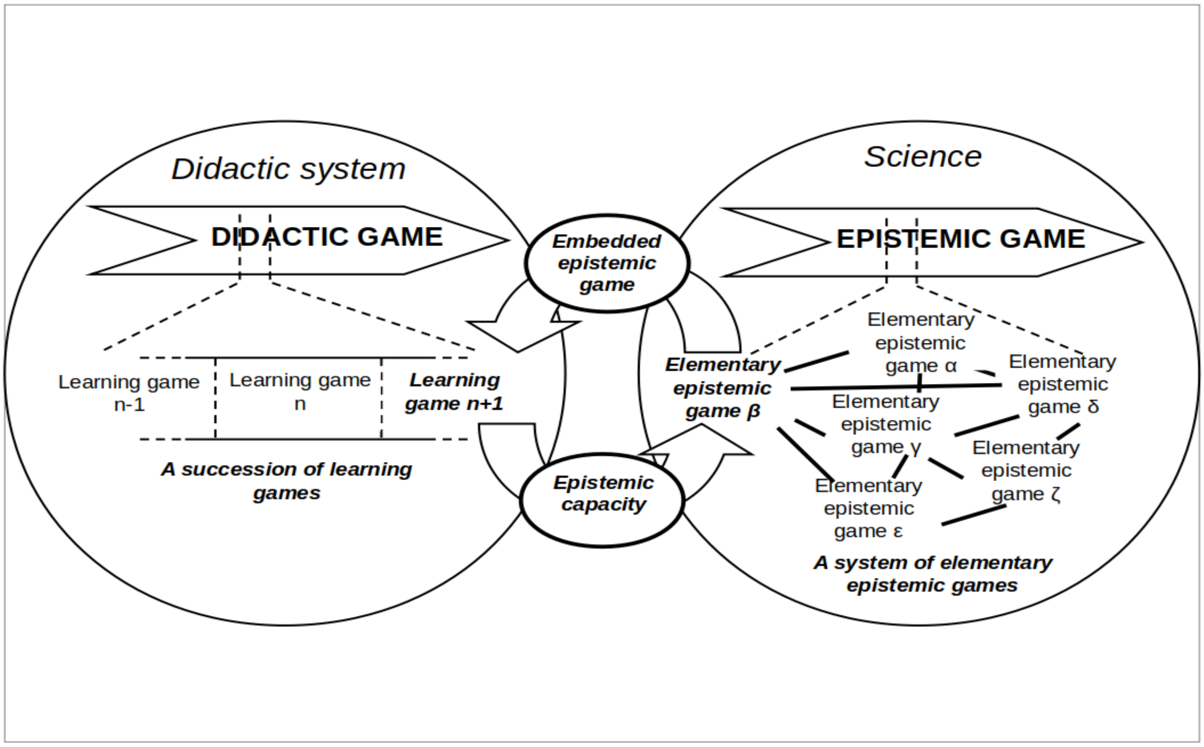
*This paper addresses the issue of the teaching and learning of phenomena that are impossible to get into classrooms, such as that of earthquakes. Over a period of 3 years, we studied the teaching sequences of a 5th grade teacher on the subject of earthquakes. During the 2*nd *and 3*rd *year of this period, a member of the research team cooperated with the teacher in a cooperative engineering teaching sequence. In this case study, we have analyzed the changes in the sequence between the 1st and 3rd year. We situate our work within the Joint Action Theory in Didactics (JATD). The JATD posits that 1) the teaching-learning process is a joint action between teachers and students about the knowledge at stake and 2) that knowledge is inherent in cultural practices. Our methodology relies on a clinical approach using video. Our case study has produced scientific results for science education research and has also become a resource for science teaching. From a science teaching viewpoint, the simulation we devised is a new resource for teaching. From a science education research viewpoint, this new simulation has a kind of "epistemic kinship" with the basic simulations that were used in the seminal works in seismology. We have concluded that this new simulation contributes to students being confronted with a genuine aspect of seismology and that this was made possible thanks to the cooperative engineering approach.*

Keywords: science education, simulations, video analysis

1. GENERAL DESCRIPTION

This paper addresses the issue of the teaching and learning of phenomena which are impossible to get into classrooms, such as that of earthquakes. The subject of earthquakes is part of the French mandatory curriculum for primary schools. Over a period of 3 years, we studied the teaching sequences of the same 5th grade teacher on earthquakes. In this case study, we analyzed the changes in this sequence between the 1st and 3rd year. Our analysis showed that the investigated teacher used two different simulations of earthquakes in his classroom sessions. We compared the two simulations with regard to their potentialities to teach and learn about earthquakes. We think of models and simulations as reducing general theories to particular events (Cartwright, 1999; Sensevy, Tiberghien, Santini, Laubé, & Griggs, 2008). In such an approach the second simulation is better than the first. This second simulation was elaborated in a didactic cooperative engineering (Joffredo-Le Brun, Morellato, Sensevy, & Quilio, 2018; Sensevy, Forest, Quilio, & Morales, 2013) with the first author in the role of a teacher-researcher (Roth, 2007).

We situate our work within the Joint Action Theory in Didactics (JATD; Sensevy, 2011, 2012). The JATD posits that 1) the teaching-learning process is a joint action between teachers and students about the knowledge at stake and 2) that knowledge is inherent in cultural practices. This theoretical position was actualized in a modeling of practices as games (Santini, Bloor, & Sensevy, 2018). Cultural practices are modeled as epistemic games, i.e. games with knowledge at stake and where the dominating focus is not teaching it. Educational practices are thus



modeled as learning games, i.e. games with knowledge at stake and where the dominating focus is on having it learned. The knowledge at stake is modeled as epistemic capacities following an agentive conception of knowledge (Sensevy & Tiberghien, 2015a). In this modeling we apprehend the work of didactic cooperative engineering as embedding epistemic games within learning games.

Figure 1. Knowledge games model in the Joint Action Theory in Didactics (Santini, Bloor, & Sensevy, 2018)

We describe learning games as an interplay between a didactic contract (Brousseau, Sarrazy, & Novotná, 2014) and a didactic milieu (Sensevy & Tiberghien, 2015b). Didactic contracts describe the actual strategic system to play learning games, i.e. what is already known. Didactic milieus describe the potential strategic system to be deciphered so as to play learning games, i.e. what is to be known. From this modeling, comparisons between learning games and epistemic games are undertaken to characterize the value of what is learned in science education with regard to science. That is to say, in the terms of the knowledge games model, (cf. fig. 1), to what extent the epistemic capacities "won" in the learning games enable learners to play epistemic games.

2. METHOD

Our methodology relies on a clinical approach (Bulterman-Bos, 2008, 2017; Foucault, 1963; Leutenegger, 2009) using video studies (Tiberghien & Sensevy, 2012). We videotaped and transcribed all the teaching sequences about earthquakes and volcanoes during the first and the third year of the case study. The sessions of cooperative engineering took place during the second and the third years. We audiotaped and transcribed them. We analyzed the whole data in a progressive refinement of hypotheses (Engle, Conant, & Greeno, 2007).

3. RESULTS

This case study was conducted over a period of 3 years. The investigated teacher was confronted with a problem: how could students work on phenomena which are impossible to get into a classroom? The first option was to represent it with an isoseismal map (cf. fig. 2). The teacher asked the students to explain the concentric pattern on the map. The students agreed that earthquakes "weaken while moving". The teacher used a simulation with playing cards (cf. fig. 3) to test this explanation as seen in the following excerpt. We focused on this learning game in the following analyzes.

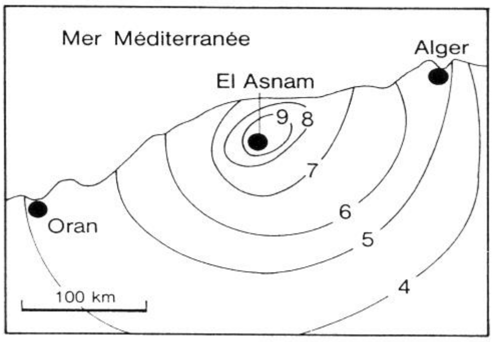


Figure 2. Isoseismal map

Figure 3. The playing cards simulation

The teacher hits the table a little bit harder. The first two pairs of cards remain upright, the ones just after fall and the last one remains upright.		
826	Student	Yeah but it's cards
The teacher hits the table stronger. Only the last pair of cards remain upright.		
827	Teacher	Ah and the last one
828	Student	One more time
829	Teacher	Ah and the last one hush
830	Student	Twelfth degree
831	Guillaume	Harder
832	Student	Twelfth degree
833	Teacher	But the last one as you see
834	Student	It's still standing
835	Teacher	So
836	Mélanie	But there was a problem because some fell down and the first two they stayed steady

837	Teacher	Yes that was what you were saying before it depends on the quality of the buildings because depending on how I put up my cards

The results of the simulation couldn't account for the concentric pattern of the isoseismal map. The teacher and the students tried together to "save" the situation by referring to the "quality of buildings". During the 1st year the didactic milieu did not provide enough feedback to confront the students with the regularities represented with the isoseismal map. The teacher was not satisfied with the playing cards simulation because it did not meet his expectation of regular results. The teacher and one of the teacher-researchers in our study worked together on a new simulation (cf. fig 4) in a cooperative engineering.

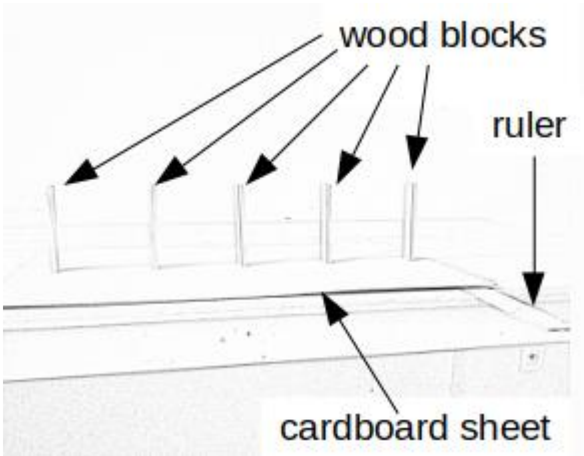


Figure 4. The new simulation designed in cooperative engineering.

The new simulation illustrated above, was then used in the same learning game by both teachers. The transcription below is an extract from a lesson where the simulation was introduced.

5	Teacher	We are going to check. So, if I push lightly [on the ruler; cf. fig. 3] and look closely at what happens - when I push lightly what happens?
256	Student	Nothing
257	Teacher	Ah yes something happened
258	Valentin	It shakes
259	Teacher	Which one? Come and show me ah how about this one?
260	Marine	The closest to the ruler
261	Teacher	It is closer to the center er when I say the center it is the place where it happens. Now I do it - I do it one more time so you can see it's shaking a little did you see it?
262	Student	No
263	Student	Ah yes
264	Teacher	So I do it lightly now we are going to do it a little bit more
265	Student	Harder
266	Teacher	What happened? hush what happened?
267	Guillaume	There were three that fell down and this one on the right that shook
268	Teacher	Yes but it's not enough for me
269	Student	The closer ones to the (inaudible)

270	Teacher	There were three that fell down but they were the closest to the – What did we call that
271	Student	The shaking
272	Teacher	The shaking or the [looks at the hypotheses produced by workgroups and written on the blackboard] center so is this the shaking that has moved?

During the 3rd year, the simulation produced the expected results in the unfolding of the learning game. The didactic milieu provided enough feedback to confront the students with the regularities represented with the isoseismal map. The learning game consisted of *running a simulation of earthquake damage with pieces of wood placed upright on cardboard with a ruler underneath to simulate earthquakes by lifting up the cardboard*. The unfolding of this learning game enacted an epistemic capacity of *assessing hypotheses about the seismic mechanism by managing a concrete model*. The analysis showed that the students are more likely to "win" this epistemic capacity with the 3rd year version of the learning game.

In the history of seismology, Reid (1910) used the results of a concrete simulation (cf. fig 5) to test his theoretical hypothesis of earthquakes as elastic rebounds.

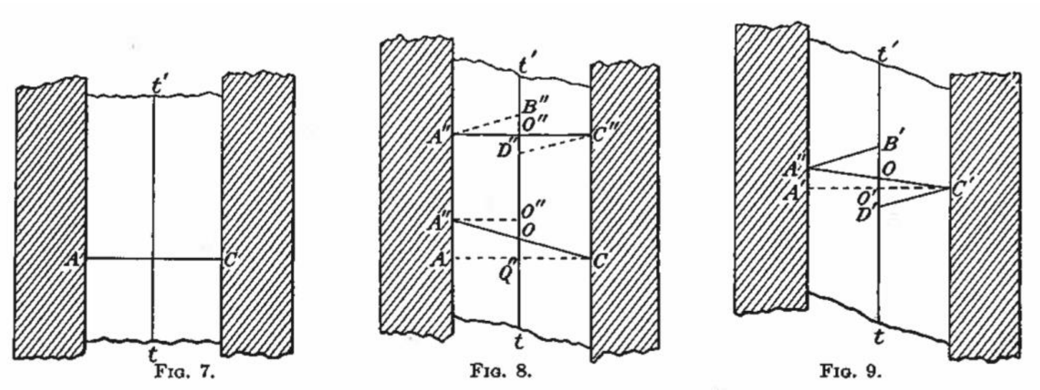


Figure 5. The stiff jelly and wood simulation used by Reid (1910, p. 20).

We modeled this piece of Reid's work as an elementary epistemic game consisting of *designing a concrete model accounting for the mechanical properties of the crust to test the elastic-rebound theory of earthquakes*. In the classroom session, the students and the teacher also tested their hypotheses on earthquakes by means of a simulation. Under such a description there is a kind of "epistemic kinship" between the learning game and the epistemic game. In both games, seismologists, students and teachers rely on basic simulations to test their hypotheses. To have the students confronted with the feedback of simulations is then favorable to give them an effective taste of seismology.

4. DISCUSSION AND CONCLUSIONS

Our case study produced both scientific results for science education research and resources for science teaching. From a science teaching viewpoint, the new simulation (cf. fig. 4) is a new resource for teaching. Its functioning nurtured the didactic milieu with regular results. It supported effectively a didactic contract of inquiry whereas the playing cards simulation didn't. From a science education research viewpoint, this new simulation had a kind of "epistemic kinship" with the basic simulation used by Reid (cf. fig. 5) in his seminal work in seismology. This new version of the learning game was then more coherent with the epistemic game of seismology. We concluded that this new simulation contributed to more effective teaching on earthquakes, and that this was made possible with the cooperative engineering approach. We reached this conclusion following an analysis of teaching effectiveness in a two-step process using our knowledge games model (cf. fig. 1). This consists of asking the following two questions: 1) Can the epistemic capacity be "won" in the unfolding of the learning game? 2) Does this epistemic capacity enable the learner to "win" the epistemic game? It follows from this description that these two conditions are necessary for students to actually experience something of science.

REFERENCES

Brousseau, G., Sarrazy, B., & Novotná, J. (2014). Didactic Contract in Mathematics Education. In S. Lerman (Ed.), *Encyclopedia of Mathematics Education* (p. 153-159). Berlin: Springer.

Bulterman-Bos, J. (2008). Will a Clinical Approach Make Education Research More Relevant for Practice? *Educational Researcher*, *37*(7), 412.

Bulterman-Bos, J. (2017). How can a clinical research approach contribute to knowledge-building for the teaching profession? *Educational Action Research*, *25*(1), 119–127.

Cartwright, N. (1999). *The Dappled World*. Cambridge: Cambridge University Press.

Engle, R. A., Conant, F. R., & Greeno, J. G. (2007). Progressive refinement of hypotheses in video-supported research. In R. Goldman, R. Pea, B. Barron, & S. J. Derry (Ed.), *Video research in the learning sciences* (p. 239–254). Mahwah, N.J.: Erlbaum.

Foucault, M. (1963). *The Birth of the Clinic*. London: Routledge.

Joffredo-Le Brun, S., Morellato, M., Sensevy, G., & Quilio, S. (2018). Cooperative engineering as a joint action. *European Educational Research Journal*, *17*(1), 187-208.

Leutenegger, F. (2009). *Le temps d'instruire. Pour une approche clinique et expérimentale de la didactique ordinaire*. Peter Lang.

Reid, H. F. (1910). *The Mechanics of the Earthquake*. Washington, DC: Carnegie Institution of Washington.

Roth, W.-M. (2007). *Doing Teacher-Research*. Rotterdam: Sense Publishers.

Santini, J., Bloor, T., & Sensevy, G. (2018). Modeling Conceptualization and Investigating Teaching Effectiveness. *Science & Education*, *27*(9-10), 921-961.

Sensevy, G. (2011). Overcoming Fragmentation: Towards a Joint Action Theory in Didactics. In B. Hudson & M. Meyer (Ed.), *Beyond Fragmentation* (p. 60-76). Portland, OR: Barbara Budrich.

Sensevy, G. (2012). About the Joint Action Theory in Didactics. *Zeitschrift für Erziehungswissenschaft*, *15*(3), 503–516.

Sensevy, G., Forest, D., Quilio, S., & Morales, G. (2013). Cooperative engineering as a specific design-based research. *ZDM*, *45*(7), 1031–1043.

Sensevy, G., & Tiberghien, A. (2015a). Agency and Knowledge. In R. Gunstone (Ed.), *Encyclopedia of Science Education* (Vol. 1, p. 27-30). New York, London: Springer Dordrecht.

Sensevy, G., & Tiberghien, A. (2015b). Milieu. In R. Gunstone (Ed.), *Encyclopedia of Science Education* (Vol. 2, p. 639-641). New York, London: Springer Dordrecht.

Sensevy, G., Tiberghien, A., Santini, J., Laubé, S., & Griggs, P. (2008). An epistemological approach to modeling. *Science Education*, *92*(3), 424–446.

Tiberghien, A., & Sensevy, G. (2012). Video studies: Time and duration in the teaching-learning processes. In J. Dillon & D. Jorde (Ed.), *Handbook « The World of Science Education »* (Vol. 4, p. 141–179). Rotterdam/Boston/Taipei: Sense Publishers.

DESIGNING A TEACHING-LEARNING SEQUENCE ABOUT ELECTROMAGNETIC RADIATION FOR GRADE EIGHT

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Electromagnetic radiation is not part of compulsory education in Austria. As the topic is important in our everyday life, we are working on a teaching-learning sequence to introduce the topic in eighth grade. With the goal to make the subject matter easier to understand for young students, we developed a novel approach to teach electromagnetic radiation, building on existing research on geometrical optics. In this paper we present results of the second and third cycles of the iterative process of design, implementation and evaluation. In both cycles we worked with single students, applying the method of probing acceptance. The results help us to understand which parts of the design work well, which learning obstacles typically arise and which aspects of student learning must be investigated further.

Keywords: Evidence Based Approaches, Secondary School, Teaching Learning Sequences

INTRODUCTION

How can you teach the complex topic of electromagnetic radiation at the middle school level? This is a question we strive to answer with our research. As electromagnetic radiation plays a huge role in our everyday life, we argue that everybody should have some basic understanding of it. However, the topic is not part of the compulsory curriculum in Austria. We see a chance to introduce the topic in eighth grade, as it is the last year in the Austrian school system where all students have compulsory physics lessons. Our aim is to develop a teaching-learning sequence and to evaluate and refine it in continuous cycles. The first challenge we faced was to come up with a way to explain electromagnetic radiation to students in their first years of physics education, especially since the wave model, that is typically used to teach the topic, is not part of the middle school curriculum. We developed a novel approach to introduce electromagnetic radiation, building on results from existing research on geometrical optics (Haagen-Schützenhöfer, 2016). As a first design step, we are developing central explanations, so called "key ideas", which build the foundation of the teaching-learning sequence. A first cycle of evaluation and refinement has already been conducted and presented elsewhere (Zloklikovits & Hopf, submitted). In this paper we present the following two cycles of investigation.

THEORETICAL BACKGROUND

Design Research

The motivation behind design research is to develop evidence-based approaches to teach a certain topic. The most prominent feature is that the development of the material is an iterative process, as the material is designed based on theoretical knowledge, implemented, evaluated and refined (Prediger, Gravemeijer, & Confrey, 2015). It is typical to start to evaluate the design with single students before implementing it in classrooms (Nieveen & Folmer, 2013). Extensive data is collected during such projects, giving many opportunities to not only generate a design that fosters learning in physics classrooms, but to also develop educational theories. There are many examples of what kind of theories can be developed or enhanced through such projects. The presented work aims to enhance domain specific educational knowledge, as the educational research on electromagnetic research is quite scarce (Prediger et al., 2015). The term "teaching-learning sequence" is especially common in the European landscape of science education, describing "medium-scale curriculum product[s] covering a scientific topic" that are developed under a design research paradigm (Psillos & Kariotoglou, 2016).

Findings from physics education

In comparison to other topics, the body on educational literature about electromagnetic radiation is quite small. First efforts to document students' conceptions have been made, showing that students do not have a sound understanding of the topic (Plotz, 2017). For example, students are not able to distinguish between ionizing and non-ionizing radiation (Rego & Peralta, 2006). They often think that every device emits harmful radiation (Neumann & Hopf, 2012), but radiation used in medicine is harmless (Henriksen & Jorde, 2001). Based on his work on investigating learning processes, Plotz (2017) formulated four basic concepts students should know about electromagnetic radiation. These encompass the propagation of radiation, its omnipresence, the classification in the spectrum as well as the interaction with matter and its transmission of energy. These concepts work as guiding principles for our teaching-learning sequence.

Our approach to teaching electromagnetic radiation

In contrast to what you might find in a textbook, the teaching-learning sequence we are developing introduces electromagnetic radiation without waves or particles. As described in (Zloklikovits & Hopf, submitted), our approach follows, what we call, an "optics approach". We came to this approach by building on the outcomes of design research on geometrical optics by Haagen-Schützenhöfer (2016), transferring the educational elements used to teach light to the rest of the spectrum. This results in characterising electromagnetic radiations via its properties and making the distinction between radiation and matter clear. We also adapted the so-called sender-receiver model (meaning that you always follow the propagation of the radiation from the source to the detector), and the depiction of radiation as cone-shaped arrows. Instead of classifying the different types of radiation in the spectrum by wavelength or frequency, we decided to use energy as the distinguishing quantity. We hoped that the different effects that radiation can have on the human body might be explained plausibly to students, as the idea that the absorption of energy causes various effects could align with even naïve ideas of energy.

We designed five key ideas that build the foundation of the teaching learning-sequence. They cover the introduction of the term "electromagnetic radiation", the interaction with matter, the transport of energy, the electromagnetic spectrum and the factors influencing the health risk opposed by radiation. In our previous research, we evaluated the first three key ideas (Zloklikovits & Hopf, submitted). The results were promising, demonstrating that it is worthwhile to investigate this approach further. Our results showed that students tend to think that all types of radiation have a warming effect on our skin. We also found that students sometimes think that radio waves can be heard, or that the reception is better inside a house than outdoors. As these perceptions do not align with the intended concept, we concluded that another context might be more fitting.

Method of probing acceptance

The aim of our research is to develop a teaching-learning sequence that provides a physical framework that students find plausible and intelligible and that they can apply to new problems, as these are necessary conditions for a conceptual change as stated by Posner, Strike, Hewson, and Gertzog (1982). A method that was developed in physics education research for this purpose is the method of probing acceptance (Jung, 1992; Wiesner & Wodzinski, 1996). This form of teaching experiments proofed to be quite useful in recent design-research projects (Haagen-Schützenhöfer, 2016; Wiener, Schmeling, & Hopf, 2015). The idea of the method is to present an explanation to a student and to investigate how the student receives this explanation. After the explanation is discussed and demonstrated on an example, the student is asked to assess it. Here one might be able to observe first resistances towards the explanation. The student is then asked to rephrase the explanation. Omissions and transformations indicate which parts of the explanations might not be well received or understood by the student. Next, the student has to solve a task. At this step, the researcher can see if the student applies the given explanations to the task, as well as which problems arise when working with the explanation.

The instructions that are developed and refined in an iterative process for this method are a prototypical version of a teaching-learning sequence (Wiesner & Wodzinski, 1996). Therefore, in the design research framework, we consider the materials developed for the teaching experiments a first, prototypical design.

Study design

As explained in the theoretical background, the aim in this stage of our research it is to develop a first prototypical design. Therefore, we aspire to answer the following research questions:

- Do students find the key ideas intelligible and plausible?
- Are students able to apply the key ideas to new problems?
- Which learning obstacles and which helpful elements can be identified for the specific learning content?

To answer those research questions, two cycles of implementation and evaluation have been conducted and are presented in this paper. In the following, we refer to them as Study 1 and Study 2. In both cycles, we conducted one-hour long one-on-one teaching experiments, applying the method of probing acceptance. Eighth-grade and ninth-grade students from two different schools in Vienna participated in those studies. We anticipated that there would hardly be a difference between the performance of eighth-grade and ninth-grade students, as the ninth grade curriculum does not cover topics that overlap with our instructions, and our findings confirmed this. Every interview was recorded and transcribed. The data was analysed and the outcomes discussed with experts. The results led us to replace the context of radio waves with mobile phone radiation. We also saw that students tended to confuse radiation, energy and heat – therefore we made sure to avoid the terms “warm” and “heat”, talking strictly about a rise in temperature when discussing the effect of infrared radiation on the human body instead. Another issue was that students were confused by a task that had them explain how the energy emitted by the sun comes to earth. Students tried to argue that the atmosphere absorbed the radiation, so we decided to change the task – instead of the sun and a solar panel, we use a lamp and a solar operated calculator instead, avoiding the distracting aspect of the atmosphere’s role. We evaluated the revised teaching experiment with six students (Study 1), analysed the transcripts and revised the material again, conducting interviews with eight students (Study 2).

Analysis of the data

The recordings were analysed with the method of evaluative qualitative text analysis (Kuckartz, 2014). A coding manual was prepared, defining for every step of the teaching experiments if the performance of the student was good ✓, satisfactory ~, or insufficient ✗. This method of analysing teaching experiments was suggested by Haagen-Schützenhöfer (2016). A “good” assessment means that a student fully approved of the key idea, whereas “satisfactory” means that they agreed with the idea but raised some doubts, insufficient that they didn’t find the explanation intelligible. In case of paraphrasing, a paraphrase was rated as "good" when a student included all the important aspects of the explanation, as "satisfactory" if a part of the explanation was left out or inaccurate, and "insufficient" otherwise. The task solving was coded as "good" when the student applied the presented explanation and was able to solve the task accordingly, needing a small assistance at most. If more assistance was needed, this step of the teaching experiments was rated as "satisfactory". When a student was not able to solve the task accordingly, it was coded as "insufficient". Missing data was not coded. A colleague coded a randomly selected transcript of each study, resulting in a cohens kappa of 0.81 (almost perfect agreement) for Study 1 and 0.71 (substantial agreement) for Study 2 (Landis & Koch, 1977). The passages of the transcripts that were rated as "satisfactory" or "insufficient" were presented and discussed with the colleagues from our research teams.

An overview of the explanations, illustrating examples and tasks the students were given in Study 1 and Study 2 can be found in Table 1. The results of the two presented investigations are displayed in Table 2, which is displayed at the end of the paper. The student names given in the table are pseudonyms. In the following, the results of the two studies are presented and discussed in more detail and give insight into the students' reasoning.

Table 1: Overview of the steps of the teaching experiments

	Study 1	Study 2
Key Idea I	Radiation is different than matter! It can't be touched, it has no mass, and it propagates with the speed of light.	Radiation is different than matter! It can't be touched, it has no mass, and it propagates with the speed of light. You need different detectors for different types of electromagnetic radiation.
Demonstration	Visible light (detectable with eyes), infrared radiation (detectable with skin)	Visible light (detectable wit eyes), UV radiation (detectable with UV beads)
Key Idea II	Radiation propagates until it hits matter. A part of the radiation is transmitted, a part reflected, a part absorbed. The amount that is transmitted, reflected or absorbed depends on the type of radiation and the matter.	Radiation propagates until it hits matter. A part of the radiation is transmitted, a part reflected, a part absorbed. The amount that is transmitted, reflected or absorbed depends on the type of radiation and the matter.
Demonstration	Absorption, reflection and transmission of light on semi-transparent paper and on water, then using infrared radiation instead of light.	Absorption, reflection and transmission of light and UV radiation on semi-transparent paper/ of visible light on an eyeglass lenses.
Task 1	Absorption, reflection and transmission of infrared radiation on tinfoil.	Absorption, reflection and transmission of UV radiation on an eyeglass lenses.
Task 2	Why is the mobile phone reception in an elevator so poor?	
Key Idea III	Sources of electromagnetic radiation emit energy – the energy is carried by the radiation. When radiation is absorbed by matter, energy is transferred to the matter.	Electromagnetic radiation is a form of energy. If electromagnetic radiation is absorbed, energy is absorbed.
Demonstration	Temperature rise of skin when it absorbs infrared radiation.	Energy transport from a lamp to a solar calculator.
Task 1	Why does a solar calculator work without a battery?	Do the eyeglass lenses absorb energy when irradiated on with UV radiation?
Task 2	When water and tinfoil are irradiated with infrared radiation, which material absorbs more energy?	
Key Idea IV	There are different types of radiation. They differ in the amount of energy they carry. In the spectrum, the types are classified by their energy. Types with similar energy are clustered.	There are different types of radiation. They differ in the amount of energy they carry. In the spectrum, the types are classified by their energy. Types with similar energy are clustered.
Demonstration	Drawing the spectrum horizontally, locating the types of radiation discussed before in the spectrum.	Drawing the spectrum horizontally, locating the types of radiation discussed before in the spectrum.
Task	Which types of radiation might be seen as dangerous?	Which types of radiation might be seen as dangerous?

Key Idea V	Electromagnetic radiation can be dangerous. The level of risk depends on the type of radiation as well as the intensity and duration of the irradiation.
Demonstration	Demonstrating intensity with visible light; light as harmless radiation; danger or X-radiation and how the risk is minimised at X-radiation examinations.
Task	Is mobile phone radiation dangerous?

STUDY 1

Results

Key Ideas I is not discussed in detail this paper, as the results our previous study showed that the idea was well received, and the studies presented in this paper strengthened this finding. However, it has to be noted that some students used the word “heat” or “warmth” instead of radiation.

The results displayed in Table 2 show that the second key idea was well assessed by the students. Some students had problems paraphrasing the key idea. Gülcan talked about radiation being conducted. Hoda and Nina said that radiation is either absorbed or reflected, neglecting that in most cases parts of the radiation are absorbed, reflected and transmitted at the same time. All students were able to solve the first task. For the second task, explaining why there is bad reception in an elevator, Hoda did not apply the given explanations, trying to argue with a change of air pressure instead.

Key Idea III covers the connections between energy and electromagnetic radiation. This idea was well received by the students as well, although some problems arose when they had to rephrase the explanation and apply it to new tasks. Gülcan talked about heat instead of radiation. Kathi stated that energy is “something like radiation, but not radiation”. While solving the task, she did not use the word “energy” at all. Julia left out that energy is transferred when radiation is absorbed.

The electromagnetic spectrum was introduced through Key Idea IV. Some students did not use the word “energy” when rephrasing the explanations, instead saying that electromagnetic radiation is classified by “the extend of impact”, “the energy the radiation emits”, or the “strength” of the radiation. Even upon request the students did not involve the word energy in their elaborations, talking about the intensity and the harmfulness of the type of radiation instead. This problem also occurred when students had to solve the task: Gülcan argued that the danger of radiation depends on the intensity. Nina said that gamma radiation is dangerous: “It is logical as it is the strongest [type of radiation]”, referring to its position in the spectrum. When asked about X-radiation, she said that she did not think that it is dangerous because it is used in medicine. A very interesting observation is that, although she did not change assessment of, Nina raised some doubts about it being harmless as it is so high up in the spectrum. Monika also deemed gamma radiation as harmful but not X-radiation. Surprisingly, she said that visible light is dangerous, as she heard that some types of light bulbs could by harmful to the eye. Looking at Table 2, one can see that all the other students had no problem with this task.

Discussion

Our findings showed that students still confused radiation and heat. Therefore, we decided to leave out infrared radiation all together for future teaching experiments, replacing it with UV radiation. In Study 2, we used UV lamps for the experiments and UV detecting beads as detectors.

We saw that replacing the context of radio waves with mobile phone radiation worked well for the students. Our findings also suggest that using a solar calculator and a lamp instead of a solar panel and the sun is better suited for the task about energy.

Throughout the investigation, we saw that students avoided the use of the word "energy". This could indicate that the idea that radiation "carries energy" might not be plausible to the students. In addition, this idea could let students conclude that energy and radiation are two different entities. In an attempt to make the connection between energy and radiation more clear, we decided to build on the forms approach of energy, as this is the common approach how energy is taught in school (Nordine, Fortus, Lehavi, Neumann, & Krajcik, 2018). Therefore, we changed the third key idea to "Electromagnetic radiation is a form of energy. If electromagnetic radiation is absorbed, energy is absorbed", elaborating that the radiation is transformed into other types of energy.

STUDY 2

In addition to the changes described in the section before, we added a new key idea to the teaching experiments, covering the potential risk posed by electromagnetic radiation. In order to keep the duration of the interviews to one hour, we only asked the students to solve one task per key idea.

Results

In Study 2, we also saw students saying that radiation is either absorbed, reflected or transmitted. The use of UV radiation instead of infrared radiation led to some problems, as students tried to detect the radiation with their eyes instead of using the UV detecting beads.

While trying to paraphrase the third key idea, Petra struggled to verbalise the connection of energy and radiation. She did not use the word energy at first, and then said that when the calculator absorbs radiation, the calculator "has energy". Only after pressed by the interviewer she said that radiation is energy. Rosa said that radiation could be transformed into energy instead of radiation being a form of energy. When solving the task, Quentin was not able to verbalise the connection between energy and radiation.

When discussing the key idea about the electromagnetic spectrum, Timo did not use the word energy and talked about the "strength" instead. He elaborated that infrared "only sees the body" and X-radiation "is able to see the bones". He was not able to verbalise what the spectrum is. Almost every student struggled with the task. Olga, Petra and Timo only argued with their pre-instructional knowledge. Petra was not able to establish a link to the spectrum. Quentin did not use the word energy in his argumentation. After request, he said that the role of energy in the spectrum is clear to him. He also said that radio waves are dangerous because *Radio*-acitvity is dangerous. Rosa talked about the "size" of the radiation and only used the word energy upon request.

Key Idea V deals with the potential risk posed by electromagnetic radiation. While Olga and Rosa included the intensity and the duration in their discussion on the potential risk, they did not take the type of radiation into account. This happened again when Rosa tried to solve the task. When asked to explain further, she said that the heat of a mobile phone could be dangerous, "like in the sun, where one gets cancer when it is 40 degrees". Quentin argued that mobile phone radiation is the radiation a mobile phone emits via the display. Steven gave a similar answer.

Discussion

One of the most prominent problems in Study 1 was that students avoided to use the word "energy" in their argumentations. We tried to make the connection between energy and radiation more clear in the second study, building on the forms approach of energy, but we could not see a difference in the results. As the ideas of the spectrum and the potential risk build on the concept of energy, this is a problem we have to take a closer look at in future investigation. Interestingly, while the spectrum helped most of the students to argue about the danger of radiation in Study 1, in Study 2 they struggled with the task. This could be a clue that explaining radiation as a carrier of energy might be a more helpful idea.

Not including infrared radiation helped to avoid the problem of students mixing up heat, energy and radiation. However, it has to be noted that it was not easy to construct the material without using infrared as an example, as it enables to easily experiment with a type of radiation that is not visible, whereas UV radiation is more abstract as one has to use detectors like UV beads to work with it. We therefore suggest starting with visible light, then moving on to infrared radiation, and then including UV radiation, a type of radiation you can neither see nor feel, as we think this might be a good learning progression.

A surprising finding was that the students seemed to have no idea what mobile phone radiation is, although it is a topic often discussed in Austrian Media. The notion that the radiation the visible radiation emitted display is quite interesting, especially as it was raised by a student who is very interested in physics and is known as a very good student.

Another interesting comment was that the light from the sun causes cancer when it is warm enough. This adds to our previous findings – students seem to think of the radiation from the sun as one type of radiation that is warm, visible and responsible for suntan and skin cancer. This is most likely a result from every day experiences.

We are aware that we worked with a small sample size and that these results are not generalizable. However, to see how students react to certain explanations, contexts and tasks are vital findings, as they help us to make informed design decisions before conducting large-scale investigations.

Table 2: Results of the content analysis of Study 1 and Study 2

Study 1

Key Idea		Gülcan	Hoda	Ivan	Julia	Kathi	Lukas	Monika	Nina
Key Idea II	Assessment	✓	✓	✓	✓	✓	✓	✓	✓
	Rephrasing	~	~	✓	✓	✓	✓		~
	Task: interaction infrared radiation & tinfoil	✓	✓	✓	✓	✓	✓	✓	✓
	Task: mobile phone reception	✓	~	✓	✓	✓	✓	✓	✓
Key Idea III	Assessment	✓	✓	✓	✓	✓	✓	✓	✓
	Rephrasing	~	✓	✓	~	~	✓	✗	✓
	Task: energy transportation solar calculator	~	✓	✓	✓	✓	✓	~	✓
	Task: energy absorption infrared radiation	✓	~	✓	✓	✓	~	~	✓
Key Idea IV	Assessment	~	✓	✓	✓	✓	✓	✓	✓
	Rephrasing	✗	✓	✓	✓	~	✓	~	✓
	Task: potentially harmful types of radiation	✗	✓	✓	✓	✓	✓	✗	~
Key Idea V									

Study 2

Key Idea		Olga	Petra	Quentin	Rosa	Stefan	Timo
Key Idea II	Rephrasing	✓	~	✓	~	✓	✓
	Task: interaction UV radiation & lenses	✓	✓	✓	~	✓	~
Key Idea III	Assessment	✓	✓	✓	✓	✓	✓
	Rephrasing	✓	~	✓	~	✓	✓
	Task: energy absorption UV radiation	✓	✓	~		✓	
Key Idea IV	Assessment	✓	✓	✓	✓	✓	✓
	Rephrasing	✓	✓	✓	✓	✓	~
	Task: potentially harmful types of radiation	~	~	~	~	✓	✗
Key Idea V	Assessment	✓	✓	✓	✓	✓	✓
	Rephrasing	~	✓	✓	~	✓	✓
	Task: potential danger of mobile phone radiation	✓	~	~	~	✓	✓

CONCLUSION & OUTLOOK

In this paper, we presented results from two cycles of an iterative design research process with the aim to develop a teaching learning-sequence suitable for middle school students. The first two key ideas were plausible and intelligible to the students and they were able to apply them to new problems. Problems surfaced as soon as the key ideas included the energy concept. This is the next challenge our research has to face.

REFERENCES

Haagen-Schützenhöfer, C. (2016). *Lehr- und Lernprozesse im Anfangsoptikunterricht der Sekundarstufe I* (Habilitationsschrift). Universität Wien, Wien.

Henriksen, E. K., & Jorde, D. (2001). High school students' understanding of radiation and the environment: Can museums play a role? *Science Education*, *85*(2), 189–206. https://doi.org/10.1002/1098-237X(200103)85:2<189::AID-SCE60>3.0.CO;2-S

Jung, W. (1992). Probing acceptance, a technique for investigating learning difficulties. In *Research in Physics Learning: Theoretical Issues and Empirical Studies. Proceedings of an International Workshop at the University of Bremen. Kiel: IPN.*

Kuckartz, U. (2014). *Qualitative text analysis: A guide to methods, practice & using software*. Los Angeles, Calif.: Sage.

Landis, J. R., & Koch, G. G. (1977). The Measurement of Observer Agreement for Categorical Data. *Biometrics*, *33*(1), 159. https://doi.org/10.2307/2529310

Neumann, S., & Hopf, M. (2012). Students' conceptions about 'radiation': Results from an explorative interview study of 9th grade students. *Journal of Science Education and Technology*, *21*(6), 826–834.

Nieveen, N., & Folmer, E. (2013). Formative evaluation in educational design research. *Design Research*, *153*, 152–169.

Nordine, J., Fortus, D., Lehavi, Y., Neumann, K., & Krajcik, J. (2018). Modelling energy transfers between systems to support energy knowledge in use. *Studies in Science Education*, *54*(2), 177–206. https://doi.org/10.1080/03057267.2018.1598048

Plotz, T. (2017). Students' conceptions of radiation and what to do about them. *Physics Education*, *52*(1), 14004.

Posner, G. J., Strike, K. A., Hewson, P. W., & Gertzog, W. A. (1982). Accommodation of a scientific conception: Toward a theory of conceptual change. *Science Education*, *66*(2), 211–227. https://doi.org/10.1002/sce.3730660207

Prediger, S., Gravemeijer, K., & Confrey, J. (2015). Design research with a focus on learning processes: An overview on achievements and challenges. *ZDM*, *47*(6), 877–891. https://doi.org/10.1007/s11858-015-0722-3

Psillos, D., & Kariotoglou, P. (Eds.) (2016). *Iterative Design of Teaching-Learning Sequences: Introducing the Science of Materials in European Schools* (1st ed. 2016). Dordrecht, s.l.: Springer Netherlands. Retrieved from http://gbv.eblib.com/patron/FullRecord.aspx?p=4107774 https://doi.org/10.1007/978-94-007-7808-5

Rego, F., & Peralta, L. (2006). Portuguese students' knowledge of radiation physics. *Physics Education*, *41*(3), 259.

Wiener, G. J., Schmeling, S. M., & Hopf, M. (2015). Can Grade-6 Students Understand Quarks? Probing Acceptance of the Subatomic Structure of Matter with 12-Year-Olds. *European Journal of Science and Mathematics Education*, *3*(4), 313–322.

Wiesner, H., & Wodzinski, R. (1996). Akzeptanzbefragungen als Methode zur Untersuchung von Lernschwierigkeiten und Lernverläufen. *Lernen in den Naturwissenschaften*, 250–274.

Zloklikovits, S., & Hopf, M. (submitted). Evaluating key ideas for teaching electromagnetic radiation. *Journal of Physics: Conference Series*.

THE NARRATIVE INSIDE: TEACHING PHYSICS WITH A NARRATIVE-BASED APPROACH

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This article shows how it is possible to structure physics content in terms of narrative structure, in order to promote learning. First, we outline four possible kinds of relationship between science, education and narrative form, in order to set our proposal in the state-of-the-art on the subject. Then we give a concise overview on basic narrative structure and grammar. Moreover, we provide two examples of "conceptual story" (two physics tales), followed by the transposition of some typical elements of narrative into conceptual story frame. Lastly, after having outlined how narrative is a crucial form of human beings' organization of reality, we try to draw some conclusions in terms of appropriation by students.

Keywords: Physics, narrative, appropriation.

NARRATIVE AND SCIENCE, NARRATIVE IN SCIENCE

Despite its prearranged structure, one of the most powerful aspects of narrative is that a story can be told not only in one, but in many ways. Research on the theme has clearly explained that "narrative" is the story (the *fabula*, the sequence of events) and "narration" is the form of the story (the plot). The plot may mirror the story or not: in this case, we have a complex plot, called *non-linear*. This distinction generates a multiplicity of visions typical of the narrative genre, but often precluded to other text types. By contrast, this characteristic is certainly shared with science: as Bruner asserts, narrative «subjunctivizes» reality opening multiple perspectives and this is the same attitude of scientific approach (Bruner, 1996, chapter 6).

Different works and studies[1] let us point out four different kinds of relationship between science and narrative (the last one, d., is the one we are going to examine in this paper):

a. Narrative *by* science (to narrate): use of images from science to represent and narrate human feelings and existential issues in a figurative way. Authors as Italo Calvino, Primo Levi and Jorge Luis Borges are recent examples of this category: many specific studies have shown that concepts and images from math, physics, chemistry, and astronomy pervade their essays, short stories and novels. Borges himself explicitly said he has drawn inspiration and ideas from books of logic and mathematic (Simon, 1971).

b. Science *by* narrative (to communicate): use of narration as a tool for communicating scientific research to a non-expert audience (cf. Dahlstrom, 2014). Narrative formats are widespread for communicating science to public, because narrative enhances comprehension, interest, and engagement. Almost every media platform sometimes proposes "narrative scientific communication" (i. e. in documentaries), because it promotes inductive reasoning and activates efficient and quick pathways of comprehension. Not least, it stimulates memory and gets people fond of the characters: everybody feels

[1] Here we mention only a few of the existing ones.

connected with a wild animal if *one* specific animal is the protagonist of a documentary, observed in its everyday life made of ups, downs and troubles. It becomes a character.

c. Science *by* narrative (to teach): use of narration as a tool for bringing students to discover scientific statements, properties etc. with an inductive and more exiting approach (cf. Demartini & Sbaragli, 2015; Prins, Avraamidou, & Goedhart, 2017). Different narrations (stories, picture books, theatre performances, puppet shows etc.) can draw pupils' attention and activate their comprehension better than a decontextualized conceptual learning. The reason for why it happens is simple: listening to a story is more involving and memorable than passively try to learn data and information. To illustrate this approach, we can mention the Italian language books written by Anna Cerasoli, designed to introduce even very young children to mathematical issues and concepts through engaging, invented plots.

d. Narrative *in* science (to teach): use of narration to make explicit the narrative structure intrinsically present in the development of scientific concepts. The difference between type d. and c. stories is that "type c. stories" are variously and imaginatively composed (i.e., the author can freely add characters and personalise its narration in a playful way), while "type d. stories" are intrinsic to scientific concepts (so we can call these stories "conceptual stories"). This kind of narrative-science relation is poorly studied; we have only found an example in mathematics (Dietiker, 2016). Here we try to point out the matter with the final purpose of encouraging its employing in teaching.

BASIC NARRATIVE STRUCTURE AND CONCEPTUAL STORIES

The structural elements of a narrative text make it reassuring and gripping at the same time. In particular, the narrative text is characterized by a constant structure consisting of an *abstract*, an *orientation*, a *complicating action*, an *evaluation*, a *result* (or resolution), and a *coda* (cf. among several studies Labov & Waletzky, 1967, Labov, 1972, Levorato 1988, Bernardelli, 2019). This widely-accepted narrative sequence − influenced by the classic Propp's story grammar and functions (Propp, 1965) − has been investigated in many studies that emphasize different aspects (i. e. Greimas, 1966; Stein & Glenn, 1976; Peterson & McCabe, 1983); also Minsky (1986), from computer science, worked on stories structure (calling it "story-frame"). We also consider Todorov's narrative theory (1969, 1981), that identifies five main stages in every narrative: *equilibrium*, *disruption*, *realisation of the disruption*, *attempt to fix disruption*, *return to a new equilibrium*. He says that

> an ideal narrative begins with a stable situation that some force will perturb. From which results a state of disequilibrium; by the action of a force directed in a converse direction, the equilibrium is re-established; the second equilibrium is quite similar to the first, but the two are not quite identical. Consequently there are two types of episodes in a narrative: those that describe a state (of equilibrium or disequilibrium) and those that describe the transition from one state to another. (Todorov, 1981, p. 51).

For our goal, the main assumption is that there is a universal and constant set of textual units that we call *equilibrium*, *perturbation*, *disequilibrium*, *outcome*, and *new equilibrium*. This sequence offers a strong and natural support to hook information into a template; as we will see above, these units naturally fit "conceptual stories" development.

TWO "CONCEPTUAL STORIES" FROM PHYSICS

In our vision, a "conceptual story" (type "d") is a story focused on conceptual development, in which the conceptual sequence is the *fabula*. Other traditional key elements of narrative text (i. e. actions, intentions, teleology, sense of time) could be more or less present depending on the phenomena, but the story can be told even without referring to them. It means that we can suppose that the narrative can be found inside the conceptual progression, regardless external agents. This paragraph provides two examples of conceptual stories.

The "Conservation of energy"

The first tale concerns the conceptual shift from the idea of conservation of mechanical energy to the idea of conservation of the total energy of a physical system. The *fabula* can be naturally framed in a narrative structure: starting from a conceptual equilibrium (the conservation of mechanical energy), a new equilibrium is reached, which is not identical to the first one, even if it has physical relations with it (the conservation of total energy, not only the mechanical one).

Equilibrium: conservation of mechanical energy
In a field of conservative forces, the work does not depend on the trajectory of the bodies, but only on their initial and final positions. In a conservative field, the mechanical energy, which is the sum of kinetic and potential energy of a mechanical system, is preserved. This result is a law that can be expressed in mathematical form: $\Delta K+\Delta V= 0$.

Perturbation: friction comes into play
On Earth, these phenomena are usually ideal. On Earth, in addition to conservation forces, other forces, such as friction, must be taken into account. The problem is that when such forces come into play, the law of conservation of mechanical energy is lost. Where is it, now?

Disequilibrium: temperature and heat
In this new state of disequilibrium made up of conservative and non-conservative forces, it could be discovered that when a friction force acts on a body, that body heats up. Here it is possible to meet the concept of heat and the quantity temperature, which expresses an internal property of the bodies. After showing how even a mechanical work can produce a rise of the temperature of a system, the relationship between work and heat is clear: they both are ways of transferring energy. In all this, however, there is still no energy conservation law.

Outcome: the internal energy of a system and the first principle of thermodynamics
Conceptually, internal energy is an energy similar to the kinetic and potential energy of a mechanical system, and it defines the internal energy state of a system. Between an initial and a final state of internal energy, there must be a certain transfer. If energy is transferred (removed) to a system in heat or work mode, the internal energy of that system increases (decreases). Mathematically speaking: ΔU=Q+W: the first principle of thermodynamics. This relationship between internal energy, heat and work, describes how the total energy, no longer just the mechanical energy of a system, changes.

New equilibrium: the conservation of the total energy of a system

Non-conservative forces have not disproved the law of energy conservation, they have only generalized its spectrum of action.

Following the definition of "type d. story", this is a pure "conceptual story", where the explicit agents, the characters, are only physical concepts such as heat, friction, temperature, internal energy etc.

The "Copernican Revolution"

The second story is partially different from the one before because characters are not only physical concepts, but physical models of interpretation of the Universe. The main character of the story is the physical conception of the causes of motion: starting from a mainly philosophical conception (the starting *Equilibrium*), it is possible to reach a more scientific vision, based on the gravitational theory and the Newtonian dynamics (*New equilibrium*).

Equilibrium: the causes of the motion of the planets

In the geocentric system, the Earth is the center of the spheres on whose surfaces stars and planets move. In such a system, the celestial world is eternal and perfect, and respects perfect laws and geometric constructions; the human world is instead imperfect and mutable. In the geocentric system, the causes of the planets' motion around the Earth are mainly philosophical and religious: on the one hand, the hypothesis of a circular movement of the celestial bodies, which are eternal, divine and immutable, corresponds to the idea that the circular trajectory is the most regular one, thus, perfect; on the other hand, the fact that the Earth is immobile and at the center of these spheres corresponds to an anthropocentric conception of nature, in which the human being is placed in the center of the Universe (and of the whole creation).

Perturbation: Heliocentrism vs *Geocentrism*

Observation of planets' motion shows that their movement cannot be exactly circular around the Earth. The geocentric model then, becomes more and more complicated: epicycles, eccentrics and equants have to be added. On the other hand, a heliocentric model, with the Sun at the center of the circular movements of the planets, seems to be more effective in representing the celestial movement. In addition, the phases of Venus, the satellites orbiting around Jupiter, craters, valleys and mountains on the Moon are discovered. These latest discoveries, however, have a consequence: the celestial world loses its character of perfection, coming to assume a nature similar to that of the Earth. In this new framework, reasons that associate planetary motion and Earth immobility to philosophical and religious ideas have been lost: the Earth is no longer the center of the Universe, and it moves in circular motion on itself and around the Sun, despite its changing and imperfect nature. Why?

Disequilibrium: between kinematics and dynamics

In the heliocentric world, some problematic phenomena need to be justified. In fact, if the Earth were really moving around the Sun and on itself, such movement would cause effects that have never been observed. For example, a constant wind from east to west, or the displacement of any object thrown into the air from its initial position. These troubles are solved by the relativity principle in classical mechanics. This principle is part of the kinematics, which aims to describe geometrically the motion of bodies. Thanks to kinematics, it is possible to formulate the first version of inertia principle; it also allows to study uniform and accelerated motions. In addition, in the heliocentric model it is possible to formulate three empirical laws concerning the motion of the planets, based on direct observations and conjectures. In particular, one of these laws states that the orbits of the planets around the Sun are not circular, but elliptical.

Outcome: the three principles of dynamics and the law of universal gravitation

The three principles of dynamics have been formulated. The first one establishes a direct proportionality between the force acting on a body and the acceleration of the body itself. Thanks to these principles, the law of gravitation is also formulated, and it is applicable to all the bodies of the Universe. It identifies a force acting between any two bodies endowed with mass. This force is called gravitational force, and its intensity depends only on the mass of the bodies and on the distance between them. Thanks to the three principles of dynamics and to the gravitational law, it is possible to deduce the three empirical laws governing the planets' motion and to physically justify it.

New equilibrium: the causes of motion

The heliocentric system requires that the planets move along elliptical orbits, with the Sun located in one of the foci. In this system, we find physical causes for the motion of the planets. These causes find a synthesis in the gravitation law and in the three principles of dynamics.

The new equilibrium leads to the new scientific vision, after many twists and turns worthy of the most adventurous narrations.

KUHN'S STRUCTURE OF SCIENTIFIC REVOLUTIONS AND NARRATIVE STRUCTURE: A REMARKABLE SIMILARITY

In *The Copernican Revolution*, Kuhn (1957) writes that «the construction of Newton's corpuscular world machine completes the conceptual revolution that Copernicus had initiated». In fact, «Newton's universe was not merely a framework for Copernicus' planetary earth. It was a new way of looking at nature and man, a new scientific and cosmologic perspective» (Kuhn, 1957, p. 261). Our *Copernican* tale follows the vision of Copernican revolution proposed by Kuhn. Following his interpretation, it is easy to put the different stages of the Copernican revolution within the narrative structure. Why? Let's consider briefly the structure of every scientific revolution proposed by Kuhn. In Kuhn's work (1962), the evolution of science is composed by 5 phases or steps: *Normal science*, *Anomalies*, *Crisis of paradigm*, *Revolution*, *Paradigm Change*; then, back to Normal Science. We think that it is quite obvious, but also amazing, to see analogies between this structure and the structure of narrative proposed in this paper (Table 1).

Kuhn's structure of a scientific revolution	**Narrative structure**
1) Normal science	a) Equilibrium
2) Anomalies	b) Perturbation
3) Crisis of paradigm	c) Disequilibrium
4) Revolution	d) Outcome
5) Paradigm change	e) New equilibrium

Table 1. Kuhn's structure of a scientific revolution and the basic narrative structure: a comparison**.**

The similarity between the two structures strengthen the hypothesis that every scientific revolution could be profitably explained in a narrative framework, without forcing. Is it possible to build a physics tale on more than one scientific revolution?

OTHER ELEMENTS OF NARRATION IN CONCEPTUAL STORIES

Now we will try to analyse and reinterpret some other typical elements of narration in the particular case of conceptual stories.

Excursus

In narratology, an "excursus" is a form of digression: it could consist of an extra-explanation, a background story, a short episode or an anecdote. Also in conceptual stories it is possible to insert a series of "excursus" useful to better understand the main physics issues. For example, in the first phase of the *Conservation of Energy* tale, it is possible to insert a digression on the conservation of mechanical energy and the results that link the concept of work to those of conservative forces and mechanical energy. In the disequilibrium phase, in order to understand the concepts of temperature, heat and their relationship, it is possible to come across the laws of calorimetry, the coefficient of thermal conductivity as responsible for the sensation of heat/cold, and many other relations between the involved quantities. In the final phases, it is possible to point out the difference between process and state variables, as well as dig up the relationships between the first principle of thermodynamics and the law of state of perfect gases, or even interpret situations of evolution in the state of gas on the basis of the new found principle.

Fabula and plot

As we said, in narratology *fabula* is the chronological cause-and-effect chain of events, while *plot* denotes the sequence of events as they are presented to the reader or listener. Both the *Conservation of Energy* tale and the *Copernican Revolution* tale have been written following the *fabula*, but this is not the only way. In the *Copernican Revolution* tale, we could start from Galileo's findings in physics and motion, then coming back to the problem of the motions of the planets, and finally moving to the new physics proposed by Newton. In the *Conservation of Energy* tale, we could start from the definition of temperature, then wondering how temperature can be increased or decreased; at this point, after introducing friction, we could question the problem of the conservation of mechanical energy, and then introduce the internal energy of a system to reach the first principle of thermodynamics.

Perspectives

The possibility of telling several versions of a story maintaining the same narrative frame also involve *focalization*. In *Conservation of Energy* tale, for example, you can follow the development of events from at least two different points of view. A first point of view is given by the macroscopic and phenomenological treatment: this is the story we proposed. The same narrative structure can be used to tell sort of another story, exploiting the microscopic approach to thermodynamics: by interpreting all the thermodynamic variables in a microscopic key (following the statistical thermodynamic theory), thermal phenomena can be studied, up to the microscopic formulation of the first principle of thermodynamics in the case of perfect gases.

INTERSECTIONS: NARRATION AND *APPROPRIATION*

Telling (and listening to) stories makes us human

As shown by many studies from different approaches (i. e. Bettelheim, 1976, Bruner, 1991, 1996, Levorato, 2000, Gottschall, 2014), narrative is a basic human instinct and a strategy for coming to terms with fundamental elements of experience. This is because narrative boasts an advantageous property: it generates meaningful contexts. This means that if an *informative text* often conveys pieces of information (sometimes weakly related and context-free), a narrative text puts knowledge in a coherent structure, naturally internalized by human beings. That is exactly why stories can be intrinsically persuasive, even more than arguments (as shown by the extreme theory of the "narrative paradigm", Fisher 1994; 1995). In this sense, stories can give instructions and information as well as pleasure and entertainment. This is also confirmed by the fact that narration is one of the earliest emerging discourse form in children (D'Amico & Devescovi, 2013). In extreme synthesis, this means that human beings are "storytelling animals" (Gotschall, 2014), naturally inclined to understand and organize the world in a narrative form. Recent and persuasive arguments are also given by cognitive science and neurosciences (i. e. Bernini & Caracciolo, 2013; Young & Saver, 2001): emotional experiences stimulated by narrative positively activate and shape our brain making our learning more durable. It is not without reason that Bartes and Duisit (1966: 237) wrote that narrative «is present at all times, in all places, in all societies; [...] there has never been anywhere, any people without narrative».

The idea of *Appropriation*

This deep connection between narration and human mind lets us link narration and Appropriation. The idea of Appropriation is a vygotskijan notion, deepened in linguistic by Bakhtin (1981), developed in the socio-cognitive field by Rogoff (1995), Sfard (2007), and adapted in order to consider the scientific discourse (Delgatto, 2011). Moving from this literature, Fantini (2014) and Levrini *et. al.* (2014, 2018) have listed some observable features that allow to recognize students' appropriation of scientific discourse when this discourse is:

A. developed around a set of words or expressions repeated several times and linked together so as to express a *personal, idiosyncratic "signature" idea* with respect to physics (thermodynamics, in this case);
B. *disciplinarily-grounded* i.e. the signature idea was used by the student as a tool for focusing on pieces of disciplinary knowledge;
C. *thick* i.e. the signature idea involved a metacognitive dimension (What does learning physics mean for the student?) and an epistemological one (What sense of the discipline does the student have?);
D. *non-incidental*, i.e. the signature idea was expressed in several activities throughout the students' classroom experience, not just in one interaction;
E. *carrier of social relationships*, i.e. the signature idea allowed the student to play a specific role in class discussions, and this role was acknowledged by others in the classroom community. (Levrini *et al*., 2018, p. 305)

From these markers an operative definition of Appropriation has been drawn up:

Appropriation is a complex, reflexive process (Marker C) of transforming scientific discourse (e.g., scientific words and utterances) so as to embody it in one's own personal story (Marker D). This process:

- results in a discourse populated with one's own intentions, idiosyncratic tastes, purposes (Marker A);
- respects the rules and constraints of science as a discipline (Marker B); and
- is intrinsically social in nature (Marker E). Namely, it is sensible both for oneself and also within the social context of the classroom. (Levrini *et al.*, 2014, p. 27).

Because Appropriation of a scientific discourse is a complex process for a student, it is necessary to activate different sub-processes, which can be enhanced by significant physics teaching/learning's tools. Of course, there are different set of activities and methodologies that can stimulate this "making one's own" of a scientific discourse.

Apart from concrete or cognitive activities, it is also important to rethink the teaching of physics from the point of view of conceptual reorganization: how is it possible to organize scientific knowledge, at the level of content and logical connections, to make students appropriate it?

A first answer is quite logical: it is necessary to create rich and dense conceptual formats, which incorporate practices of constructive and stimulating complexity. These forms of complexity are codified in terms of a multi-perspectiveness (same contents analysed from different perspectives), multidimensionality (contents analyzed from a conceptual, experimental, formal, epistemological etc. point of view) and longitudinality (widening, refining and revising already acquired knowledge) (Levrini *et al.*, 2014).

A second answer specifically concerns the idea that a narrative conceptual restructuring is one of the critical and preliminary aspect which encourage appropriation. As Fantini says:

I think that the base, for the universe of scientific discourse to be transformed by everyone, should be an adequate disciplinary restructuring that restores an image of physics not as a set of truths, but as a construction of thought, as a narration of stories of concepts, so as to be able, as Bakhtin said, to make the words of other their own. (Fantini, 2014, p. 182, translation by the authors)

Now, we think that this last aspect could be a further evidence to support the creation and the use of "type d." stories in the teaching/learning of physics. If listening to stories and storytelling make us human and help us to give meaning to the world, then using a narrative approach in physics teaching could help students to deeply internalize scientific information, improving long-term scientific literacy and stimulating interest. In particular, this approach could spontaneously boost the appropriation process because it encourages students to discover and build sense, constructing their utterances and discourses in a situated, dialogic and participative way.

CONCLUSION

In light of what we have said, we believe that a framework involving narrative can contribute to a fruitful teaching and learning process, because narrative may stimulate and enhance comprehension, curiosity, and involvement, offering a natural stepping-stone to an in-depth knowledge. In *The Culture of Education* (Bruner, 1996), Jerome Bruner deals with a strong postulate: there are essentially two ways to organize and manage knowledge, the logical-scientific thinking, and narrative one. Actually, in many cases the two attitudes can profitably combine.

REFERENCES

Bakhtin, M. M. (1981). *The Dialogic Imagination*. Austin: University of Texas Press.

Bettelheim, B. (1976). *The uses of Enchantment. The Meaning and Importance of Fairy Tales*. New York: A. Knopf, Inc.

Bernardelli, A. (2019). *Che cos'è la narrazione*. Roma: Carocci.

Bernini, M. & Caracciolo, M. (2013). *Letteratura e scienze cognitive.* Roma: Carocci.

Bruner, J. (1991). The Narrative Construction of Reality. In *Critical Inquiry 18*, 1−21.

Bruner, J. (1996). *The Culture of Education*. Cambridge, MA: Harvard University Press.

Delgatto, J. (2011). *Applications of the Theories of Mikhail Bakhtin in Science Education*, College of Education. Paper 1. Accessibile in rete all'indirizzo: http://via.library.depaul.edu/soe_etd/1.

Dietiker, L. (2016). *Generating Student Interest with Mathematical Stories*. In *The Mathematics Teacher*, *110*, 4.

Fantini, P. (2014). *Verso una teoria locale dell'appropriazione dell'insegnamento/apprendimento della fisica*. Tesi di Dottorato di ricerca in Antropologia ed Epistemologia della Complessità, Università di Bergamo, 57−115.

Fisher W. R. (1994). Narrative Rationality and the Logic of Scientific Discourse. *Argumentation*, *8*, 21–32.

Fisher W. R. (1995). Narration, Knowledge, and the Possibility of Wisdom. In Fisher & Robert F. Goodman (eds.). *Rethinking Knowledge: Reflections Across the Disciplines (Suny Series in the Philosophy of the Social Sciences)*. New York: State University of New York Press.

Greimas, A. J. (1966). *Sémantique structural. Recherche de méthode*. Paris: Larousse.

Gottschall J. (2014). *L'istinto di narrare. Come le storie ci hanno reso umani*. Torino: Bollati Boringhieri.

Kuhn, T. (1957). *The Copernican Revolution.* Harvard: Harvard University press.

Kuhn, T.S. (1962). *La struttura delle rivoluzioni scientifiche*. Chicago: University of Chicago Press.

Labov, W. & Waletzky, J. (1967). Narrative Analysis: Oral Versions of Personal Experience. In Bambery, Michael G. W. (ed.), *Oral Versions of Personal Experience: Three Decades of Narrative Analysis*. Special Volume of Journal of Narrative and Life History, *7*, 3−38.

Labov, W. (1972). *Language in the Inner City. Studies in the Black English Vernacular*. Philadelphia: University of Pennsylvania Press.

Levorato, M. C. (1988). *Racconti*, *storie e narrazioni*. *I processi di comprensione dei testi*. Bologna: il Mulino.

Levorato, M. C. (2000). *Le emozioni della lettura*. Bologna: il Mulino.

Levrini, O., Fantini, P., Pecori, B., Tasquier, G., & Levin, M. (2014). Defining and operationalizing "appropriation" for science learning. *Journal of the Learning Sciences*, *24*(1), 93−136.

Levrini, O., Levin, M., Fantini, P. (2018). Personal, deeply affective, and aesthetic engagement with science content. When disciplinary learning becomes a vehicle for identity construction. In Amin, T.G., & Levrini, O. (2018). *Converging perspectives on conceptual change*, Oxon: Routledge, 305−312.

Minsky, M. (1986). *Sociey of Mind*. New York: Simon & Schuster.

Propp, V. (1968). *Morphology of the folktale*. Trans. Laurence Scott, Second Edition: U. Texas Press [Russian ed. 1928: *Morfologia skaski*].

Todorov, T. (1969). Structural Analysis of Narrative. *NOVEL: A Forum on Fiction*, vol. 3, 1, 70–76.

Todorov, T. (1981). *Introduction to Poetics.* Trans. Richard Howard, introduction by PeterBrooks, Minesota U. P. [Translation of: *Poétique*, Paris, Seuil 1968 & 1973].

Peterson, C. & McCabe, A. (1983). *Developmental psycholinguistics: three ways of looking at a child's narrative*. New York: Plenum.

Rogoff, B. (1995). Observing sociocultural activity on three planes: Participatory appropriation, guided participation and apprenticeship. In J. V. Wertsch, P. del Rio, & A. Alvarez (Ed.), *Sociocultural studies of mind*. Cambridge, England: Cambridge University Press, 139–164.

Simon, H. (1971). *Primera Plana va más lejos con Herbert Simon y Jorge Luis Borges*. Primera Plana, 414. Buenos Aires, 42–45.

Sfard, A. (2007). When the rules of discourse change, but nobody tells you: Making sense of mathematics learning from a commognitive standpoint. *Journal of the Learning Sciences*, *16*, 567–615.

Stein, N. & Glenn, C. (1976). An analysis of story comprehension in in elementary school children. In R. Freedle (Ed.). *Discourse processing: multidisciplinary perspective*. Hillsdale: Lawrence Erlbaum Associates.

Young, K. & Saver, J.L. (2001). The Neurology of Narrative. *SubStance*, *30*, No. 1/2, Issue 94/95: Special Issue *On the Origin of Fictions: Interdisciplinary Perspectives*, 72–84.

IMAGINATION; WHERE SCIENCE FORMULATE DIFFERENT HYPOTHESIS AND EXPLANATIONS HELPING THE UNDERSTANDING OF THE LANGUAGE AND SOUL OF CHEMISTRY

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New understanding is realized by creative learning where students are involved in meaningful learning, ownership of learning, control of learning processes and innovation. In order to produce learning situations where creative learning is achieved, teachers have to create trustful atmospheres where students are allowed to think and discuss without critical evaluation from the teacher. It is also important to create practical exercises in which theoretical models are processed and connected to observations and subject matter. During several years we have developed courses in science with the goal to promote students to become independent learners and explorers out of their own prerequisites as future professional teachers. We have investigated different methods and designs of teaching; conceptual understanding and conceptual change theory, discourse-based understanding and Dewey's view of learning. In this study we are focusing on exploring the variation of students creative learning through a chemistry course. Permitting the particulate subject matter of chemistry to demonstrate as universal dramaturgical framework for conceptual learning and embodied experience. Chemistry involves considerable amounts of abstract conceptual thinking, molecular understanding and language. The focus of our study is the exploration of how conceptual abstract molecular understanding of phenomena in nature emerges through different teaching approaches, and imagination transformed into universal understanding, which provides the students with a sense of empowerment and a positive outlook on their future profession as teachers.

Keywords: knowledge construction, aesthetic learning process, reflection

INTRODUCTION

"Imagination is the meeting ground where old and new come together - what was, what is, and what could be. The imagination takes us beyond and behind the everyday." (Ellen Levine prof. EGS)

It is important for teachers to establish an environment for knowledge construction and creative learning that allow students to think and discuss without critical evaluation. In changing from teacher-centred to student-centred teaching, as well as ethically observing the boundaries where students are responsible for their own learning is part of achieving an open and trusting learning environment (Pollard et al., 2018). Creative learning emerges when learning is meaningful, self-motivated and innovative (Jeffrey, 2006). Teaching should be inquiry based and connect observations to theoretical models for students to create their own knowledge (Jeffrey, 2006). By asking questions and solving problems during inquiry, students can make connections between theories and praxis (Jeffrey, 2006). Another important aspect of creative learning is when students are engaged, collaborating with others and enjoying further exploration (Gibson, 2010; Pollard et al., 2018).

Our work with aesthetic learning process is based in intermodal art theory and the philosophy of phenomenology (Knill et al., 2004). An aesthetic learning process is where one or more modalities are expressed through their specific language in art (music, art, dance, etc.). As one expression develops and encounters a second expression which then flows into a third modality of felt sense the dramaturgical sequence evolves and moves. In our study we implemented a five-part psychokinetic imagery model created by Daria Halprin. (Halprin, 2002; Knill et al., 2004) .

We have developed courses in science in order to achieve and motivate students to become independent learners focusing on their future as teachers. A variation of methods and designs of teaching have been investigated and the students creative learning has been equally analysed, to further develop an understanding of what signifies a trusting learning environment. In this study we have been exploring and focusing on a chemistry course for future 4 – 6 grade primary school teachers. Chemistry involves considerable amounts of abstract thinking. Furthermore, as many students have had bad experiences of chemistry from school the encounter with new knowledge of chemistry is in many cases perceived as a challenge.

OBJECTIVE

The focus of our study was the exploration if and how a universal understanding of conceptual abstract molecular thinking and language as well as phenomena in nature emerges and manifests itself through different designs of teaching and imagination.

Could the design of the course promote creative thinking and create conceptual understanding of chemistry? How do students experience aesthetic learning processes in connection to their own learning in chemistry?

COURSE DESCRIPTION

17 preservice teacher students were trained by one science teacher and one teacher in aesthetic learning process to foster their independent and creative learning of chemistry. The course consisted of 10 days over a four week-period, which included practical activities mixed with discussions in groups followed by discussions with the teacher in order to connect theory with practical exercises. The students wrote short reflections at the end of each week as well as a short reflection after the two sessions of aesthetic learning process answering the following two questions: “What do you take with you from your own learning process and/or in connection with other’s and/or the working process of the session?”, “What amazed and/or surprised you the most?”. Students were studying and working with questions in a science textbook in English as well as a textbook on chemistry education in Swedish during the campus

free days. A guided visit to the Vasa museum in Stockholm at the end of the course showed the chemistry around a wrecked ship from 17th century saved sixty years ago. At the end of the course the students were assessed through a written examination.

METHODS

The five written reflections where analysed by qualitative methods scoring demonstrations of professional development, process thinking and learning processes. The analysis was focused on six categories: A. changed attitude towards chemistry, B. connection to everyday life, C. importance of practical exercises for learning, D. importance of group discussions for learning, E. chemical descriptions using concepts and F. connection to future profession as teacher. The quality of the five individual written reflections were also analysed using the quality markers 4R's of Doll's, *Relations*, *Recursion, Richnes*s and *Rigor* (Doll, 1993) (Mutvei, A. et al., 2017). Recursion is understanding in depth by the connection of the past with the present in depth. Relations is understanding through interaction with and connection to the other unknown, things and people within the context. Richness is understanding and expressing different levels and dimensions of interpretations and perspectives, to give different interpretations, perspectives and possibilities. Rigor is consistently using knowledge in new ways and in new unexpected situations. The use of the R's was assessed using a scale 0−3 where 0 refers to the absence of the specific concept and 3 to regular and active use of the processes referred to by the concept. The aesthetic learning process sessions were analysed by ethnographic method making observation and taking careful and meticulous written notes (LeCompte & Goetz, 1982). The different steps of the five-part model during the aesthetic learning process (Tobieson, U. & Mutvei, A., 2017) were identified and the outcome was assessed by the students through oral reflections at the end of each session as well as a written individual reflection.

Table 1. Overview of the four weeks chemistry course.

Week 1	**Week 2**	**Week 3**	**Week 4**
Chemistry and didactic literature	Chemistry and didactic literature	Chemistry and didactic literature	Chemistry and didactic literature
Lab-exercises – inquiry based	Lab-exercises – inquiry based	Lab-exercises – inquiry based	Lab-exercises – inquiry based
Group discussions	Group discussions	Group discussions	Group discussions
Guidance by the teacher	Guidance by the teacher	Guidance by the teacher	Guidance by the teacher
		Guided visit to the Vasa Museum in Stockholm	
		Aesthetic learning processes	Aesthetic learning processes
Chemistry reflection 1	Chemistry reflection 2	Chemistry reflection 3	
		Aesthetic learning process reflection 1	Aesthetic learning process reflection 2
			Written exam

RESULTS

Our results showed that students with a negative conception to chemistry changed their opinion during the 10 days that the course lasted and thereafter enjoyed paying attention to phenomena in everyday life with a multiple of perspectives on chemistry. All students expressed the importance of practical exercises, aesthetic learning process and group discussions for their own learning skills. The reflections contained detailed explanations of chemistry, concepts used properly in describing their particulate learning through a universal language. They also used their experiences when they discussed how to design teaching situations and lesson content. The first week many students expressed their negative experience of chemistry at school and that they were more interested now and found it meaningful (Figure 1, A reflection 1). At the end of the course students described how they will teach as professional teachers (Figure 1, F reflection 3). Also, a few students reflected on chemistry as school subject and learning in more general terms at the end of the course.

A	changed attitude towards chemistry
B	connection to everyday life
C	importance of practical exercises for learning
D	importance of group discussions for learning
E	chemical descriptions using concepts
F	connection to future profession as teacher

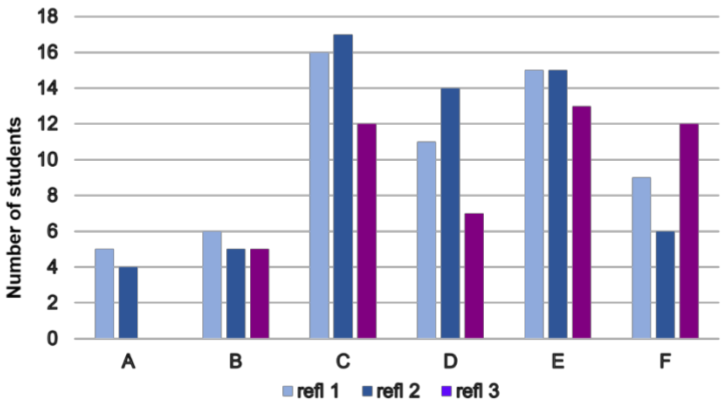

Figure 1. The graph shows the number of students using categories A – F in each reflection (refl. 1 – 3.)

How did the students express their learning in chemistry after one week of the course?

The chemistry reflections after one week of the course were analysed by using the 4R's of Doll's (Doll, 1993) to evaluate the students' learning of chemistry by using literature studies, group discussions, lab exercises and inquire based learning (Table 2). The quality of the students' understanding, by answering two questions about what they have learned and what surprised them, showed that they already after the first week, used concepts to explain different phenomena, and especially, how to use their experience of learning in their professional lives as teachers. All students noticed the importance of interactions with and connection to the other, sometimes unknown parts of the content knowledge and persons within the context for their learning processes (Relation 2 and 3). Many of them could also describe the process (Relation 3) (Table 2). All students expressed their understanding by using factual terms that belong to the current discourse in everyday life and in their own language. The use of own words indicates acquired knowledge (Richness 2 and 3). A few students also could express their knowledge from several perspectives and dimensions (Richness 3). However, only two students described their knowledge related to new situations (Rigor) (Table 2).

Table 2. Qualitative analysis of students' reflection 1 using the 4 R's of Doll's. The lower row of the table shows the percentage of total students that had high quality (2 and 3) in their understanding (n=17).

level of 4 R's of Doll	**Reflection 1** (number of students)			
	Recursion	Relations	Richness	Rigor
3	1	9	4	1
2	3	8	12	1
1	2	0	1	0
0	11	0	0	15
	35%	100%	100%	12%

Example of students' learning from reflections after the first week of the course:

"What surprised me most is probably how much the literature is linked to the practical parts that are carried out during the laboratory work and how to share the knowledge with my peers and connect their knowledge to and with my own."

"To think about, in my future role as a teacher I have to let the students draw their own thoughts and ideas before using illustrations from different textbooks, maybe start from the students' own thoughts, questions and statements instead of – it is like this."

"What surprised me was that because of the experiments we conducted, I more easily understood the connection between the different phases (liquid, solid and gas) as well as sublimation, diffusion and evaporation. This could then be reworked theoretically and related to one's own experiences in everyday life."

How did the students express their learning in chemistry using aesthetic learning processes?

At the end of the course, the students had two sessions lead by an art teacher with the aim of connecting the knowledge in chemistry of the course with aesthetic learning processes, both for developing more and deeper perspectives and to use this in their own teaching. Through aesthetic learning processes, chemistry is repeated in new ways through the making of art, providing more perspectives and creating new knowledge (Knill et al., 2004). The artmaking awakens emotions and creates experiences when using the whole body and all the senses, necessary to deepen the learning processes (Tobieson, U. & Mutvei, A., 2017). At the end of each session an aesthetic analysis of the shared and achieved experiences was done together in the class. The students shared their experiences of the importance to use representations from the theory of chemistry and how they realized the differences between everyone's view. The students showed each other different perspectives on the molecular world which gave them new experiences. They appreciated the group processes and the inclusive way of working, and also the way of repetition of concepts which gave a holistic view of chemistry. The students should also write a reflection on what surprised and amazed them and what they brought from their work process and content during the sessions.

The reflections from the aesthetic learning process were analysed using the 4R's of Doll's assessing the students' quality of description of their learning. The students' reflections showed a considerable increase in using their chemistry knowledge outside the context (Table 3). All students were better in seeing patterns in other areas (Rigor 1) and many could see patterns through unexpected orientations related to unrelated subject areas (Rigor 2). One third of the students were also able to see, pay attention and use other subject areas to show a deeper understanding and to generalize a complex content (Rigor 3). The students also saw the importance for learning out of previous experiences (Recursion 2) and noticed, described and explained moments of change in the learning process that have led to insight and/or understanding (Recursion 3) (Table 3).

Table 3. Qualitative analysis of students' Aesthetic learning process reflection 2 at the end of the course using the 4R's of Doll's. The lower row of the table shows the percentage of the total number of students that showed high quality (2 and 3) in their understanding (n=17).

level of 4 R's of Doll	**Aesthetic learning process reflection 2** (number of students)			
	recursion	relations	richness	rigor
3	6	5	10	6
2	7	12	5	3
1	3	0	2	7
0	1	0	0	1
	94%	100%	100%	94%

Examples from aesthetic learning processes, reflection 2

"The practice of giving each other an aesthetic response, was a great way to interpret and connect different concepts that we have learned so far, together with the different paintings. It sounded a bit fuzzy at first but after two, three paintings I started to see the different concepts take shape and suddenly, I could name many of the concepts of chemistry. It surprised me that I knew more concepts than I thought. It was really a way of going from abstract to concrete."

"We got to paint chemical reactions. To find new ways to create new perspectives on the theory was important. It gives joy but also greater understanding as the aesthetic gives new angles and makes us think differently."

"It was interesting partly that you got to take into account what you had already studied and worked with. Then, to have the opportunity to do something completely different during art-making was a chance to create a deeper understanding of the different parts of chemistry. A lot of the various chemical concepts that had been spinning around in the head were now actually being embodied."

SUMMARY

It is important to design teaching using a variety of learning situations in order to reach a good understanding of chemistry where students use a particle model, show understanding of different chemical relationships, define concepts and make explanations. The students appreciated group discussions and practical exercises for their learning especially when they used their concepts to explain different phenomena in everyday life. Our results show that art making in the aesthetic learning processes deepens the understanding of concepts in chemistry as learning occurs beyond the usual environment. During the aesthetic learning processes students also expressed wonder and imagination for their own learning in their reflections.

CONCLUSION

All students expressed the importance of practical exercises, group discussions and art-making, as well as the wonder of imagination for their own learning. Our results showed that the course design promoted creative thinking and deepened the students understanding of chemistry, which provided them with a sense of empowerment and a positive outlook on their future profession as teachers.

REFERENCES

Doll, W. E. Jr. (1993). *A post-modern perspective on curriculum*. Teachers College Press.

Gibson, R. (2010). The 'art'of creative teaching: Implications for higher education. *Teaching in Higher Education*, *15*(5), 607–613.

Halprin, D. (2002). *The Expressive Body in Life, Art, and Therapy: Working with Movement, Metaphor and Meaning*. Jessica Kingsley Publishers.

Jeffrey, B. (2006). Creative teaching and learning: Towards a common discourse and practice. *Cambridge Journal of Education*, *36*(3), 399–414.

Knill, P. J., Barba, H. N., & Fuchs, M. N. (2004). *Minstrels of Soul: Intermodal Expressive Therapy*. EGS Press.

LeCompte, M. D., & Goetz, J. P. (1982). Ethnographic Data Collection in Evaluation Research. *Educational Evaluation and Policy Analysis*, *4*(3), 387–400. https://doi.org/10.3102/01623737004003387

Mutvei, A., Lönn, M., & Mattsson, J.-E. (2017). Technology in preschool: From idea to product. *Conference Proceedings New Perspectives. in Science Education*, *6*.

Pollard, V., Hains-Wesson, R., & Young, K. (2018). Creative Teaching in STEM. *Teaching in Higher Education*, *23*(2), 178–193. http://dx.doi.org.till.biblextern.sh.se/10.1080/13562517.2017.1379487

Tobieson, U., & Mutvei, A. (2017). Science integrated with aesthetic expressions for better understanding of science subject matter. *Electronic Proceedings of the ESERA 2017 Conference. Research, Practice and Collaboration in Science Education*, *part 3/strand 3 (co-ed. Sabine Fechner & Andrée Tiberghien)*, 542–554.

A PLAY-CENTRIC APPROACH TO SCIENCE EDUCATION

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Game-based learning has attracted increasing attention as an effective approach to teaching. Researchers have shown that games are highly engaging and motivating, which can benefit science education. However, taking advantage of these qualities to facilitate the teaching and learning of complex science subjects may not be an easy task. To discuss how non-digital games could be designed and used to support a wide range of learning outcomes in science education, a workshop was delivered at ESERA 2019, which was divided into two parts. In the first part the participants were introduced to an educational astronomy board-game developed by the researchers and had a chance to play the game with other participants. In the second part, the participants were divided into groups and presented step-by-step on how to create an educational board/card game. At the end, the participants reflected on and discussed their experience with game development during the workshop and shared their ideas with the other participants in the room. Here we present the structure and content of the workshop and propose a discussion of the advantages and barriers when adopting games for educational contexts.

Keywords: Teaching methods in science, Collaborative learning, Knowledge construction.

INTRODUCTION

Students who are deeply inspired and engaged by the things they learn in science classrooms early on will often carry these attitudes through their lives and are more likely to expand on what is taught (Laursen, Liston, Thiry & Graf, 2007). Science education is recognised worldwide as having a critical role in society. It is important to bring scientific knowledge continuously to broader society in order to promote science literacy and expand students and educators' views of where science can lead (Gil Pérez & Vilches, 2005). It also allows students to make decisions critically and have a better understanding of the scientific and technological processes in the world in which we live. However, new methods are necessary to provide adequate access to science across all parts of society (National Research Council, 2002).

The use of creative learning methods, such as games, in formal education can be a valuable method to immerse and engage learners with science (Cardinot & Fairfield, 2018). The growing popularity of games has led to an increase in the numbers of studies that focus on the use of Game-Based Learning (GBL) as a creative approach the teaching and learning of science subjects (Ramani, Siegler & Hitti, 2012). This methodology has been shown to facilitate learning in a variety of subjects, to motivate learners and to promote the development of social skills. Gee (2008) argued that play-centric approaches can have a positive impact on student's motivation to learn due to the challenges and immersed experience promoted within a game which are fundamental for science understanding. In recent years a number of studies have investigated the effect of learning through play to convey scientific concepts in classrooms (Su, Cheng & Lin, 2014), yet there is very little use of games in the everyday teaching and learning of science.

Learning new and complex material can be intimidating (Tan and Barton, 2010). Particularly, in science learning previous studies have found a cause and effect relationship between competence, engagement and perceived difficulty. The fear of failure in science can prevent students from pursuing a career in STEM (Science, Technology, Engineering and Maths). However, GBL can provide an effective way to offer engaging experience in which students are provided an opportunity to manipulate, to experiment and to explore science (Beier, Miller and Wang, 2012). It presents problem-solving situations through game mechanics at different levels, allowing students to learn as they advance in the game but also when they fail to complete a task, which turns failure into an opportunity to iterate toward success (Spires, Rowe, Mott and Lester, 2011). Thus, one remarkable thing about the benefits of using games in science education is that they could remove much of the intimidation inherent in the learning process of complex subjects (Subrahmanyam and Renukarya, 2015).

Currently, in the literature, there is evidence showing that games can create learning environments that facilitate immersion (Jennett et al., 2008), allowing interactivity and collaboration among peers (Pange, Lekka and Katsigianni, 2017), and increase motivation to learn (Foster, 2008). However, there is currently little guidance on how to design such materials to best support the learning of science. When creating educational games, it is important to take into account the design issues that may arise when merging learning outcomes in games. This paper intends to provide a practical and straightforward framework for science educators and researchers to design educational science games (Michael and Chen, 2005). By presenting a structure for the game design process, we hope to provide instructors, curriculum developers, and researchers with new principles for designing effective educational games for teaching different concepts in science.

WORKSHOP STRUCTURE

The workshop presented a space for discussing how to exploit games in real learning practice and how to create meaningful learning experiences with GBL. Through hands-on exercises, the workshop brought together research and practice for reflecting on the value of games in science education. The design process guided participants to exercise their critical-thinking and problem-solving skills, gaining insight into the implementation of game design to teach science subjects and the integration of non-digital games in their future practices. The workshop is divided into two main sections:

1. Get started: captivate learners with non-digital games in the classroom

The first section of this workshop introduced the attendees to an educational game designed for teaching a novel astronomy board game developed to facilitate the learning and teaching of astronomy topics (see Figure 1). The learning mechanism in the board game was focused on integrating the curriculum to pedagogical elements into the design process, which made gameplay more enjoyable. Participants had the opportunity to play the game and, then, critically reflect on the learning opportunities that a non-digital game has to offer. After the gameplay, the attendees were presented with an evaluation form to assess different aspects of the game that could promote scientific learning (see Figure 2).

Figure 1. Board-game designed for teaching physics and astronomy, which participants played during the workshop (Cardinot & Fairfield, 2019).

Evaluation Form

		Poor	Fair	Good	Very Good	Excellent
1	The game has clear learning objectives that are merged with gameplay.					
2	The game is a valid formative assessment, actionable for teachers.					
3	The game includes instruction to guide students toward greater understanding					
4	The game promotes strategic thinking.					
5	The game shows multiple representations of the content.					
6	The game deeply engages students.					
7	The game motivates students to challenge themselves.					

Additional notes on the game?

What do you think is the best way to use this game for your students?

Figure 2. Evaluation form used to evaluate the game. The resource was given to the attendees to assess the strengths and weaknesses of games for teaching science.

2. Dive into non-digital game design: discover tools and techniques

The second part aimed to get participants started in educational game development in small groups. The exercise had seven steps (see Figure 3) along with discussions, in which participants were asked to complete a workbook with their answers. At the end, each group presented their ideas to the other groups followed by a discussion with participants on the value of using games in science education, and get top tips for incorporating games into teaching practice. Below is a short description of what included in each step.

Learning outcomes	Verbs	Content	Output (mechanics)	Constraints and Challenges	Components	Rules

Theme: ____________________

Figure 3. Workbook used to support the development of an educational game.

Part 1 - Setting learning outcomes and action verbs. Similar to any other teaching intervention, the learning outcomes should be specific, well defined and taken into account from the beginning of the development. However, designing a learning outcome is not a simple task and requires careful consideration and reflection before implementation. Since this was a group exercise, participants were asked to find a general aim, i.e. a general overview of why they were creating a game. When designing a game, the learning outcomes of a game are essentially the details of what students should have learnt by the time they have finished the game. In addition, learning outcomes can also be used to assess their learning.

Part 2 – Mechanics. This refer to the players' actions in the game. Participants were given a list of popular games (e.g. Monopoly, Jenga, Uno, etc.). Each participant picked one of the game on the list and asked to explain how you play that game to the rest of the group. Then, they were asked to brainstorm how they could change that game mechanics to fit their learning outcome, using the matrix to write their ideas.

Part 3 – Constraints and challenges. This means what actions players need to perform to advance in the game, i.e. obstacles placed in the players' way to make reaching the goal a fun and interesting journey.

Part 4 – Components. In this part, they should consider what their game should have included to meet their mechanics, for example a board game, dice, cards, pawns, timer, etc. They should also take into consideration their audience, number of players and gameplay time length.

Part 5 – Rules. These may be defined as statements and directions that players must follow within the game in order for it to be played correctly. For example, one should consider the win and lose conditions for the game to end.

Part 6 – Theme. The scenario of the game to immerse the players. It should provide a context to help players remember the rules of the game and make better and more informed decisions in the game, and can also be related to the educational content of the game.

Part 7 – Prototyping. Participants used the materials provided to create a quick physical prototype, including a board, cards or any other bits as needed. The most important thing about this initial prototype is to run through their ideas quickly and gather feedback about the game from others before moving to the design.

CONCLUSION

Knowledge construction that takes place while playing games is fundamentally different from the learning experiences associated with traditional teaching tools. The GBL methodology entails setting learning goals in which learners maintain the enjoyment of play while ensuring that students will absorb and embrace the knowledge. Hence, students feel ownership over their learning and are motivated to establish relationships with other players. However, this is not an easy task, as educators and researchers alike encounter barriers in adopting games for teaching science such as the lack of professional development/training on how to use games. The workshop we have outlined explores learning principles in games and shows to the participants how to apply them into their practices to enhance student engagement and performance. Furthermore, our hands-on approach provides a valuable opportunity for both in-depth technical discussion and networking.

ACKNOWLEDGMENTS

This work is funded by CAPES-Brazil, scholarship number 88881.128466/2016-01. We would like to thank the Institute of Physics in Ireland for their support.

REFERENCES

Beier, M. E., Miller, L. M., & Wang, S. (2012). Science games and the development of scientific possible selves. Cultural studies of science education, 7(4), 963-978.

Cardinot, A., & Fairfield, J. A. (2018). Entertaining Physics Education: Using an Astronomy Board Game to Enhance Student Learning and Motivation. Proceedings of GIREP-MPTL Conference 2018, San Sebastian, Spain.

Cardinot, A., & Fairfield, J. A. (2019). Game-Based Learning to Engage Students With Physics and Astronomy Using a Board Game. International Journal of Game-Based Learning (IJGBL), 9(1), 42-57.

Davies, D., Jindal-Snape, D., Collier, C., Digby, R., Hay, P., & Howe, A. (2013). Creative learning environments in education - A systematic literature review. Thinking skills and creativity, (8), 80-91.

Foster, A. (2008). Games and motivation to learn science: Personal identity, applicability, relevance and meaningfulness. Journal of interactive learning research, 19(4), 597-614.

Gee, J. P. (2003). What video games have to teach us about learning and literacy. Computers in Entertainment (CIE), 1(1), 20-20.

Gee, J. P. (2008). Learning and games. The ecology of games: Connecting youth, games, and learning, 3 , 21–40.

Gil Pérez, D., & Vilches, A. (2005). The contribution of science and technological education to citizens' culture. Canadian Journal of Math, Science & Technology Education, 5(2), 253-263.

Jennett, C., Cox, A. L., Cairns, P., Dhoparee, S., Epps, A., Tijs, T., & Walton, A. (2008). Measuring and defining the experience of immersion in games. International journal of human-computer studies, 66(9), 641-661.

Kober, N. (2015). Reaching students: What research says about effective instruction in undergraduate science and engineering. National Academies Press.

Laursen S, Liston C, Thiry H & Graf J. (2007). What good is a scientist in the classroom? Participant outcomes and program design features for a short-duration science outreach intervention in K-12 classrooms. CBE Life Sci Educ, 6(1), 49-64.

Michael, D. R., & Chen, S. L. (2005). Serious games: Games that educate, train, and inform. Muska & Lipman/Premier-Trade.

National Research Council. (2002). Learning and understanding: Improving advanced study of mathematics and science in US high schools. Washington, DC: The National Academies Press.

Pange, J., Lekka, A., & Katsigianni, S. (2017). Serious Games and Motivation. In Interactive Mobile Communication, Technologies and Learning (pp. 240-246). Springer, Cham.

Ramani, G. B., Siegler, R. S., & Hitti, A. (2012). Taking it to the classroom: Number board games as a small group learning activity. Journal of educational psychology, 104(3), 661.

Spires, H. A., Rowe, J. P., Mott, B. W., & Lester, J. C. (2011). Problem solving and game-based learning: Effects of middle grade students' hypothesis testing strategies on learning outcomes. Journal of Educational Computing Research, 44(4), 453-472.

Subrahmanyam, K., & Renukarya, B. (2015). Digital games and learning: Identifying pathways of influence. Educational psychologist, 50(4), 335-348.

Su T, Cheng MT, Lin SH. (2014) Investigating the effectiveness of an educational card game for learning how human immunology is regulated. CBE Life Sci Educ, 13(3), 504-15.

Tan, E., & Barton, A. C. (2010). Transforming science learning and student participation in sixth grade science: A case study of a low-income, urban, racial minority classroom. Equity & Excellence in Education, 43(1), 38-55.

PART 4: STRAND 4

Digital Resources for Science Teaching and Learning

Co-editors: *Jesper Haglund & Jesper Bruun*

CONTENTS

STRAND 4: INTRODUCTION

DIGITAL RESOURCES FOR SCIENCE TEACHING AND LEARNING

Strand four focuses on science learning in digitally enriched environments. Within this focus, a wide range of perspectives and topics were presented as part of the strand at ESERA 2019, and this is reflected in the 22 papers in this section of the electronic proceedings. The breadth of the strand can also be seen from the countries of the authors of the contributions, in Europe: Austria, Cyprus, Finland, France, Germany, Greece, Italy, and Slovenia, as well as outside Europe: Argentina, Brazil, Japan, and the USA.

One prominent theme among the papers in the study of the use of mobile digital devices in science education, including mobile apps and sensors for data collection. Related areas include the use of computer programs that support students' learning of science content. In this regard, gamification is a clear trend, in which game-based teaching approaches are developed and tested in order to support students' learning and attitudes towards science. Other digital tools focus on the use of different modalities, such as simulations and the use of signing language for deaf students.

Other studies focus on teacher education, with studies of teachers' knowledge and beliefs in relation to teaching with digital tools, and studies of the use of digital tools in the teaching of pre-service and in-service teachers. The conditions for teaching is also central in studies of online learning platforms and online forums, and how they can be combined with physical teaching, as reflected in concepts like blended learning and flipped classroom teaching, and comparisons between virtual and physical lab environments. Such questions have risen to the top of the agenda of many teachers and educational researchers at the time of editing the electronic proceedings, although tragically to a large degree due to the Covid-19 pandemic.

Furthermore, a few of the studies explore how digital resources may be recruited in the development of novel methods in science education research, including the use of automatic network analysis to study teachers' and students' dialogue in physics classrooms, and eye tracking in the study of determination of butterfly species.

We hope that strand four will continue to provide a forum for those who are interested in science teaching and learning in digitally enriched environments to share findings and exchange ideas to improve the future science education.

Jesper Haglund & Jesper Bruun

CHARACTERISING THE EDUCATIONAL POTENTIALS OF MOBILE APPLICATIONS RELATED TO ECOLOGY

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Ten free-download mobile applications (apps) to be used for Ecology teaching and learning have been characterised. The analysis has included not only their technological characteristics but also their ecology content as well as the didactic aspects proposed by such apps. The technological resources studied have shown a high degree of usability, but two-dimensional images with low or null degree of realism have prevailed. Most of the apps have shown a wide variety of contents in their proposal. Few apps included activities for users, and when they did include them, the activities were limited to closed-ended questions or games. In most cases, no assessment activities that would enable meta-reflection were presented. The scientific thinking skills that were mostly promoted were: categorising observations, recognising patterns and thinking about causes and effects. As a result of the systematic analysis of the apps, they can be classified into three large groups: 'simulations', 'gaming apps' and 'encyclopaedia apps' in which different levels of interactivity, multimedia content, breadth, skills involved and cognitive demand prevail.

Keywords: ICT Enhanced Teaching and Learning, Secondary School, Multimedia and Hypermedia Learning

INTRODUCTION

Ecology is the epistemological support for understanding environmental problems, and it feeds school knowledge with a complex, open, multidimensional vision of science. In this context, ecology offers a systemic, non-mechanistic perspective: working with complex entities, the global vision of the world and the integration of analysis with synthesis, with a strong tendency towards multi- and inter-discipline (Hill, Wilson & Watson, 2004). However, at school, ecology concepts are usually presented as a set of dogmas; students deal with topics such as the ecosystem or ecological relationships as closed, static concepts, with one single possible formulation (Gonzalez del Solar & Marone, 2001). Without doubt, this way of teaching makes it difficult for students to acquire ecology school knowledge in line with scientific knowledge, and limits their capacity to establish relationships and combine contents.

For more than 15 years, the use of ICT as Ecology learning mediators has been proposed, with the development of specific computer programmes that enable the simulation of population and community dynamics, among other things. Nowadays, educational systems face the challenge of incorporating mobile phones in the classroom. In this scenario, mobile phones have long ceased to be mere communicative mediators to become centres of information, communication, audio and video recording and editing, and resource and content repositories.

Therefore, taking advantage of this device in the teaching and learning processes has many more advantages than one can imagine. This study is then based on two important premises: the availability of this educational tool and the ability of students to use it (Cantillo Valero, Roura Redondo & Sánchez Palacín, 2012). However, despite their ubiquity and the types of learning they can reinforce, these technologies are often not allowed or ignored in formal education systems. This represents a missed opportunity, as the potential of mobile phones can be significant and will continue to grow (Villalonga & Marta-Lazo, 2015).

In view of the prevailing need to incorporate mobile technologies in classrooms and considering the advantages of mobile apps that have been studied for the teaching of other biological contents, it is of interest to investigate the potentials of ecology-related mobile apps.

METHOD

The keywords 'Ecology', 'Ecology Teaching', 'Learning Ecology', 'Ecology Education' (both in English and in Spanish) were used in the search. Ten free-download apps developed for Ecology teaching and learning for the Android operating system (the main one used in Argentina) were selected for the analysis. The chosen apps, which were available in the Google Play Store digital platform, were the following: The Rain Forest Game, TaddyPole, Ksolve-Ecology, Ecology and Evolution Test - ECO, Ecology and Biosphere, Cours d' Ecologie, Ecosystem, Ecology Nuggets, Perspectives in Ecology, and Trilha Ecológica.

A methodology based on content analysis (Bardin, 1986) was followed, and those apps that included biodiversity and ecosystem structuring contents were selected. A qualitative analysis tool was developed, and categories contained in three dimensions were defined for such tool.

The 'ICT' dimension included the technical characteristics of each app taking up the categories proposed by Fernández-Pampillón Cesteros, Domínguez Romero & de Armas Ranero (2013); Martínez, Mir & Garcia Romano (2017) and Oliveira & Galembeck (2016). The 'Content' dimension analysed the depth with which the central Ecology topics were presented; to such end, the ideas presented by Adey (1997) and Bermudez & De Longhi (2006) were taken into account. As regards the 'Didactic' dimension, the pedagogical-didactic potentials of the apps were analysed according to the categories suggested by Vázquez-Alonso & Manassero-Mas (2018). Aspects emerging from the analysis were included in the tool, which was validated by means of a revision process carried out by experts in the field of Ecology.

RESULTS

Eight of the ten apps that were analysed were in English, one in French and one in Portuguese. With respect to the 'ICT' dimension, in general, the apps did not require Internet connection for their use. Usability was high, as the contents that were searched could be found quickly and the interface was intuitive. The multimedia content mostly included content with decorative or ornamental audio, 2D images with illustrative purposes and strong predominance of text. The degree of realism was low or null in most of the cases (Figure 1).

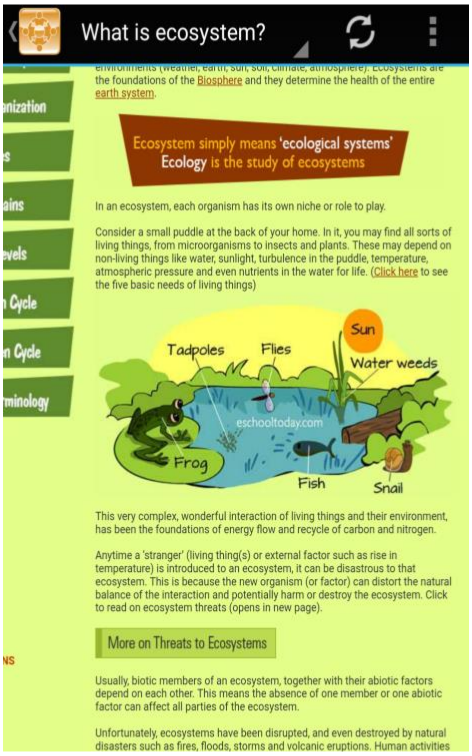

Figure 1. Example of an app that featured ornamental audios, illustrative images and predominance of text (Image taken from the Ecosystem app).

Interactivity was predominantly low, given the fact that the user's actions are limited to selecting steps to move forward in only one direction within the framework of the app proposal. Only one of the apps enabled to modify the values of different variables, and to observe different results according to the selection (Figure 2 a and b).

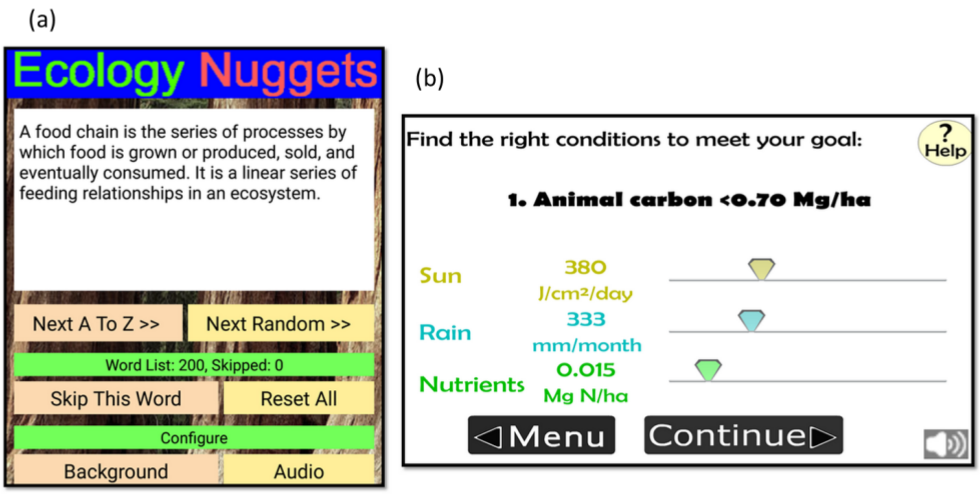

Figure 2. Example of an app with low interactivity (a) and an app with high interactivity (b) (Images taken from the Ecology Nuggets and The Rain Forest Game apps, respectively).

In relation to the ‘Content’ dimension, the Ecology branches that were most frequently found in the apps were General Ecology and Community and Ecosystem Ecology. Most of the apps included a wide variety of contents in their proposal, and only a couple of them focused on specific concepts (Figure 3 a and b).

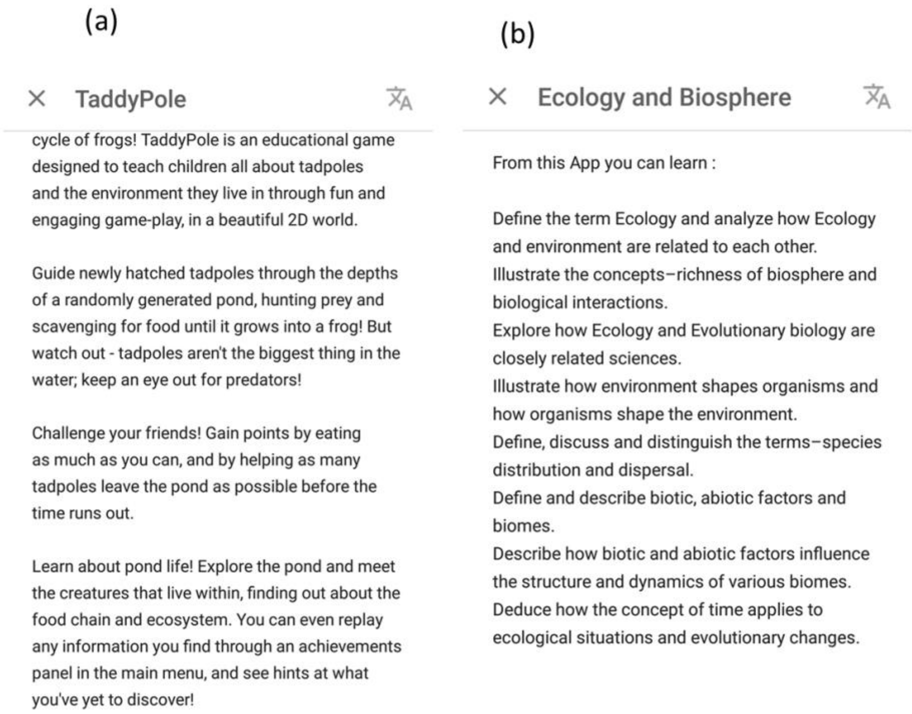

Figure 3. Example of an app with low breadth centered on the topic wetland ecosystem (a) and an app with high breadth that includes numerous topics (b) (Images taken from the TaddyPole and Ecology and Biosphere apps, respectively).

The biodiversity and ecosystem structuring contents were dealt with at different levels of complexity in the apps analysed, finding cases in which the description of elements and relationships present in the ecosystem were presented from an additive point of view that may reinforce students’ prior ideas, and biodiversity was explained from a perspective that does not recognise its different levels of expression. However, some apps address a higher level of complexity and describe the variety of life, including species, ecosystem and genetic diversity (Figure 4 a and b).

Regarding the ‘Didactic’ dimension, it was found out that, in general, activities are not included in the proposals offered by the apps. In those cases in which activities were actually included, none of them was collaborative, and they focused on the development of close-ended questions or game-type instructions (Figure 5). In most instances, no assessment activities that would enable meta-reflection were presented. Finally, it can be stated that the scientific thinking skills that are mostly promoted by the apps are: categorising observations, recognising patterns and thinking about causes and effects. Moreover, the apps mainly require defining concepts and classifying.

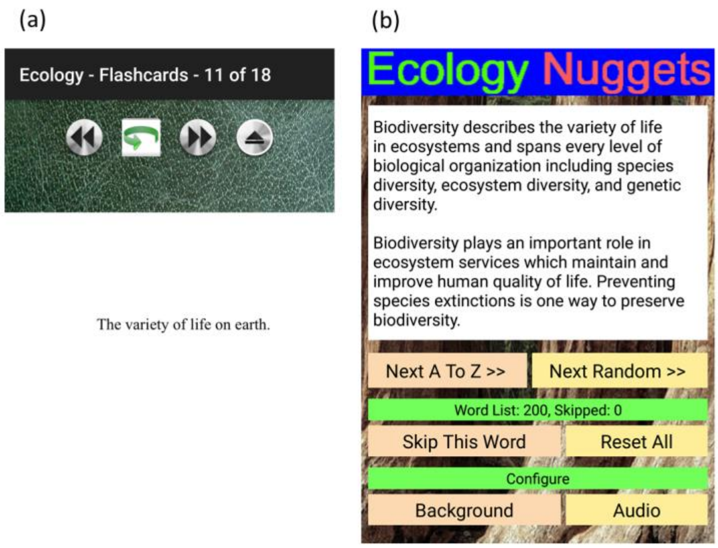

Figure 4. Example of an app that addresses biodiversity structuring content at a low level and in an additive way (a) and an app that presents a higher level of complexity (b) (Images taken from the KSolve-Ecology and Ecology Nuggets apps, respectively).

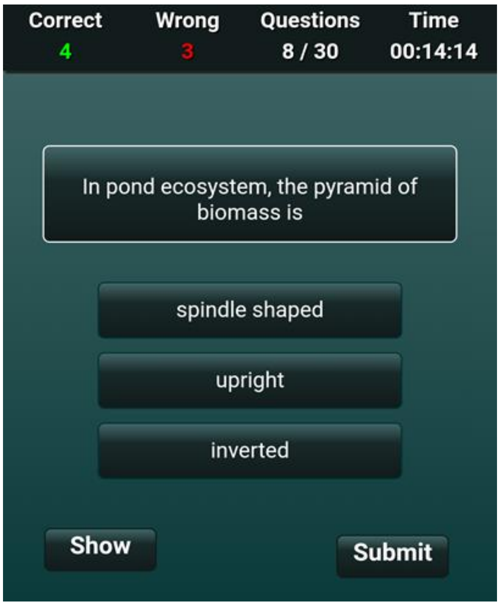

Figure 5. Example of an app that presents activities focused on closed questions (Image taken from the Ecology and Evolution Test - ECO app).

As a result of the systematic analysis of the apps, they can be classified into three large groups: 'simulations', 'gaming apps' and 'encyclopaedia apps', as shown in Table 1. Interactivity decreased considerably from an app that enables to simulate phenomena to another one with an encyclopaedia-type approach. In simulation and gaming apps the multimedia content was used to explain the topics whereas in encyclopaedia apps the multimedia content had an ornamental purpose. Simulations and gaming apps centred on specific topics, while encyclopaedia apps presented a wide content breadth. Expected skills and cognitive demand showed significant parallelism, with higher values in simulation apps.

Table 1. Characteristics that are fostered in each type of app. (+++): High level. (++): Intermediate level. (+): Low level.

Category	Simulation	Gaming	Encyclopaedia
Interactivity	(+++)	(++)	(+)
Multimedia content	(+++)	(++)	(+)
Breadth	(+)	(+)	(+++)
Skills involved	(+++)	(+)	(+)
Cognitive demand	(+++)	(+)	(+)

DISCUSSION AND CONCLUSIONS

The results found in this study regarding the 'ICT' dimension were similar to those reported by Martínez, Mir & Garcia Romano (2017) and Oliveira & Galembeck (2016). On the other hand, taking into account the ideas proposed by Vázquez-Alonso & Manassero-Mas (2018) and Hill, Wilson & Watson (2004), just a few apps are aimed at developing more complex skills and at transmitting a vision of ecology closer to the scientific one.

Considering the availability of mobile devices, we suggest the design and selection of apps that enable students to take an active role in their learning. In this sense, this research provides valuable information to interdisciplinary teams working on the development of user-centered mobile apps that want to contribute to the education of people, so that they not only have "ecological awareness" but also "ecological knowledge" (Bermudez & De Longhi, 2008) Furthermore, given that teaching requires a constant planning process and that mobile apps alone do not guarantee learning, the categories of analysis presented in this work can be useful for teachers who want to design teaching sequences and activities with these technological resources.

As for further work in this research line, it would be of interest to incorporate other structuring contents of Ecology such as the notions of environment and sustainability, or general Biology apps, which may contain sections devoted to Ecology.

ACKNOWLEDGEMENT

Thanks to the National Interuniversity Board (CIN) in Argentina for the funding granted to conduct this research.

REFERENCES

Adey, P. (1997). Dimensions of progression in a curriculum. *The Curriculum Journal*, 8(3), 367-39.

Bardin, L. (1986). *El análisis de contenido* [*Content Analysis*]. Madrid: Akal.

Bermudez, G., & De Longhi, A.L. (2006). Propuesta curricular de hipótesis de progresión para conceptos estructurantes de ecología [Progression Hypotheses Curriculum Proposal for Ecology Structuring Concepts]. *Campo Abierto*, *25*(2), 13-38.

Bermudez, G., & De Longhi, A.L. (2008). La educación ambiental y la ecología como ciencia . Una discusión necesaria para la enseñanza [Environmental Education and Ecology as a Science. A Necessary Discussion for Teaching]. *Revista Electrónica de Enseñanza de las Ciencias*, 7(2), 275–297.

Cantillo Valero, C., Roura Redondo, M., & Sánchez Palacín, A. (2012). Tendencias actuales en el uso de dispositivos móviles en educación [Current Trends in the Use of Mobile Devices in Education]. *La Educación Digital*, 47, 1–21.

Fernández-Pampillón Cesteros, A., Domínguez Romero, E., & de Armas Ranero, I. (2013). *Herramienta de Evaluación de la Calidad de Objetos de Aprendizaje (herramienta COdA)* [*Assessment Tool of Learning Object Quality*]. Madrid: Universidad Complutense de Madrid. Retrieved from https://eprints.ucm.es/12533/1/COdAv1_1_07jul2012.pdf

Gonzalez del Solar, R., & Marone, L. (2001). The "Freezing" of Science: Consequences of the Dogmatic Teaching of Ecology. *BioScience*, *51*(7), 555–556. doi: https://doi.org/10.1641/0006-3568(2001)051

Hill, S.B., Wilson. S., & Watson, K. (2004). Learning Ecology – A New Approach to Learning and Transforming Ecological Consciousness: Experiences from Social Ecology in Australia. In E. V. O'Sullivan and M. Taylor (eds.), *Learning Toward an Ecological Consciousness: Selected Transformative Practices* (pp. 47-64). New York: Palgrave Macmillan.

Martínez, G.F., Mir, F. & Garcia Romano, L. (2017). Caracterización de aplicaciones móviles para la enseñanza y el aprendizaje de la anatomía humana [Characterising Mobile Applications for Human Anatomy Teaching and Learning]. *Enseñanza de las Ciencias,* special edition, 1597-1603. Retrieved from: https://ensciencias.uab.es/

Oliveira, M.L. & Galembeck, E. (2016). Mobile applications in cell biology present new approaches for cell modelling. *Journal of Biological Education, 50*(3): 290-303. doi: 10.1080/00219266.2015.1085428

Vázquez-Alonso, A. & Manassero-Mas, M.A. (2018). Más allá de la comprensión científica: educación científica para desarrollar el pensamiento [Beyond Scientific Comprehension: Scientific Education to Develop Thinking]. *Revista Electrónica de Enseñanza de las Ciencias, 17*(2), 309-336. Retrieved from http://reec.uvigo.es/volumenes/volumen17/REEC_17_2_02_ex1065.pdf

Villalonga, C., & Marta-Lazo, C. (2015). Modelo de integración educomunicativa de 'apps' móviles para la enseñanza y aprendizaje [Educommunicative Integration Model of Mobile 'Apps' for Teaching and Learning.]. *Pixel-Bit. Revista de Medios y Educación*, (46), 137–153. Retrieved from http://www.redalyc.org/articulo.oa?id=36832959014

DEVELOPMENT OF AN INCLUSIVE, DIGITAL MEDIA-SUPPORTED LEARNING ENVIRONMENT FOR INQUIRY-BASED LEARNING

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Inquiry-based learning (IBL) is one possible teaching approach used to develop competences in three aspects: doing science, understanding scientific knowledge acquisition, and learning scientific content. Various studies show that IBL is successful under certain conditions, like proper scaffolding and teachers' reasonable understanding of scientific knowledge acquisition. Our project aims to support the implementation of IBL by supporting teachers and students alike. It offers additional digital scaffolding via a mobile website for students while they are participating in real-life experiments in the classroom. To develop digital support, in a first step teaching materials on inquiry-level 1 and 2 on the topic "chemical reactions" are implemented in two different urban schools in the eighth and ninth grade. Analysis of the gathered data (audio-recordings and the laboratory journals) helps in detecting areas for scaffolding. A digital environment providing scaffolding for the analysed areas is developed and assessed in an eighth grade of an urban secondary school. This paper shows the development from the first analogue inquiry box to the revised second inquiry box.

Keywords: scaffolding, multimedia and hypermedia learning, inquiry-based teaching

INTRODUCTION AND THEORETICAL BACKGROUND

Inquiry-based learning (IBL) is considered an important part of laboratory practice and it can contribute to gaining manifold competences in the field of doing inquiry, knowledge about inquiry and its connection to acquiring scientific content (Abrams, Southerland, & Evans, 2008). Nevertheless, it is not widespread, which is certainly because it is not easy to implement (Blanchard et al., 2010). Many national Science Education Standards and the curricula demand an implementation of inquiry-based science education. However, for example in Austria, only one in four teachers applies inquiry-based learning in regular lessons (Hofer, Lembens, & Abels, 2016). Therefore, the main aim of this project is to increase the use of inquiry-based learning by supporting teachers. Amongst the common reasons teachers give for a poor implementation of IBL are the high requirements for both teachers and students. In addition, there are several other potential areas of difficulty when implementing IBL. Two of the most-frequently mentioned pitfalls are a lack of scaffolding (cp. Blanchard et al., 2010; Kirschner, Sweller, & Clark, 2006; Mostafa, 2018) and the lack of meta-skills in doing inquiry (Blanchard et al., 2010; Lustick, 2009).

Our project (www.inquirysteps.com) aims to tackle both of the aforementioned pitfalls by introducing a digital media-supported learning environment to support teachers and students alike in inquiry-based lessons. In IBL, individual support for students – especially considering the high diversity in the classroom – is a particular challenge. Here, our project offers the possibility of increased individual and problem-specific support with the help of a website. In addition to the task-specific information, information about scientific inquiry and about scientific knowledge acquisition are provided. In other words, hypermedia provides multifaceted access to information (Arnold, Kilian, Thillosen, & Zimmer, 2018). However, the blended learning environment is what makes this project special, as it combines real-life hands-on experiments with digital scaffolding, supplemented with real-life scaffolding by the teacher.

Scaffolding should be provided in a way so that every student can learn within the “zone of proximal development” (Vygotsky, 1978). In diverse classrooms, the learning of all students has to be supported so the high as well as the low achievers should be actively addressed (Sliwka, 2010). Scaffolding is multidimensional and it may be divided into macro-scaffolding (planned in advance) and micro-scaffolding (ad-hoc scaffolding) (Hammond & Gibbons, 2005). The project focusses on macro-scaffolding which encompasses the tasks and all information and aids prepared to support the activities of the students. This will be applied to hands-on teaching material for inquiry-based learning at level 1 and 2 (Blanchard et al., 2010). Table 1 shows the responsibilities of the teachers and the students for each level.

Table 1: Levels of Inquiry (Blanchard et al., 2010)

	Source of the question	Data collection methods	Interpretation of the results
Level 0: Verification	Given by teacher	Given by teacher	Given by teacher
Level 1: Structured	Given by teacher	Given by teacher	**Open to student**
Level 2: Guided	Given by teacher	**Open to student**	**Open to student**
Level 3: Open	**Open to student**	**Open to student**	**Open to student**

On level 1, the teacher provides the question as well as the method to gather data. Only the interpretation of the results is left to the students, whereas on level 2, the teacher only provides the question to be answered. The method and the interpretation are open to the students.

Other aspects of the scaffolding that needs to be provided include language, easy access, structure and navigation of the supporting website.

METHOD

In a previous project, a unit concerning the topic “chemical reaction” without digital support was designed and tested with middle-school students. The tasks and instructions of the unit can be assigned to Level 1. As a first step in the project, the tasks were formulated and expanded to enable IBL at level 2. In addition, it was important to adequately formulate the tasks for a diverse group of students.

This enhanced learning unit was tested by students of the 8th and 9th grade to detect learning difficulties and to research possible supporting mechanisms to overcome the pitfalls mentioned in the introduction. The unit was still analogue. The analysis was guided by the following research questions: Which scaffolding measures do they already use? What obstacles do the students encounter? What do the students need additionally? These questions were formulated against the background that the hurdles and needs are identified before digital implementation.

The timeline of our project is shown in Table 2.

Table 2. Timetable of the research project

Date	Data sources	Collected Data, expected outcome

December 2018	Data collection 9th grade chemistry class, urban business school	Audio-recordings
February 2019	Data collection 8th grade, urban secondary school	Audio-recordings, laboratory journals
March – May 2019	Data analysis – extraction necessary scaffolding measures	Deductive analysis of the audio-recordings and the lab journal using the scaffolding categories (Puddu, 2017) supplemented by inductive categories (Temper, 2019)
May – June 2019	Realising of the digitalised scaffolding measures	
End of June 2019	Implementing of the new digitalised scaffolding Data collection 8th grade, urban secondary school	Audio-recordings, digital lab journal entries Analysis with deductive and inductive coding for further improvement of the digital scaffolding

The first inquiry box on the topic chemical reactions is shown in Figure 1 on the left side. It contained petri dishes, a flask, a spatula, a balloon, snap-on lid glasses containing the chemicals, etc.

Figure 1: Content of the first (on the left side) and the second inquiry box (on the right side).

The data was analysed by using qualitative content analysis (Kuckartz, 2014) using deductive scaffolding categories (Puddu, 2017) which were supplemented by inductive categories (Temper, 2019).

Using the results, the tasks were digitalised and the inquiry box updated. The second inquiry box is shown in Figure 1 on the right side. The required support was implemented digitally following the premises: Which parts of the required scaffolding can be digitally adopted? What additional scaffolding has to be implemented to make the setting as inclusive as possible? How can digital help be made available to students in the best possible way and at the right time? The website was tested with eight graders concerning usability, acceptance and comprehension.

RESULTS

The first inquiry box (see Figure 1 left) contained the following tasks: The first task addressed the wording of the German word "Stoff" which means substance or matter. In German, the same word is used for cloth or fabric, so the scientific use of the word is introduced. The second task is about the mixing of substances, especially about the mixing of watercolours. Subsequently, the leaners fulfil the third task in which different substances react. The fourth tasks contrasts mixing and a chemical reaction between substances to highlight the differences. Afterwards the development of gas is introduced as an additional example for a chemical reaction. Up to this step, the learners only work on level one tasks. The next one, "What has bubbled?" is a level 2 task where the students have to plan the research. Finally, the students have to answer questions if the mentioned processes are chemical reactions or not.

The students' answers were collected and analysed to detect possible improvements of the box.

Table **3** lists the processes and the answers the groups have given on the question "Is this a chemical reaction?".

Table 3: results of the first box

Process: (12 groups)	Yes, this is a chemical reaction:
Tearing paper	0/12
Gas formation in the effervescent tablet	7/12
Mixing of two substances	**7/12**
Inflating a balloon	1/12
Burning paper	0/12
Reaction of two substances	8/12
Breaking a glass ball	0/12
Mixing colors	**7/12**

The results show that the answers to two questions were problematic. The students stated that the mixing substances and mixing colours are chemical reactions. To gain an in-depth perspective and explain this outcome, we analysed the audio-recordings and the laboratory journals in this order.

Problem 1: Too long to wait

The title of the inquiry box is "chemical reactions", but the students have mastered two tasks before they experience the first chemical reaction. The expectations the box raised might have compromised the observations and the interpretations. Based on the results obtained from the analysis of the data, the digital version was different. The aim to contrast mixing and reaction was skipped in favour of concentrating on chemical reactions.

Problem 2: Too many devices

One problem might be the overwhelming number of things in the first inquiry box. The students had difficulties with finding the necessary things in due time. Therefore, an additional game was introduced in the digitised version, in which the students had to assign pictures and names of the laboratory equipment, as shown in Figure 2. Those difficulties might have distracted the students from the learning goal.

Figure 2: Game: „laboratory equipment“

Problem 3: Too much to read

The analysis of the audio-recordings showed that the students did not read the manual and skipped the explanations. Some groups even mentioned that in the discussion. Sentences like “We should have read everything first.” were found repeatedly in the data. As a consequence, for the digital version, videos were made instead of written explanations. In the videos, the students can hear and see what to prepare for the next experiment. At important positions, as after preparing the required materials, the video would stop and the students have to press a button to continue with the video.

The revised inquiry box

The revised inquiry box (see Figure 1) contained less equipment and the tasks differed a bit. The first task was the game “laboratory equipment” followed by the task about the wording substance/matter. After that, two chemical reactions were made by the students, identified by colour changing. The next task offered the development of gas as an example of a chemical reaction. The level 2 task “What has bubbled?” remained the same. The last task again comprised the questions about chemical reactions.

The design of the website for this revised box complies with current guidelines (cp. Arnold et al., 2018; Golser, 2019; Mair, 2005). We wanted the website to be easy to use, so a clear navigation and colouring was needed. It has to be easy to read with adjustable font size, left justified. We used short sentences und few technical terms. Many instructions were adapted and supported by videos and pictures.

The following table (Table 4) shows the results of the last task of the inquiry box where the students read about different processes and they have to answer the question “Is this a chemical reaction?”.

Table 4: Results of the second box in comparison to the first box

Process: (10 groups)	Yes, this is a chemical reaction:	Yes: original box
Tearing paper	0/10	0/12
Gas formation in the effervescent tablet	8/10	7/12
Inflating a balloon with the mouth	1/10	1/12
Burning paper	4/10	0/12
Reaction of two substances to a new substance	10/10	8/12
Breaking a glass ball	0/10	0/12

Mixing of watercolours	0/10	7/12

The answers collected in the last task of the revised box suggest that the new structure was more effective (see Table 4). Most of the answers were correct, except the burning paper. Only four out of ten groups recognized this process as a chemical reaction. The reason is unclear and subject of further investigation.

OUTLOOK

The first step was to create a website, which is working for the students for their first steps in inquiry-based learning and is also be easy to use for teachers so they implement the inquiry box into their teaching. To be able to provide more inquiry boxes a new, professional website was programmed which included more scaffolding and support possibilities. With this new website, systematic research is needed to find out whether learning with inquiry boxes is effective. For this purpose, qualitative as well as quantitative methods are used.

REFERENCES

Abrams, E., Southerland, S. A., & Evans, C. (2008). Inquiry in the Classroom: Identifying Necessary Components of a Useful Definition. In E. Abrams, S. A. Southerland, & P. Silva (Eds.), *Inquiry in the Classroom: Realities and Opportunities* (pp. xi-xlii). Charlotte, North Carolina: Information Age Publishing.

Arnold, P., Kilian, L., Thillosen, A., & Zimmer, G. (2018). *Handbuch E-Learning [Handbook E-Learning]*. Bielefeld: Bertelsmann Verlag.

Blanchard, M. R., Southerland, S. A., Osborne, J. W., Sampson, V. D., Annetta, L. A., & Granger, E. M. (2010). Is Inquiry Possible in Light of Accountability?: A Quantitative Comparison of the Relative Effectiveness of Guided Inquiry and Verification Laboratory Instruction. *Science Education, 94*(4), 577-616.

Golser, L. S. (2019). *Die digitale Umsetzung einer Lernbegleitung im Rahmen des Projekts "INQUIRYsteps" am Beispiel eines Versuchs der Lernschachtel "chemische Reaktionen".* (BEd Bachelor thesis), University of Vienna, Vienna.

Hofer, E., Lembens, A., & Abels, S. (2016). Enquiry-based science education in austrian teacher professional development courses. In I. Eilks & B. Ralle (Eds.), *Science education research and practical work* (pp. 271-277). Aachen, Germany: Shaker.

Kirschner, P. A., Sweller, J., & Clark, R. E. (2006). Why Minimal Guidance During Instruction Does Not Work: An Analysis of the Failure of Constructivist, Discovery, Problem-Based, Experiential, and Inquiry-Based Teaching. *Educational Psychologist, 41*(2), 75-86.

Kuckartz, U. (2014). *Qualitative Inhaltsanalyse. Methoden, Praxis, Computerunterstützung [Qualitative Content Analysis. Methods, Practice and Computer Assistence]*. 2. überarbeitete Auflage: Beltz Juventa.

Lustick, D. (2009). The Failure of Inquiry: Preparing Science Teachers with an Authentic Investigation. *Journal of Science Teacher Education, 20*(6), 583-604.

Mair, D. (2005). *E-Learning - das Drehbuch: Handbuch für Medienautoren und Projektleiter*. Berlin: Springer.

Mostafa, T. (2018). How do science teachers teach science - and does it matter? doi:https://doi.org/10.1787/f3ac3fd6-en

Puddu, S. (2017). *Implementing Inquiry-based Learning in a Diverse Classroom: Investigating Strategies of Scaffolding and Students' Views of Scientific Inquiry* (Vol. 247). Berlin: Logos.

Temper, L. (2019). *Weiterentwicklung und Evaluation von Materialien zum Thema „Chemische Reaktionen" im Projekt Inquiry Steps [Further development and evaluation of tasks concerning the topic "chemical reaction" within the project Inquiry Steps].* (Magister Diplomarbeit), Universität Wien, Wien.

A BLENDED LEARNING APPROACH FOR IN-SERVICE TEACHERS TRAINING BASED ON ONLINE MOODLE PLATFORM

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As part of the Italian ministerial project "National Scientific Project" (PLS, Piano Lauree Scientifiche), on chemistry's learning empowering, the University of Camerino has been holding residential training courses addressed to in-service high school science teachers. Meeting the demands for the implementation of digital media in education, a course in blended mode has been run since 2016, offering teachers both face-to-face classes and online activities, hosted on a dedicated e-learning Moodle platform.

"The online chemical experiments: instructions for use" course was planned with a bottom-up approach, which included discussions with a group of teachers in order to reach a common agreement on which key chemistry concepts should be addressed. The first aspect involved refreshing some disciplinary issues as Science teachers are often not graduated in chemistry but in other subjects. The second task was the adoption of the extended Johnstone's model (Mahaffy,2014) for the presentation of chemistry topics, considering that the three levels are normally showed in the curriculum, but its tetrahedral extension to real life cases is often neglected. Then the implementation of multimedia tools followed, thus providing original materials in Italian and in English to respond to the demand for CLIL (Content and Language Integrated Learning) methodology. The analysis of the final questionnaire administered at the end of the course showed the teachers' positive ratings on the blended training method and on the quality and usefulness of digital materials.

Keywords: Technology in Education and Training, In-service Teacher Training, Computer Supported Learning Environments.

1. INTRODUCTION

Since 2007, the Italian Ministry of Education (MIUR) has promoted and funded many initiatives with the main objective of changing learning environments and promoting digital innovation in schools. Despite the investments, in the S.Y. 2014/15, regarding the students' skills, Italy was 25th in Europe for the number of Internet users (59%) and 23rd for basic digital skills (47%).

This gap was also visible in the case of specialist ICT skills (Italy 17th) and the number of graduates in STEM disciplines, for which Italy was 22nd, with 13 citizens per 1,000 (Mangione, Mosa & Pettenati, 2016).The data from the OECD TALIS 2013 survey saw Italy in first place for the ICT training needs of its teachers: at least 36% said they were not sufficiently prepared for digital teaching, compared to an average of 17% (OCDE, O., 2014). The 2015 Eurydice Report also underlined how digital skills were certainly among the training needs most felt by Italian teachers, both in terms of teaching enhanced by technologies, both as regards the use of technologies for their profession (European Commission/EACEA/Eurydice, 2015). In 2015

MIUR launched the new National Digital School Plan (Schietroma, 2016) with numerous actions aimed at strengthening technological infrastructures and a massive investment on in-service teacher training, On the other side, in Italy the development of e-learning system in Universities has taken place in the absence of significant regulatory action but through independent initiatives for elevating the quality of traditional didactics with the support and integration of online communication (Capogna, 2012).

In addition to the promotion of digital innovation, since 2004 MIUR has been funding "Piano Lauree Scientifiche" (Marasini, 2010), a project designed to increase the number of chemistry careers and the enrolment to the academic course of chemistry, industrial chemistry and materials science. The strongest point of the project is the collaboration between schools and universities for the development of STEM skills in high school students and for the training of teachers on the design of digitally supported teaching and learning contents.

2. THE "ONLINE CHEMICAL EXPERIMENTS: INSTRUCTIONS FOR USE" COURSE- I EDITION

Since 2006, the Chemistry Department of the University of Camerino has been taking part to "Piano Nazionale Lauree Scientifiche", with activities for students and residential training courses for in-service teachers of Natural Sciences. In 2016, a chemistry training course was set up in blended mode to comply with the requests of institutions and teachers, with multiple aims regarding the teaching and the learning of chemistry.

2.1 Design of the course

Over the last ten years, blended learning has been growing in demand and popularity in higher education and has become a large-scale teaching phenomenon. It becomes increasingly evident that blended learning can overcome various limitations related to online learning and face-to-face instruction. A meta-analysis of more than 1100 empirical studies published between 1996 and 2008 concluded that blended learning proves to be more effective than either online learning or face-to-face instruction (Means,Toyama,, Murphy, Bakia,& Jones, 2009). Among the different blended learning approaches described in the literature, the high-impact method was chosen, building our course from scratch (Alammary,Sheard & Carbone,2014).

The benefits of building a course from scratch are widely discussed (Littlejohn & Pegler, 2007; Wozney,Venkatesh,& Abrami,2006), including the possibility of rethinking and redesigning the course considering the learners' needs and the learning outcomes to achieve. Designing an effective blended learning course requires indeed to identify all parts of the course that could be better presented in an online format, and then an examination of available educational technologies is needed to select those that best meet the users' needs.

Regarding the modality of e-learning, the course designers chose to adopt the model of assisted training (Banzato &Midoro, 2015), that provides both individual study based on materials prepared specifically for self-learning and interaction with online tutors, experts and colleagues.

Once established the model of the course, a bottom-up strategy was adopted to fulfil the training needs of the teachers, most of them haven't a Chemistry degree, but graduated in Biology, Geology or Natural Sciences. A working group was then set up to respond to the demands of a group of natural science teachers who previously followed the residential training courses.

Teachers' main requests were:

(i) mastering technological tools both for the immediate use in the blended course and for their introduction in teaching practice,

(ii) refreshing topics to be treated with an experimental approach,

(iii) acquiring new teaching methods that integrate new technologies, such as the Flipped Classroom method (Tucker, 2012).

2.2 Design of the chemistry units

The extended Johnstone's model, also called the tetrahedral model, proposed by Mahaffy (2014), was adopted for the organization of the chemistry units. The three thinking levels in learning chemistry are widely used into the design of secondary and post-secondary curriculum. The rehybridization of the triangle metaphor into a tetrahedron (Sjöström,2013) introduces the human contexts in chemistry as fourth vertex, thus providing a clear framework for grounding the three dimensions of chemistry curriculum in "real world" problems and solutions, including industrial processes and environmental applications. Highlighting the human element provides strong rationale for emphasizing case studies, active learning, and investigative projects for linking "school chemistry" to everyday life.

This model's issues were therefore adopted in the design of the course units, with the precise aim to make chemistry topics nearer to students' interests.

2.3 Structure of the course

In November 2016 the first edition of the "Online Chemistry Experiments: Instructions for Use" course was hosted on the UNICAM Moodle platform, followed by 28 science teachers belonging to 12 high schools of Marche Region. The total duration of the course was 25 hours, including 5 hours of face-to-face training, organized in 2 residential seminars, and 10 hours of online activities, assisted by two tutors. The first residential meeting illustrated the chemistry issues of the course, while in the second meeting teachers tested themselves the digital tools for building innovative paths.

On the Moodle platform, the course was structured in 12 units, addressing different general chemistry concepts model (Table 1) and designed according to the Mahaffy's tetrahedral model.

Table 1. The topics of the 12 units of Inorganic Chemistry hosted on the Moodle Platform.

Unit	*Topic*
1	Reaction of calcium and water to form gaseous Hydrogen
2	Double exchange reactions and an approach to qualitative chemical analysis
3	Effect of temperature on NO_2 dimerization
4	Test of CO and CO_2 during the aspiration process of a lit cigarette
5	Ammonia reaction with cupric sulfate
6	Effect of concentration and temperature on chemical equilibria in solution
7	Reactivity of alkaline metals
8	Reactivity of earth alkaline metals
9	Visualization of water polarity
10	Electrolytic properties of solutions highlighted by a toy car
11	Thermal conversion of an allotropic form to another one

12	Photo-assisted reduction of thionine

Teachers were also supported with a webinar, held by the online tutors, addressing new approaches in chemistry education, such as IBSE methodology, problem solving in the chemistry laboratory, the implementation of authentic tasks and the assessment of laboratory activities. Moreover, the “Scientix” project was presented, a European project that collects and promotes best practices in science teaching and learning in Europe and organizes trainings and workshops for STEM teachers. A technical and a disciplinary forum were also hosted on the learning platform, allowing discussion and exchange of ideas among the participants and with the tutors. At the end of the course a final monitoring questionnaire was administered online. All the materials were in Italian and in English to respond to the demands for the introduction of CLIL methodology in the Italian school curricula (Leone, 2015).

Furthermore, during the course, two teachers undertook an action research project on the teaching of some chemical concepts, involving two 11th grade classes of pupils (16-17 years old) and using the pedagogical model of the Flipped Classroom and the IBSE approach, with emphasis on the 5E Learning Cycle (Schettini et al., 2017).

2.4 Structure of the units

The core of each unit is a video showing a laboratory activity related to the topic (Figure 1). The adoption of video tutorials leads to optimized teaching and learning processes in the fundamental chemistry education in universities (He,Swenson & Lents, 2012). The main advantage of videos is the connection of both visual and auditory elements. Mayer’s Cognitive Theory of Multimedia Learning additionally states that the simultaneous presentation of verbal and visual material, as realized in videos, is the most effective solution for beginners and visual-style learners (Mayer, 2009).

According to the fourth vertex of the tetrahedral model, in-depth materials in digital form were provided in every unit, as examples of real-life connections and cross-sectorial applications of the chemical concepts (Figure 2). A technical sheet of the experiment, theoretical references with description of the symbolic and sub-microscopic level of the phenomenon, problem solving exercises and a self-assessment test were associated to each video.

Figure 1. Screenshots of the video of Unit 1 (Reaction of calcium and water to form gaseous hydrogen).

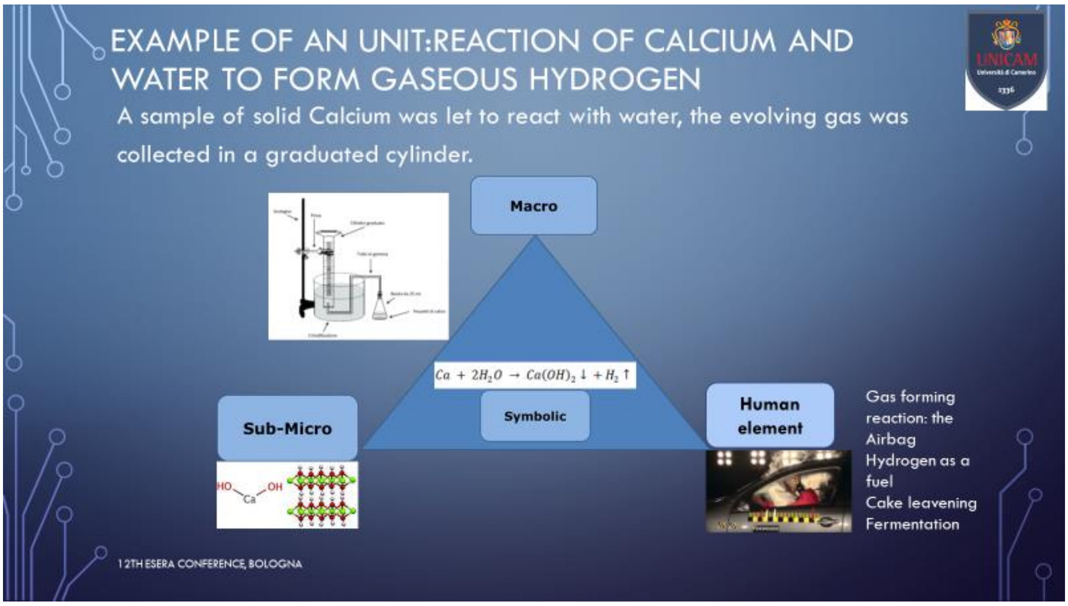

Figure 2. Structure of Unit 1, according to Mahaffy's model.

2.5 Teachers' survey

At the end of the course, a final questionnaire of 61 questions was administered to assess the degree of teachers' satisfaction about the training. The questionnaire was divided into four sections (general aspects of the course, usefulness of the videos and related materials for the training, use of the videos and related materials with students, webinar on new approaches in chemistry education) and directly administered online on the Moodle platform. All the 28 teachers, attending the course, completed the questionnaire. The responses were automatically elaborated by the Moodle software and provided in the form of percentage of the different answers (for closed questions where more than one answer was possible) or delivering the statements answered to open questions. Regarding teachers' general opinion on the course, 25% judged it "excellent", 42,86% "very good" and 32,14% "good" and 75% of the teachers would recommend its frequency, even charged. When teachers were asked to rate (with a score from 0 to 10) the skills acquired by the different activities, the best results were achieved by "using and studying the videos of the experiments", followed by "refreshing basic chemistry knowledge" and "studying examples from real life situations" (Figure 3).

Furthermore, when asked on which aspects of their professional development the course provided the best upgrade, teachers chose the "introduction of examples in lessons" (23,08%) and "contextualization in real-life situations" (15,38%), highlighting science teachers needs for connecting chemistry topics to everyday life to increase students' motivation, according to Mahaffy's model. 19.23% of the teachers chose the" knowledge of online training opportunities" option, as the course focuses also on web resources for teachers' training (Figure 4).

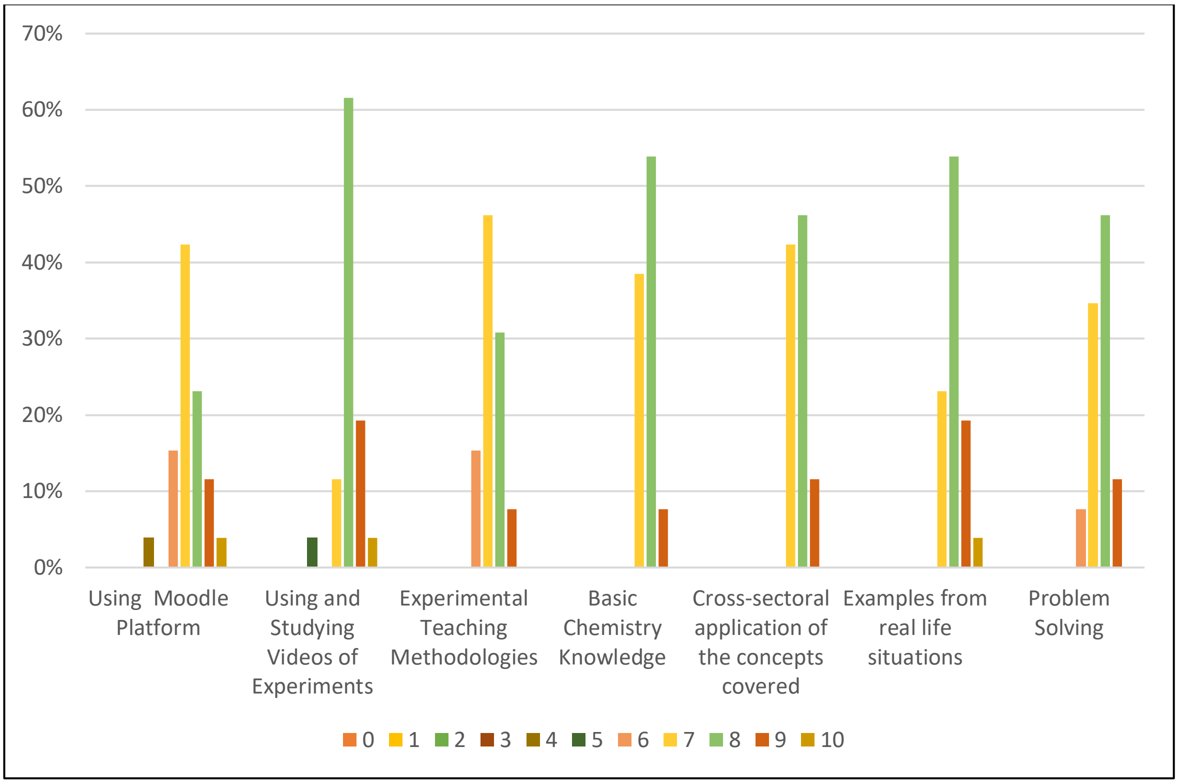

Figure 3. Ratings of the different activities' impact on teachers' skills.

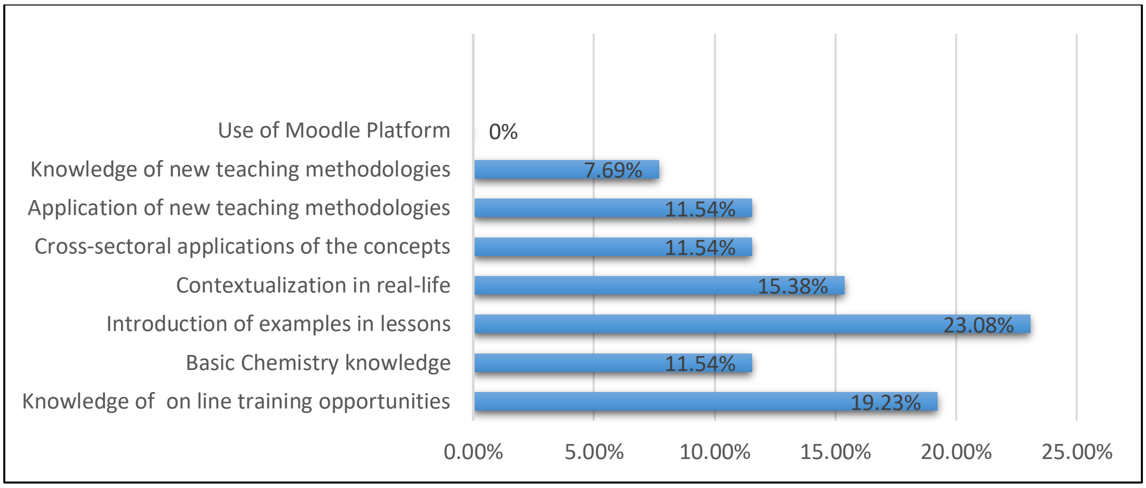

Figure 4. Percentage of answers to the question about skills upgrade.

On the overall, teachers considered more useful for their training the educational material accompanying the videos, followed by simply watching the videos and then by the webinar's attendance, probably for its short duration (Table 2).

Table 2. Percentage of answers to the questions about different activities' usefulness.

How useful was for your	YES	MORE YES THAN NO	MORE NO THAN YES	NO

professional development?				
Watching the videos	73.08 %	19.23 %	3.85 %	3.85 %
The education material accompanying the videos	96.15 %	3.85 %	0.00 %	0.00 %
The webinar	61.54 %	30.77 %	0.00 %	7.69 %

Regarding the use of videos in the classroom, 15.38% of teachers employed them a lot and 42.31 % only a little. Most of them considered the videos *"well described in the different steps, taking a short time and with a visual impact able to arouse students' curiosity and attention"*. Some teachers used the videos in the absence of laboratory and others, after the practice, for reviewing and reflecting on the different steps. Some teachers reported that they didn't use the videos extensively, because the topics were not included in their current course of study and asked for more experiments to record, even about organic chemistry. Some teachers showed videos in their classroom as a starting point before introducing an analytical law or as validation, after studying an analytical law, even in flipped classroom modality. Furthermore, 42.31% teachers included video-related questions in their tests.
Regarding the other resources 'use with students, teachers reported, above all, the use of examples related to real-life, followed by the cross-sectorial application to concepts. The lack of use of video in English was motivated in some cases by the limited time available or by students' insufficient language skills (Figure 5).

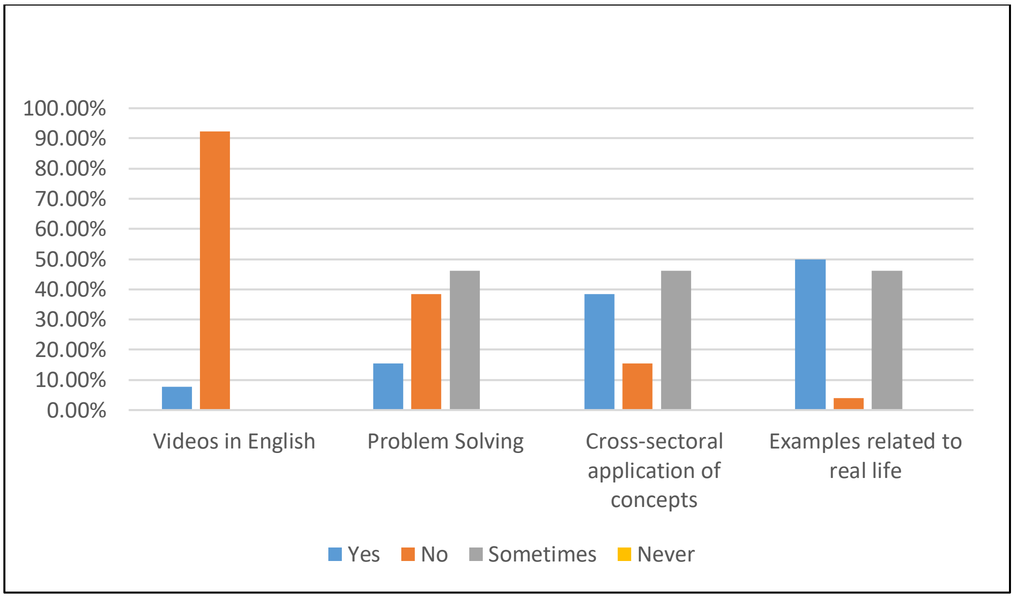

Figure 5. Percentage of answers to the question about use of resources with students.

Regarding the interest of the topics afforded in the webinar, teachers preferred the assessment of students' skills by the means of authentic tasks and the suggestions for the evaluation of laboratory activities (more than one answer available), as showed in Figure 6.

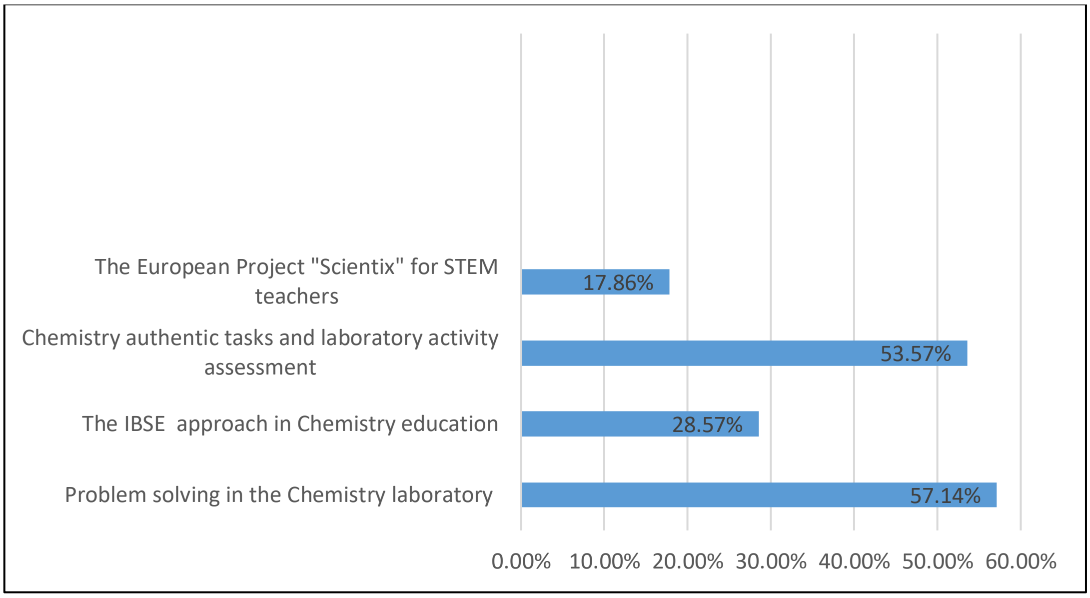

Figure 6. Percentage of answers to the question about webinar's topics interest.

3. THE "ONLINE CHEMICAL EXPERIMENTS: INSTRUCTIONS FOR USE" COURSE- I EDITION

In 2017, a second edition of the course was delivered with 13 teachers and it was implemented, following teachers' opinion and suggestions derived from the reported survey. Two webinars were included, instead of one, and the teachers received training in the Flipped Classroom methodology, as required.

Furthermore, all teachers were asked to design a learning unit, including the digital materials of the platform, especially videos, and adopting one of the innovative teaching methods experimented during the course.

Then, they were asked to approach the fourth vertex of the tetrahedron model in their units, connecting the chemical concepts to students' experience and real-life contexts. The learning units were evaluated with a rubric, considering the following aspects: (i) adequacy to the students' characteristics and to school context, (ii) structure of the educational path, (iii) use of the Moodle platform materials and originality of the proposal , (iv) propriety of the real-life connections and (v) quality of evaluation tests.

4. CONCLUSIONS AND FURTHER IMPLEMENTATION

The course has been useful as a stimulus for the teachers' active reflection on the benefits derived from adopting an experimental approach to the teaching of chemistry, for the acquisition of experimental procedures and for the possibility of replacing a "real" chemistry lab, in the absence of reagents or suitable equipment. Conversely, lack of familiarity with the Moodle platform, inadequate Internet connection and, in some cases, the impossibility of repeating the experiment in a laboratory were perceived as critical issues.

According teachers' request, a greater number of videos will be designed and provided, introducing also organic chemistry topics and they will be made accessible to pupils as well. For the next editions it is expected to increase the number of webinars, introducing more examples of new approaches to chemistry teaching and learning. Furthermore, collaborative activities among group of teachers to be developed in the Moodle learning context will be promoted.

ACKNOWLEDGEMENT

We are grateful to Piano Lauree Scientifiche and to the School of Advanced Studies of University of Camerino for their support. The University of Camerino's e-learning coordinator and its personnel are profusely acknowledged for the competent and helpful technical support.

REFERENCES

Alammary, A., Sheard, J., & Carbone, A. (2014). Blended learning in higher education: Three different design approaches. Australasian Journal of Educational Technology, 30(4).

Banzato, M., & Midoro, V. (2005). Models of e-learning. Italian Journal of Educational Technology, 13(3), 60.

Capogna, S. (2012). University and E-learning Classes in Italy. E-Learning and Digital Media, 9(2), 143-156.

European Commission/EACEA/Eurydice. (2015). Adult Education and Training in Europe: Widening Access to Learning Opportunities (Eurydice Report).

Gallet, C. (1998). Problem-Solving Teaching in the Chemistry Laboratory: Leaving the Cooks... Journal of Chemical education, 75(1), 72.

He, Y., Swenson, S., & Lents, N. (2012). Online video tutorials increase learning of difficult concepts in an undergraduate analytical chemistry course. Journal of Chemical Education, 89(9), 1128-1132.

Johnstone, A. H. (2000). Teaching of chemistry-logical or psychological?. Chemistry Education Research and Practice, 1(1), 9-15.

Leone, A. R. (2015). Outlooks in Italy: CLIL as language education policy. Working Papers in Educational Linguistics (WPEL), 30(1), 3.

Littlejohn, A., & Pegler, C. (2007). Preparing for blended e-learning. Abingdon, Oxon: Taylor & Francis.

Mahaffy, P. (2004). The future shape of chemistry education. Chemistry Education Research and Practice, 5(3), 229-245.

Mangione, G. R., Mosa, E., & Pettenati, M. C. (2016). Dalla Gelmini alla Giannini. Il Piano Nazionale Scuola Digitale, i PON disciplinari e il ruolo dell'INDIRE nella formazione continua degli insegnanti. [From Gelmini to Giannini.The National Plan for a Digital School, the disciplinary PONs (National Objective Projects of European Social Fund) and the role of the INDIRE in teachers' continuing education] FORMAZIONE & INSEGNAMENTO. Rivista internazionale di Scienze dell'educazione e della formazione, 13(3), 139-166.

Marsh, D. (2008). Language awareness and CLIL. Encyclopedia of language and education, 1986-1999.

Mayer, R. E. (2009). Multimedia learning (2nd ed.). New York, NY, US: Cambridge University.

Means, B., Toyama, Y., Murphy, R., Bakia, M., & Jones, K. (2009). Evaluation of evidence-based practices in online learning: A meta-analysis and review of online learning studies. Washington, DC:U.S. Department of Education.

OCDE, O. (2014). TALIS 2013 Results: An International Perspective on Teaching and Learning. OECD Publishing.

Schietroma, R. (2011). Il Piano Nazionale Scuola Digitale. [The National Plan for a Digital School].Annali della Pubblica Istruzione, 2, 15-29.

Schettini C., Galassi R., Zamponi S., Bossoletti D., Pirani T.(2017). Un approccio integrato Flipped Classroom-Inquiry-Based in un percorso di ricerca-azione sulla reattività dei metalli. In "Atti del XXVI Congresso Nazionale della Società Chimica Italiana" (pg 358)- Società Chimica Italiana (Roma).

Sjöström, J. (2013). Towards Bildung-oriented chemistry education. Science & Education, 22(7), 1873-1890.

Tucker, B. (2012). The flipped classroom. Education next, 12(1), 82-83.

Wozney, L., Venkatesh, V., & Abrami, P. (2006). Implementing computer technologies: Teachers' perceptions and practices. Journal of Technology and teacher education, 14(1), 173-207.

COLLABORATING PRIMARY STUDENT TEACHERS IN DESIGNING EXPERIMENTS WITH THE USE OF ICT

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Technology enactment in science education is a continuous, yet unaccomplished goal. Contributing factors, as the student-oriented use of Information and Communication Technology (ICT) tools, collaboration and reflection between peers should be taken into account. This research aims to study how student teachers collaborate in a Learning Community (LC) framework in order to design and develop science experiments with the use of ICT tools, such as dataloggers. Data analysis provide empirical data supporting that collaboration played an important role a) in the discussion at the LC meetings, as teachers showed an increasing tendency to use participatory dialog for knowledge construction and to engage in peers' conversations about their experiments, b) in the design process, as there was an increasing influence from peers in the development of experiments.

Keywords: Peer Interaction, Classroom Discourse, Data Logging

INTRODUCTION

Using Information and Communication Technology (ICT) tools such as microcomputers/dataloggers i.e. electronic sensors & probes, data collection devices and the appropriate data analysis software in the school laboratory has the potential to enhance science learning. In specific, using data logging can contribute to increased conceptual learning (Nikolaou et al. 2007, Sokoloff et al. 2007), graph construction & interpretation skills (Nikolaou et al. 2007) and interdiscipline connections with the relative mathematical modelling of the phenomena (Lavonen et al. 2003). Additional attitudinal benefits can be obtained, since data logging motivates students as well as procedural advantages concerning the reduction of time needed to collect data and to repeat the experiment (Barton 2005).

However, there are several crucial factors to consider in order to take advantage of the additional value that ICT offer in the classroom. Factors like the pedagogy used, e.g. whether technology is used in a student-oriented and inquiry-based approach, as also the general "classroom ecology" effects dramatically on the efficiency of using ICT for science teaching (Prestridge 2017, Bell et al. 2013, Odom et al. 2011, Waight & Abd-El-Khalick 2007). In particular, using ICT for administration purposes, to complete worksheets and reading reflects "passive"/mechanical use and is not correlated with increased student achievement; on the contrary, using ICT in the classroom as part of the inquiry process with the active engagement of the students, e.g. for observation and prediction of phenomena reflects "active" use and contributes to better student achievement (Waight & Abd-El-Khalick 2018, Prestridge 2017, Odom et al. 2011). Moreover, using ICT in an authentic context for science learning (Bell et al. 2013) which relates to students' everyday life (Iliaki et al. 2019) also effects on successful integration of technology, because teachers learn how to use ICT for the accomplishment of specific teaching goals. The idea of learning *with* technology rather than *about* technology is crucial when implementing ICT for science teaching (Waight & Abd-El-Khalick 2007).

As implied from the above, successful integration of ICT in science education highly depends on the teacher, regarding cognitive factors i.e. knowledge on how to use technology for science teaching, and affective factors i.e. his beliefs and attitudes towards technology (Prestridge 2017, Ertmer & Ottenbreit-Leftwich 2013), whilst the general context and the characteristics of ICT tools also have an impact (Waight & Abd-El-Khalick 2018). In order to define the needed knowledge to implement ICT, a framework for teacher professional knowledge for efficiently teaching science with the use of technology was presented by Mishra & Koehler (2006). Technological, Pedagogical & Content Knowledge (TPACK), knowledge derived from the intersection of Technological Knowledge, Pedagogical Knowledge and Content Knowledge, is required by teachers in order to develop and efficiently integrate experiments with the use of ICT in their teaching.

Collaboration can play an important role in supporting teachers on implementing an educational innovation, such as the meaningful integrating of ICT discussed above (Juuti et al. 2016, Kafyulilo et al. 2015, Bell et al. 2013). As any educational innovation, implementing ICT is an open-ended task that cannot be used in just one way in the classroom, whilst collaboration between teachers, researchers and experts through several iterations is needed (Waight & Abd-El-Khalick 2018, Juuti et al. 2016). During this process, discussion and reflection between peers can promote the inquiry stance needed from the teachers (Kervinen et al. 2016, Waight & Abd-El-Khalick 2007) and assist them to change their beliefs and their teaching practices concerning ICT (Prestridge 2017, Elster 2010). Under this prism, the establishment of Learning Communities (LCs), small groups that may consist of students, teachers and experts, has the potential to provide the student-centered learning environment and the collaborative and dialogic environment needed. Therefore, through reflection and mutual engagement, LCs can assist the design of experiments with ICT and effect on changes in teaching practices with the use of ICT.

However, further parameters regarding the operation of the LC, such as reflection with peers, guidance from experts, members' active engagement and inquiry stance have to be promoted for an efficient LC (Couso 2016), since in many cases LCs are overtaken from administrative issues, pressure from test scores and limited availability of time (Jones et al. 2013) . In specific, discourse with emphasis on meaning making, where conflicts and different views take place, supported by a group leader who promotes task engagement, is suggested for an efficient LC (Bennett et al. 2010). Consequently, training teachers through participatory meaning-making dialog and interacting with peers is needed in order to facilitate technology enactment in schools.

Hence, the present study implemented a collaborative LC framework to support primary student teachers on meaningful integration of ICT, particularly data logging, to the design and development of science experiments in an authentic science education laboratory context in order to teach school students. The discussion that took place during the LC meetings and the influence that discussions had in the design of the experiments were analysed in order to study the potentialities and obstacles that student teachers address as well as the effect that collaboration had in the design process.

Research questions

Therefore, the research questions of the study are:

- What is the content and the nature of primary student teachers' conversation during the LC meetings concerning the design of science experiments with the use of ICT?
- How far the discussions in the LC influence the development of science experiments with the use of ICT?

METHOD

Implementation of the study

The study was carried out during an undergraduate science laboratory lesson and lasted 13 weeks. Participants were 12 fourth graded primary student teachers, divided in 6 groups of two student teachers, whilst teacher groups were separated in two sets of groups (3 groups in each set). The task assigned to the student teachers comprised the design and development of experiments with the use of dataloggers in three branches of science, i.e. either Mechanics/Waves/Optics for the first set of teacher groups (Figure 1a) or Electromagnetism/ Thermodynamics/Chemistry for the second set (Figure 1b).

Figure 1a: Science branches for set A

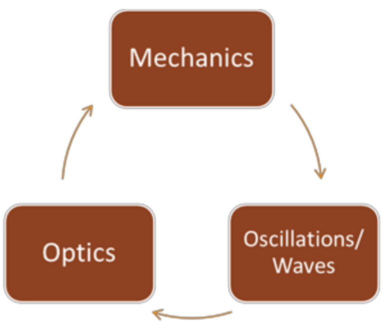
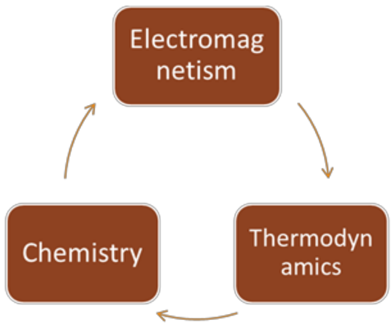
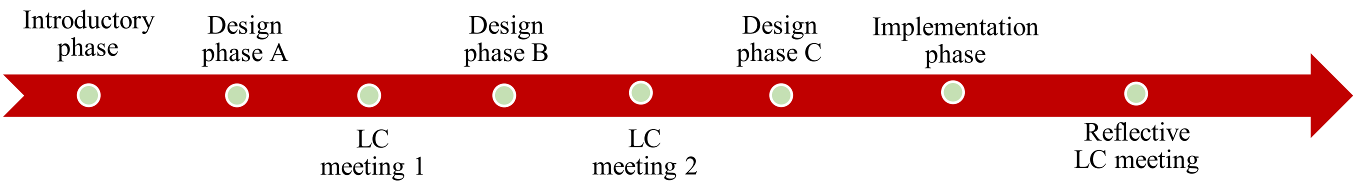


Figure 1b: Science branches for set B



The study, as shown in Figure 2, comprised: a) an introductory phase, where student teachers got familiar with the datalogging devices, b) three design phases. The first two design phases consisted of two weekly lab sessions and a LC meeting, in terms of reflection from the design and development of experiments at the previous lab sessions. At the end of each of the two phases, there was a cyclical switch of the science branches between the groups, which ended with a third design phase consisted of two weekly lab sessions c) an implementation phase, where student teachers were called upon to apply the developed material in teaching school students during organized visits to the science education lab of the university and d) a reflective LC meeting on the whole procedure.

Figure 2: Implementation of the study



Theoretical framework

Theoretical framework of the study is the Model of Educational Reconstruction for Teacher Education (ERTE) (Van Dijk & Kattmann 2007). According to this model and as it was adapted to the present study, there is a continuous and dynamic interaction between: a) the educational reconstruction made from the student teachers in order to design science learning environments with the use of data logging with: b) empirical studies on teacher training, TPACK, integration of technology and c) the overall design of teacher education contexts.

Data analysis

The data source of our study was: a) the transcripts from the discussions during the LC meetings, b) the experiments developed from the student teachers, c) the weekly lab reports and d) field notes during the lab sessions. Data analysis was carried out following two directions: analysis *of the conversation* and analysis *of peer interactions* in the LC meetings.

In order to analyse the conversation in the LC meetings, categories from Kittleson & Southerland's (2004) research were used and further modified for the needs of the present study. Thus, discussion was analyzed (y axis) as for its content to: a) Conceptual: referring to underlying science concepts, b) Laboratory: concerning the experimental procedure and the inquiry method used, c) Technology: conversation about implementing ICT and the use of ICT tools, d) Administrative: organizational talk e) Off-Task: conversation that doesn't address the task at hand, e.g. extracurricular talk. Discussion was also analyzed (x axis), as for its rhetorical nature to: a) Explanation: when a LC member or teacher group was transferring information in a rather traditional teacher-centered way e.g. lecturing the others, b) Negotiation: when multiple people participate in the conversation, both in consonant and dissonant ways. Discussion held in the LC meetings was semi-scaffolded from the administrator/expert and was based in two elements: the teaching goals that the experiments address and the use of ICT in the experiments. The analysis unit used is the *thematic quotation (TQ)*. TQ was defined as an excerpt of the conversation, which includes adequately codable information, considering the above categories. Data from the LC meetings trancripts were analysed statistically with the use of non-parametric tests, since TQs were coded in categories and exported in binary mode. Furthermore, the transcripts from the LC meetings were also analysed with the use of qualitative content analysis (Mayring 2014) in order to triangulate data from the statistical analysis and to provide more deep insights about the teachers' views and obstacles about the design of experiments with the use of ICT.

In order to analyze the peer interactions about the design of their experiments, network analysis was used (Borgatti et al. 2018). The analysis unit used is the *Design Influence (DI)*. DI was defined as any idea or comment expressed from a LC member, regarding the design of an experiment, which was implemented by a peer teacher group in subsequent design phases. In our study, each DI was represented with an arrow starting from the sender –the one who expressed the idea/comment and ending to the receiver –the teacher group which implemented the idea in the design process of experiments. Several network metrics were used for the analysis, such as: a) degree i.e. the sum of DIs, b) density –the sum of DIs divided to the theoretical maximum DIs, c) centralization which is related to whether the network is dominated by one person or not and d) homophily, the extent to which the nodes interact more between a specific sub-group (the set of groups that share the same science branches in our study) in relation to the total interactions. Respective sociograms in each phase were created to represent the network activity.

RESULTS

Conversation in the LC

Considering the nature of the conversation, it seems that student teachers' discussion was based on negotiation much more than explanation of concepts. This tendency became even more evident in the second LC meeting (p<0,001), as shown in Figures 4&5 and in Table 1. As for the content of the discussion, we can see in Figure 3 that student teachers dedicated adequate time in all three domains, even though Lab domain discussion prevails (p<0.001). Interesting is also the fact that the discussion about ICT showed a reduction from LC1 to LC 2 (p=0,001), which, according to the qualitative analysis of the transcripts, is related to the initial difficulties concerning the use of ICT that student teachers addressed at the first phase, where they seem to have discussed more about ICT comparing to the second phase.

Figure 3: Discussion in LC1,2 – Summary

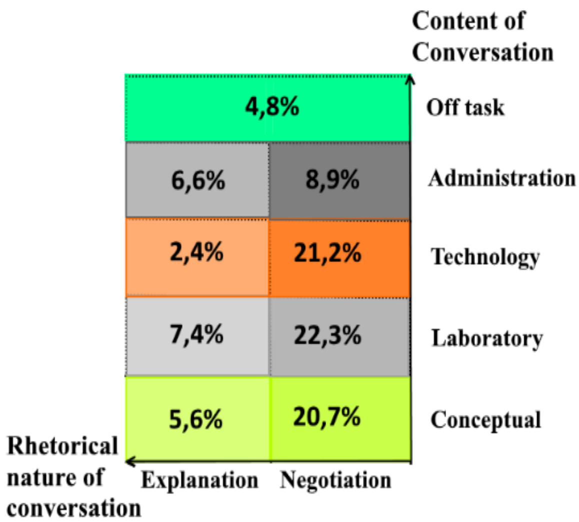


Table 1: TQs in LC1 & LC2

Content of conversation	LC2	LC2	Sig.

Conceptual	1702	1482	p=0,644
Laboratory	1867	1715	p=0,160
Technology	1594	1263	p=0,001
Administration	967	908	p=0,149
Off Task	284	295	p=0,045
Rhetorical Nature of conversation	**LC1**	**LC2**	
Explanation	1551	1114	p<0,001
Negotiation	4581	4254	p<0,001

Figure 4: Discussion in LC1

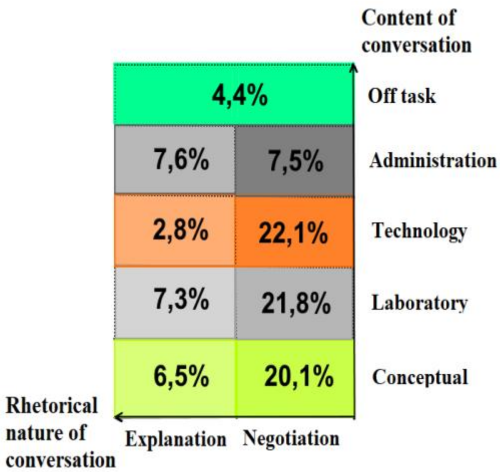
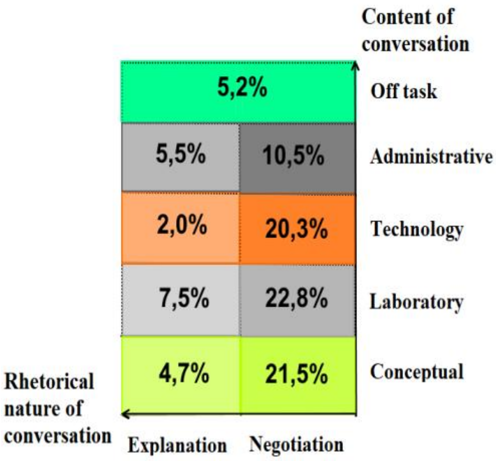


Figure 5: Discussion in LC2



Investigating the participation of student teachers in discussions about the experiments of their peers in relation to discussions about their own experiments, encouraging is the fact that 5 student teachers showed significant increase ($p<0,01$) from LC1 to LC2, whilst only 2 showed significant decrease ($p<0,01$), as shown in Table 2. That means that student teachers showed a tendency to engage more in discussions concerning peers, which is deemed to be an indicator of collaboration between them.

Table 2: Participation of teachers in discussions about the experiment of their peers

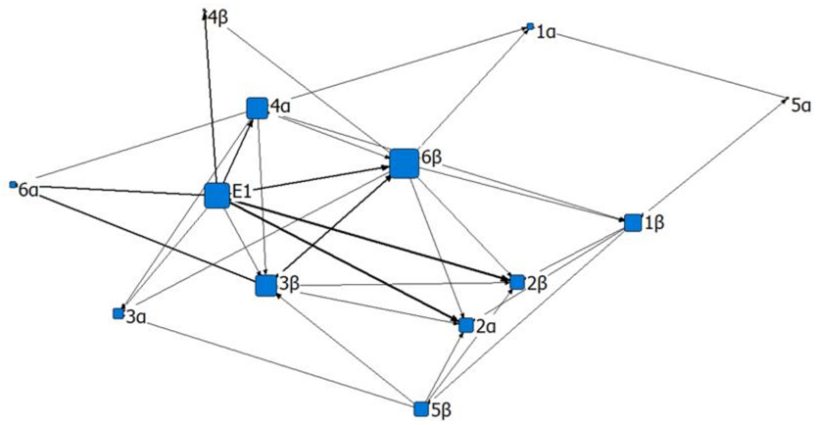
Teacher	**LC1** %TQs to peer groups	**LC2** %TQs to peer groups	Sig.
1a	21,1%	33,9%	p=0,008

1b	24,2%	45,6%	p<0,001
2a	48,3%	44,5%	p=0,368
2b	27,7%	50,0%	p<0.001
3a	56,6%	27,0%	p<0,001
3b	18,2%	23,6%	p=0.096
4a	63,6%	74,5%	p<0.001
4b	35,7%	47,9%	p=0.004
5a	29,0%	22,1%	p=0,109
5b	60,4%	46,4%	p<0.001
6a	23,4%	24,8%	p=0,778
6b	50,5%	51,8%	p=0,773

Peer Interactions

As far as the influence of the discussions in the development of experiments is concerned, it seems that student teachers evaluated peer discussion as quite an auxiliary factor in the design procedure, as they adopted ideas and drew information from the conversations with peers to a significant extent (n=28 DIs in respective total 60 experiments in phases B & C, as shown in Figure 6). Furthermore, a respective tendency to increase this influence from their peers from design phase B to design phase C was also noted (n=11 DIs implemented in phase B to respective n=17 DIs in phase C). On the other hand, the network of DIs could be characterised moderately dense and highly centralized, which means that student teachers made significant use of the guidance of the expert. Moreover, need for support from the expert was needed more in latter phases, since centralization increased in LC2, which can be related to the increased difficulty that student teachers address in designing new experiments in latter phases, according to the qualitative analysis of the discussions.

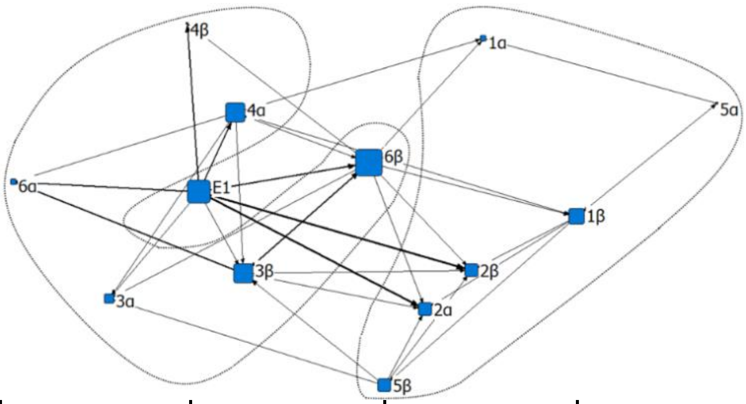
Figure 6: Total DIs in both LC meetings & whole network metrics



	LC1,2	LC1	LC2
Degree (DIs)	28	11	17
Density	0,359	0,141	0,218
Average Degree	4,308	1,692	2,615
Centralization(out)	0,472	0,403	0,542
Centralization(in)	0,201	0,132	0,181

Regarding the DIs between peers (expert excluded), we can calculate the homophily for the two set of teacher groups. As seen in Figure 7, teacher groups in each set interacted more with peers that shared the same science branches. This result can be interpreted in relation to the increased TPACK that these peers potentially developed in these specific science content areas and by using the specific data logging tools, so that they could influence peers in the same set of teacher groups, respectively.

Figure 7: Homophily between the two set of teacher groups



	Set of teacher groups A	Set of teacher groups B
Set of teacher groups A	8	4
Set of teacher groups B	8	14
Homophily:	-0,294	

DISCUSSION

Considering the analysis of the discussion and the analysis of the peer interactions, we can conclude that student teachers interacted collaboratively in a continuously growing manner: a) in the discussion at the LC meetings, by participating in negotiation of concepts and cognitive conflicts, b) in engaging in conversations concerning their peers and c) in the design process of experiments, by been influenced from their peers. Furthermore, the need for assistance from the expert was also found critical in the design process, as well as in managing the on-task discussion through a semi-scaffolded way. Moreover, interactions between peers were enhanced in cases where teacher groups shared same goals e.g. same science content and same data logging tools. Empirical data of this study seem to advocate that collaboration and on-task participatory discussions seem to be helpful for student teachers in order to integrate technology in science education laboratories.

REFERENCES

Barton, R. (2005). Supporting teachers in making innovative changes in the use of computer-aided practical work to support concept development in physics education. *International Journal of Science Education*, 27(3), 345-365.

Bell, R. L., Maeng, J. L., & Binns, I. C. (2013). Learning in context: Technology integration in a teacher preparation program informed by situated learning theory. *Journal of Research in Science Teaching*, 50(3), 348-379.

Bennett, J., Hogarth, S., Lubben, F., Campbell, B., & Robinson, A. (2010). Talking science: The research evidence on the use of small group discussions in science teaching. *International Journal of Science Education*, *32*(1), 69-95.

Borgatti, S. P., Everett, M. G., & Johnson, J. C. (2018). *Analyzing social networks*. Sage.

Couso, D. (2016). Participatory Approaches to Curriculum Design From a Design Research Perspective. In *Iterative Design of Teaching-Learning Sequences* (pp. 47-71). Springer, Dordrecht.

Elster, D. (2010). Learning Communities in Teacher Education: The impact of e-competence. *International Journal of Science Education*, *32*(16), 2185-2216.

Ertmer, P. A., & Ottenbreit-Leftwich, A. (2013). Removing obstacles to the pedagogical changes required by Jonassen's vision of authentic technology-enabled learning. *Computers & Education*, *64*, 175-182.

Jones, M. G., Gardner, G. E., Robertson, L., & Robert, S. (2013). Science Professional Learning Communities: Beyond a singular view of teacher professional development. *International journal of science education*, *35*(10), 1756-1774.

Juuti, K., Lavonen, J., & Meisalo, V. (2016). Pragmatic Design-based research–Designing as a shared activity of teachers and researches. In *Iterative design of teaching-learning sequences* (pp. 35-46). Springer, Dordrecht.

Iliaki, G., Velentzas, A., Michailidi, E., & Stavrou, D. (2019). Exploring the music: a teaching-learning sequence about sound in authentic settings. *Research in Science & Technological Education*, *37*(2), 218-238.

Kafyulilo, A. C., Fisser, P., & Voogt, J. (2015). Supporting teachers learning through the collaborative design of technology-enhanced science lessons. *Journal of Science Teacher Education*, *26*(8), 673-694.

Kervinen, A., Uitto, A., Kaasinen, A., Portaankorva-Koivisto, P., Juuti, K., & Kesler, M. (2016). Developing a collaborative model in teacher education–An overview of a teacher professional development project. *LUMAT: International Journal on Math, Science and Technology Education*, *4*(2), 67-86.

Kittleson, J. M., & Southerland, S. A. (2004). The role of discourse in group knowledge construction: A case study of engineering students. *Journal of Research in Science Teaching*, *41*(3), 267-293.

Lavonen, J., Juuti, K., & Meisalo, V. (2003). Designing a user-friendly microcomputer-based laboratory package through the factor analysis of teacher evaluations. *Int. J. Sci. Educ.*, *25*(12), 1471-1487.

Mayring, P. (2014). Qualitative content analysis: theoretical foundation, basic procedures and software solution.

Mishra, P., & Koehler, M. J. (2006). Technological pedagogical content knowledge: A framework for teacher knowledge. *Teachers college record*, *108*(6), 1017.

Nicolaou, C. T., Nicolaidou, I., Zacharia, Z., & Constantinou, C. P. (2007). Enhancing fourth graders' ability to interpret graphical representations through the use of microcomputer-based labs implemented within an inquiry-based activity sequence. *Journal of computers in Mathematics and Science Teaching*, *26*(1), 75-99.

Odom, A. L., Marszalek, J. M., Stoddard, E. R., & Wrobel, J. M. (2011). Computers and traditional teaching practices: Factors influencing middle level students' science achievement and attitudes about science. *International Journal of Science Education*, *33*(17), 2351-2374.

Prestridge, S. (2017). Examining the shaping of teachers' pedagogical orientation for the use of technology. *Technology, Pedagogy and Education*, 1-15.

Sokoloff, D. R., Laws, P. W., & Thornton, R. K. (2007). RealTime Physics: active learning labs transforming the introductory laboratory. *European Journal of Physics*, *28*(3), S83.Songer, N. B. (1998). Can technology bring students closer to science. *The international handbook of science education*, *1*, 333-347.

Van Dijk, E. M., & Kattmann, U. (2007). A research model for the study of science teachers' PCK and improving teacher education. *Teaching and Teacher Education*, *23*(6), 885-897.

Waight, N., & Abd-El-Khalick, F. (2018). Technology, Culture, and Values: Implications for Enactment of Technological Tools in Precollege Science Classrooms. In *Cognition, Metacognition, and Culture in STEM Education* (pp. 139-165). Springer, Cham.

Waight, N., & Abd-El-Khalick, F. (2007). The impact of technology on the enactment of "inquiry" in a technology enthusiast's sixth grade science classroom. *Journal of Research in Science Teaching*, *44*(1), 154-182.

PROFESSIONALISATION OF PROSPECTIVE TEACHERS FOR DIGITISATION IN CHEMISTRY EDUCATION – DEVELOPMENT AND EVALUATION OF A UNIVERSITY SEMINAR

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With the publication of "The Digital Competence Framework for Citizens" and "The European Framework for the Digital Competence of Educators", the development of digital competences and thus learning with and about digital media at school has greatly increased in significance in the past few years (Redecker, 2017; Vuorikari et al., 2016). While education policy makers have recognised the great potential of innovative information and communication technologies regarding teaching and learning, schools are facing the challenge of implementing the frame of reference and adapting to the increasingly digitalised society (Drossel & Eickelmann, 2017). Since the majority of teachers does not feel well enough prepared to meet the requirements, it is of great importance to professionalise both teaching staff and prospective teachers for the use of digital media in the classroom (Cetin-Dindar et al., 2018; Drossel & Eickelmann, 2017). Consequently, this project aims to develop and evaluate a university seminar that prepares prospective chemistry teachers for implementing digital tools in teaching and learning effectively as well as appropriately.

The study is an intervention study that tests the interventions' effects by using a quasi-experimental design with repeated measures. Based on the adapted evaluation steps by Kirkpatrick, this seminar is evaluated on the four levels attractiveness, cognitive changes, practical implementation, *and* effects on the learners *(Kirkpatrick, 1979). The first results of the pilot study show that the seminar participants assess the seminar as very attractive. Moreover, the seminar participation leads to a significant positive change regarding the prospective teachers' attitudes towards the implementation of digital tools in chemistry lessons, their TPACK self-efficacy beliefs and TPACK competence regarding lesson planning. Additionally, the learners at school assess the digitally supported lessons executed by the participants as positive.*

Keywords: Technology in Education and Training, Teacher Professional Development, ICT Enhanced Teaching and Learning

THEORETICAL BACKGROUND AND MOTIVATION

Since the publication of the strategic concept "The Digital Competence Framework for Citizens" and its identification of key components of digital competence, schools are urged to adapt to the digitalised society and prepare their students for the challenges in a digital world (Gerick et al., 2017; Vuorikari et al., 2016). Accordingly, teaching professions are facing the great challenge of transforming their teaching and learning methods in order to introduce digital learning as a habitual teaching practice on a pan-European basis (Drossel & Eickelmann, 2017). In order to support educators in developing digital competences on professional level, "The

European Framework for the Digital Competence of Educators – DigCompEdu" serves as a reference frame. However, most teachers lack the necessary skills to effectively use digital tools to improve student performance and therefore also assess their own digital competencies as very limited (Chai et al., 2013; Drossel & Eickelmann, 2017). Yet, the successful implementation of digital tools highly depends on the teachers' self-efficacy in using digital tools and their attitude towards the general implementation of technology in the classroom (Eickelmann & Vennemann, 2017; Mishra & Koehler, 2006; Sánchez-Prieto et al., 2016). Consequently, it becomes evident that there is an urgent need for action regarding the professionalisation of teaching staff and prospective teachers (Chai et al., 2013; Drossel & Eickelmann, 2017; Gudmundsdottir & Hatlevik, 2018). In this context, it is not only important to strengthen teachers' digital skills, but also to promote digital self-efficacy perception and to positively influence teachers' attitudes towards technologies in continuing education and training programs (Bastian & Riplinger, 2016; Cetin-Dindar et al., 2018; Instefjord & Munthe, 2017).

In response to these challenges, we developed a university seminar to professionalise prospective chemistry teachers in the effective and appropriate use of digital tools in teaching and learning. The central theoretical framework in this research to investigate the seminar participants' development is the technological pedagogical content knowledge (TPACK), which is a model to describe the knowledge required by teachers to integrate technology in teaching and learning (Mishra & Koehler, 2006; Schmidt et al., 2009). The TPACK model originates from the pedagogical content knowledge (PCK) according to Shulman (1986), which describes the central domains of professional knowledge of teachers. It consists of pedagogical knowledge (PK), content knowledge (CK) and their intersection, pedagogical content knowledge (PCK). The TPACK model is an extension of this original model, which added the domain of technology knowledge. At the same time, further knowledge domains emerge. These are the technological pedagogical knowledge (TPK), the technological content knowledge (TCK) and ultimately, the technological pedagogical content knowledge (TPACK), which represents the intersection of all knowledge domains. Moreover, these specific knowledge domains are additionally bound to their respective contexts or situational conditions such as the technical equipment, the interior design or the school concept (Mishra & Koehler, 2006). In this project, the focus is on the technology-related areas of knowledge.

THE SEMINAR

Basis of this project is the seminar entitled "Teaching Methods and Multimedia for Chemistry Education". We developed the seminar with the aim of professionalising students of chemistry education for the competent use of digital tools in chemistry lessons. Within the seminar sessions, the students therefore deal with different aspects of implementing digital tools in chemistry lessons at both theoretical and especially practical level. In the following, the revised seminar concept of the main study are described.

The selected contents of the seminar sessions derived from various examples of best practice and research results on the use of digital tools from a detailed literature review. This included the identification of the necessary professional knowledge of teachers for the use of technologies as well as research on the concrete practical implementation of digital learning in both general and chemistry-specific school teaching. Proceeding from this literature research, we designed our seminar sessions for a pilot study. During the first and last seminar sessions, we collect the required data for our study. Another seminar session serves as a buffer. Since we only slightly optimised and modified this piloted seminar concept, Table 5 depicts the adapted contents and their associated thematic blocks of the main study (cf. Zimmermann & Melle, 2019). However, the evaluation of the seminar of the main study is still pending.

In these seminars sessions, the students first receive new content and information via PowerPoint presentations, followed by a practice-oriented working phase. The seminar's strong focus on the practical implementation of the covered topics aims at establishing a close link between the topics dealt with and actual teaching practices (Eickelmann & Vennemann, 2017). Hence, the students try out new programs and apps, or independently develop a wide variety of teaching examples. Each individual student has access to an iPad for this purpose. The students work very independently in order to be able to test all digital tools as effectively as possible.

Table 5 Seminar Contents and Thematic Blocks.

Session	Content	Thematic block
1.	Introduction and Pre Tests	
2.	Legal and Educational Framework	I. Basics of teaching with digital tools
3.	Organisation of Teaching in the Digital Classroom	
4.	Potentials of Digital Tools in Dealing with Diversity	
5.	Multimedia Teaching Materials I	II. Practical implementation of teaching chemistry with digital tools
6.	Multimedia Teaching Materials II	
7.	Multimedia Teaching Materials III	
8.	Learning with YouTube and Explanatory Videos	
9.	Chemical Experiments with Digital Tools I	III. Digital Technologies and Scientific Inquiries
10.	Chemical Experiments with Digital Tools II	
11.	Gamification and Game-based Learning	IV. Methodological basics for Implementing Digital Technologies
12.	Assessment, Diagnostics and Feedback	
13.	Pool of Ideas and Lesson Planning	
14.	Post Tests	

Session 2: Legal and Educational Framework

The seminar starts with defining and classifying the broad term ‘media’ as well as emphasising the general importance of media as mediators in the classroom. In this context, the presentation also points to the particularity of media in teaching chemistry which intends to show that the reflected selection of teaching media depends on the learning objective (Bernholt et al., 2018). Subsequently, we discuss the topic of media socialisation and digitalisation of society with regard to the technical equipment in German families and the possession of devices by young people, leading to the conclusion that it can be assumed that learners at school are fundamentally familiar with digital media (MPFS, 2018). The second part of the presentation focuses on what it means for students at school to be digitally competent (KMK, 2017; Medienberatung NRW, 2018; Vuorikari et al., 2016), followed by the necessary skills of educators for promoting digital competences (Mishra & Koehler, 2006; Redecker, 2017). This seminar session concludes with a description of the current educational, infrastructural, and personnel conditions for digital learning as well as the formulation of prerequisites for the successful implementation of digital technologies in teaching and learning.

Session 3: Organisation of Teaching in the Digital Classroom

The beginning of this session focuses the potential of different hardware available in schools. After presenting different possibilities of classroom management in the digital classroom, we list various learning scenarios and their terminology. These include the following: E-learning, mobile learning, massive open online course, game-based learning, blended learning, station rotation model and flipped classroom. Directly after this information input a station rotation follows with three different stations and tasks. At the first station, the students try out various functions of an interactive whiteboard app by connecting the iPad to the Apple TV. Thus, they get to know a way in which tablets can serve as a substitute for interactive whiteboards. Station two deals with digitising analogue teaching materials and editing it with the Apple Pencil. At the third station, the students create a mind map.

Session 4: Potentials of Digital Tools in Dealing with Diversity

Since innovative information and communication technologies (ICT) promise great potential in terms of education and participation, especially in the age of inclusion, we point out the potential of the advancing digitisation for teaching in heterogeneous learning groups in this seminar session. The potential of ICT especially lies in their adaption to users' needs since the information ICT provide can be adapted flexibly to the individual users' processing requirement (Meyer et al., 2014). Additionally, we refer to the educational concept Universal Design for Learning (UDL) (CAST, 2018), which provides a framework and specific guidelines for planning lessons with universal accessibility and thus enables joint teaching in heterogeneous learning groups. Furthermore, technologies are seen to be indispensable for the implementation of the UDL guidelines because they contribute meaningfully to increasing individual adaptability (Edyburn, 2010; Rose et al., 2007). This is followed by demonstrating different possibilities to differentiate with the aid of digital tools. In the subsequent working phase, the seminar participants discuss and analyse various digitally supported possibilities for individually supported teaching and learning in reference to specific teaching unit examples.

Session 5 to 7: Multimedia Teaching Materials

The topic "Design of multimedia teaching materials" covers three seminar sessions and is designed in the form of a workshop. In the first of these three sessions, the students receive a short introductory lecture on multimedia learning, especially focusing the "Cognitive Theory of Multimedia Learning" (Mayer, 2014). The aim of this lecture is to show that digital media have the potential of increasing the accessibility of the learning content and support the storage of information in our long-term memory by the combined use of different cognitive structures, for example through the dynamic combination of different visual forms of presentation and auditory information. Since the human information processing system is limited, especially when learning with multimedia teaching materials, we also discuss the "Cognitive Load Theory" (Sweller, 2005) and its implications for the design of multimedia teaching and learning material to avoid overloading the working memory of the learners (Clark & Mayer, 2011; Hartley, 2014; Mayer, 2014). Afterwards, the workshop starts in which the students work independently and at their own pace at seven different stations. Thematic focuses are the creation of Books, stop-motion videos, augmented reality, digital representations of chemical compounds, animations with PowerPoint, staged learning aids and differentiated teaching materials with QR codes.

Session 8: Learning with YouTube and Explanatory Videos

Since explanatory videos are among the most popular digital learning tools for both young people and adults and are considered effective and motivating, we devote an entire seminar session to this topic (Kulgemeyer, 2018). The information input mainly focuses the categorisation and the application of explanatory videos in informal and formal e-learning scenarios, meaning that explanatory videos are not only used to present information within the classroom but are also frequently used by students without pedagogical supervision (Buzzetto-More, 2014; Szeto & Cheng, 2014). This leads to the issue that likes or views are the most decisive selection criterion for students when choosing a specific video, however, the popularity of a video is not necessarily a predictor of correct content (Peters & Kulgemeyer, 2016). Finally, we present various possibilities of integrating explanatory videos in the classroom (e.g. flipped classroom). During the following working phase, the students create a storyboard and then their own explanatory video on a topic of their choice. For this purpose, the students receive an additional information text as well as a selection of possible apps or programs with which they can create different types of explanatory videos.

Session 9 and 10: Chemical Experiments with Digital Tools

In the first seminar session on "Chemical Experiments with Digital Tools", the students learn about different possibilities to support the introduction and instruction of experiments using technologies. For this, the students create a trailer, a short and interesting video for arousing interest in the learning content. In addition to further possibilities and teaching examples, we discuss and try out the introduction of a new topic via a self-developed comic strip. At the end of the first of these two seminar sessions, we present potential benefits of digital tools for the instruction of experiments. In the second session, the focus lies on the digitally supported conduction and documentation of experiments. Possibilities for conducting experiments are for example virtual screen experiments or virtual reality experiments. Subsequently, we demonstrate the potential of digital measurements via sensors and the digital display and analysis of the measured values. Afterwards, different possibilities of video documentation and their integration into the classroom are considered. In this context, we address the documentation of experiments in slow motion and in a time-lapse. Among other benefits, these are either suitable for decelerating chemical processes and thus for capturing phenomena that pass too quickly for the human eye or for accelerating chemical processes that are usually only observed in the initial and final state of a reaction in the classroom (Vollmer & Möllmann, 2018). In the subsequent work phase, the students work on three different stations: At station 1, the students carry out a virtual screen experiment, at station 2, they record a slow-motion experiment and at station 3, the students work on a multimedia experiment protocol with the aid of which they carry out an experiment and document it in a time-lapse.

Session 11: Gamification and Game-based Learning

This seminar session is methodically designed according to the flipped classroom model. Hence, the seminar participants receive a preparatory learning video which deals with various theories and approaches to gamification and game-based learning. According to the methodology of the flipped classroom, the seminar participants deepen the contents of the preparatory video during the seminar. For this purpose, they discuss the potential of game mechanics used in given examples. Moreover, they create playful interactive exercises themselves on different learning platforms.

Session 12: Assessment, Diagnostics and Feedback

This seminar session focuses various theories on assessment, diagnostics as well as feedback and concludes that diagnostics and feedback should be interlinked processes. Additionally, the strong influence of feedback on learning performance is highlighted (Hattie & Timperley, 2007), while also emphasising that the timing of feedback is crucial as its immediacy has a particularly strong impact on the effects of feedback (Hattie, 2008). Thus, based on the advantages of automated correction, the great potential of digitally supported feedback in the classroom lies in the direct individual feedback of audience response systems (ARS). The lecture concludes with the presentation of possibilities of integrating ARS in the classroom. In the further course of the seminar session, the students create ARS themselves and try them out in the seminar group, while displaying the individual results in real time via the projector.

Session 13: Pool of Ideas and Lesson Planning

The aim of this final seminar session is to provide the seminar participants the opportunity to connect and structure the contents learned in the seminar. In this context, the idea is not to design a whole lesson, but to generate specific ideas for the design of individual teaching phases within a lesson. Hence, we ask the students to assign the range of programs, apps and methods they learned in the seminar to their respective teaching phases and to add a short note on their functionality. Finally, we discuss the opportunities and limitations of digital tools in teaching and learning at German schools.

REASEARCH DESIGN AND METHODS

The developed seminar "Teaching Methods and Media for Digitisation in Chemistry Education" is an obligatory course for all chemistry teacher students in the master's programme. Since the seminar participants attend this seminar directly before their school internship semester, we can also evaluate the practical implementation of the contents learned. To measure the intervention's success, we use various test and evaluation instruments (cf. Zimmermann & Melle, 2019). With regard to the evaluation steps by Kirkpatrick (1979), we evaluate the seminar on the four levels (1) attractiveness, (2 & 3) cognitive changes, (4) practical implementation and (5) effects on the learners, focusing on the following main research questions:

(1) Do the future teachers assess the seminar as attractive?

(2) Does the seminar have an impact on the prospective teachers' …

a: … attitudes towards the implementation of digital tools in chemistry lessons

b: … TPACK self-efficacy perceptions?

(3) Do the future teachers improve their skills in integrating digital tools in their lesson plans?

(4) Are the future teachers able to implement the seminar contents during their internship semester adequately?

(5) Which effects do the seminar participants' lessons have on the students at school?

The study is an intervention study with which we measure the seminar participants' development by means of a repeated measures design. In the first seminar session, we assess the seminar participants' attitude towards teaching with digital tools (5-point Likert scale, 34 items, α = .968, according to the technology acceptance model by Davis et al., 1989) and their TPACK self-efficacy (5-point Likert scale, 31 items, α = .968; focused TPACK domains: TK, TCK, TPK, TPACK; cf. Schmidt et al., 2009). Moreover, we determine their skills in designing lesson plans for digital learning. For this purpose, the students have the task of planning a lesson in which they should implement digital tools in the best possible way. Afterwards, we conduct an interview with the students in which they have to present, explain and justify their lesson plans in detail. To evaluate these results, we developed a coding manual to analyse the TPACK competences, focusing on the changes in the domains of TK, TCK and TPK (5-point Likert scale, $ICC_{unjust.} = .961$*).*

After these pre-tests, the intervention follows. During the intervention, we examine the quality of the seminar after each of four different thematic blocks (5-point Likert scale, 24 items, α = .850). In the last seminar session, we again measure the attitude and TPACK self-efficacy as well as the ability to design lesson plans for digital learning in order to compare the pre- and post-results. Additionally, the students assess the overall seminar quality by means of an attractiveness test with open questions. Within the following internship semester, the practical implementation of the seminar contents is examined (κ between .665 and 1.000). Besides videotaping the implemented lessons, we determine the effects of the seminar participants' lessons on the learners at school with a questionnaire (5-point Likert scale, 10 items, α = .878; open task format). At the end of the internship semester, we measure the seminar participants' attitude and TPACK self-efficacy in dealing with digital tools a third time to assess the long-term effect of the seminar.

PRELIMINARY RESULTS

With regard to the evaluation step *attractiveness,* the first results of the pilot study show that the seminar participants assess the seminar as attractive ($M = 4.37$, $SD = 0.45$, $n = 7$, from 1 = negative to 5 = positive). Moreover, the students are also very positive about the lecturer ($M = 4.80$, $SD = 0.07$, from 1 = negative to 5 = positive) as well as the working phases and the methodological design of the seminar ($M = 4.54$, $SD = 0.20$, from 1 = negative to 5 = positive). Focusing the level of *cognitive changes,* the future teachers' attitudes ($M_{Pre} = 3.91$, $M_{Post} = 4.32$, from 1 = negative to 5 = positive, $p < .001$, $d = 2.60$, $n = 7$) and their TPACK self-efficacy beliefs ($M_{Pre} = 3.05$, $M_{Post} = 4.26$, from 1 = negative to 5 = positive, $p = .001$, $d = 2.09$, $n = 7$) increase significantly with a large effect size. Moreover, the participation in the seminar significantly improves the students' TK ($M_{Pre} = 2.63$, $M_{Post} = 4.33$, $p < .001$,

$d = 4.16$, $n = 7$), TPK ($M_{Pre} = 2.53$, $M_{Post} = 4.35$, $p =< .001$, $d = 3.68$, $n = 7$) and TCK ($M_{Pre} = 2.77$, $M_{Post} = 4.41$, $p < .001$, $d = 3.58$, $n = 7$) with regard to lesson planning on a scale from 1 = negative to 5 = positive.

Regarding the assessment of the *practical implementation* at school, first impressions of the sample of the pilot study show that the knowledge domains TK and TCK of the seminar participants are already relatively advanced, while the knowledge domain TPK indicates further need for improvement. Lastly, the analysis of the evaluation step *effects on learners* shows that the learners were attentive ($M_{Attentiveness} = 4.19$, $SD = 0.70$, from 1 = negative to 5 = positive, $n = 88$) and experienced the digital learning materials used by the students as motivating ($M_{Motivation} = 4.37$, $SD = 7.69$, from 1 = negative to 5 = positive, $n = 88$).

DISCUSSION AND OUTLOOK

Overall, these first results presented are only preliminary as they only include data collected from the pilot study and thus, only comprise a small sample of seven students. Nevertheless, the first results of the pilot study suggest that the seminar is effective in improving pre-service chemistry teachers' TPACK self-efficacy perception as well as their TPACK skills regarding lesson planning and practical implementation. Moreover, we were also able to improve the seminar participants' attitude towards the implementation of digital tools in chemistry lessons and to detect positive outcomes concerning the effects on the learners at school.

In the course of the further investigation, we are currently examining the yet unevaluated data such as the prior experience and the long-term effect of the seminar on the participants TPACK self-efficacy perception and attitude.

After we had revised the seminar sessions and test instruments, we began our main study in November 2018 in which we are testing the seminar with a targeted sample of $N \approx 30$. Depending on the number of seminar participants, we will run the seminar as shown in Table 1 further times. Moreover, we will compare the results to a control group at another university in order to exclude effects caused by test repetition or the natural development of the students.

ACKNOWLEDGMENT

We would like to thank the participating future chemistry teachers and the cooperating schools of the seminar participants' internship semesters.

References

Bastian, J., & Riplinger, T. (2016). Tablets for a redefinition of learning? An analysis of video observations to determine the integration of tablets in the classroom. *Proceedings of EdMedia 2016-World Conference on Educational Media and Technology*, 143–149. https://www.learntechlib.org/primary/p/172944/

Bernholt, S., Broman, K., Siebert, S., & Parchmann, I. (2018). Digitising Teaching and Learning – Additional Perspectives for Chemistry Education. *Israel Journal of Chemistry*, *223*, 1.

Buzzetto-More, N. A. (2014). An Examination of Undergraduate Student's Perceptions and Predilections of the Use of YouTube in the Teaching and Learning Process. *Interdisciplinary Journal of e-Skills and Lifelong Learning*, *10*, 17–32.

CAST. (2018). *Universal design for learning guidelines version 2.2 [graphic organizer].* http://udlguidelines.cast.org/more/downloads

Cetin-Dindar, A., Boz, Y., Yildiran Sonmez, D., & Demirci Celep, N. (2018). Development of pre-service chemistry teachers' technological pedagogical content knowledge. *Chemistry Education Research and Practice*, *19* (1), 167–183.

Chai, C. S., Koh, J. H. L., & Tsai, C.-C. (2013). A review of technological pedagogical content knowledge. *Journal of Educational Technology & Society*, *2* (16), 31–51.

Clark, R. C., & Mayer, R. E. (2011). *e-Learning and the Science of Instruction*. Pfeiffer.

Davis, F. D., Bagozzi, R. P., & Warshaw, P. R. (1989). User Acceptance of Computer Technology: A Comparison of Two Theoretical Models. *Management Science*, *35* (8), 982–1003.

Drossel, K., & Eickelmann, B. (2017). Teachers' participation in professional development concerning the implementation of new technologies in class: a latent class analysis of teachers and the relationship with the use of computers, ICT self-efficacy and emphasis on teaching ICT skills. *Large-scale Assessments in Education*, *5* (1), 279.

Edyburn, D. L. (2010). Would You Recognize Universal Design for Learning if You Saw it? Ten Propositions for New Directions for the Second Decade of UDL. *Learning Disability Quarterly*, *33* (1), 33–41.

Eickelmann, B., & Vennemann, M. (2017). Teachers‘ attitudes and beliefs regarding ICT in teaching and learning in European countries. *European Educational Research Journal*, *16* (6), 733–761.

Gerick, J., Eickelmann, B., & Bos, W. (2017). School-level predictors for the use of ICT in schools and students' CIL in international comparison. *Large-scale Assessments in Education*, *5* (1), 3.

Gudmundsdottir, G. B., & Hatlevik, O. E. (2018). Newly qualified teachers' professional digital competence: implications for teacher education. *European Journal of Teacher Education*, *41* (2), 214–231.

Hartley, J. (2014). Designing instructional and informational text. In J. M. Spector (Ed.), *Handbook of research on educational communications and technology* (4th ed., pp. 917–947). Springer.

Hattie, J. (2008). Visible learning: A synthesis of over 800 meta-analyses relating to achievement. *International Review of Education.* Advance online publication.

Hattie, J., & Timperley, H. (2007). The Power of Feedback. *Review of Educational Research*, *77* (1), 81–112.

Instefjord, E. J., & Munthe, E. (2017). Educating digitally competent teachers: A study of integration of professional digital competence in teacher education. *Teaching and Teacher Education*, *67*, 37–45.

Kirkpatrick, D. L. (1979). Techniques for evaluating training programs. *Training and Development Journal*, *33* (6), 78–92.

KMK. (2017). *The standing Conference's "Education in the Digital World" strategy Summary*. https://www.kmk.org

Kulgemeyer, C. (2018). A Framework of Effective Science Explanation Videos Informed by Criteria for Instructional Explanations. *Research in Science Education*, *26* (1), 435–456.

Mayer, R. E. (Ed.). (2014). *Cambridge handbooks in psychology*. *The Cambridge handbook of multimedia learning* (Second edition). Cambridge University Press.

Medienberatung NRW. (2018). *Medienkompetenzrahmen NRW*. https://medienkompetenzrahmen.nrw.de

Meyer, A., Rose, D. H., & Gordon, D. (2014). *Universal design for learning: Theory and practice*. CAST Professional Publishing. http://udltheorypractice.cast.org

Mishra, P., & Koehler, M. J. (2006). Technological Pedagogical Content Knowledge: A Framework for Teacher Knowledge. *Teachers College Record*, *108* (6), 1017–1054.

MPFS. (2018). *JIM 2018 - Jugend, Information, (Multi-)Media. Basisuntersuchung zum Medienumgang 12- bis 19-Jähriger*. https://www.mpfs.de/

Peters, C. H., & Kulgemeyer, C. (2016). Exploring the explaining quality of physics online explanatory videos. *European Journal of Physics Education*, *37* (6).

Redecker, C. (2017). *EUR, Scientific and technical research series: Vol. 28775*. *European framework for the digital competence of educators: DigCompEdu* (Y. Punie, Ed.). Publications Office.

Rose, D. H., Hasselbring, T. S., Stahl, S., & Zabala, J. (2007). *Assistive Technology and Universal Design for Learning: Two Sides of the Same Coin*. https://pdfs.semanticscholar.org/75a2/2d319afce4e5323d0ed22abe27f2e913c841.pdf

Sánchez-Prieto, J. C., Olmos-Migueláñez, S., & García-Peñalvo, F. J. (2016). Informal tools in formal contexts: Development of a model to assess the acceptance of mobile technologies among teachers. *Computers in Human Behavior* (55A), 519–528.

Schmidt, D. A., Baran, E., Thompson, A. D., Mishra, P., Koehler, M. J., & Shin, T. S. (2009). Technological Pedagogical Content Knowledge (TPACK). *Journal of Research on Technology in Education*, *42* (2), 123–149.

Sweller, J. (2005). Implications of Cognitive Load Theory for Multimedia Learning. In R. Mayer (Ed.), *The Cambridge Handbook of Multimedia Learning* (pp. 19–30). Cambridge University Press.

Szeto, E., & Cheng, A. Y.-N. (2014). Exploring the Usage of ICT and YouTube for Teaching: A Study of Pre-service Teachers in Hong Kong. *The Asia-Pacific Education Researcher*, *23* (1), 53–59. y

Vollmer, M., & Möllmann, K.-P. (2018). Slow speed—fast motion: time-lapse recordings in physics education. *Physics Education*, *53* (3), 35019.

Vuorikari, R., Punie, Y., Carretero, S., & van den Brande, L. (2016). *DigComp 2.0: The digital competence framework for citizens*. *EUR, Scientific and technical research series: Vol. 27948*. Publications Office.

Zimmermann, F., & Melle, I. (2019). Designing a university seminar to professionalize prospective teachers for digitization in chemistry education. *Chemistry Teacher International*, 1–9.

AUTOMATIC NETWORK ANALYSIS OF PHYSICS TEACHER TALK

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Literature shows that the characteristics of the instructional content have a direct influence on students' learning. Those characteristics could be number of connections between the content structure elements, the number of important topic-related concepts and the occurrence of key concepts. This type of analysis takes enormous quantity of time, if it is done manually. Thus, our aim in this study is to make the lesson analysis automatic and to find what network measures correlate with students learning gain. We automatically studied lessons from 25 teachers and 328 students and compared the teachers' networks with students' learning gain (LG) through the analysis of teachers' concept networks. The network measures are the Number of nodes, Number of edges, Density, Diameter, Average clustering, Average degree and Average degree centrality. The results show that the measures Density, Diameter and Degree Centrality resulted to be significant for the LG. Density is related with LG in negative way: as more dense the graph is, less LG for the students. The results are coherent with previous results and open a new branch for automatic analysis of lessons.

Keywords: Classroom Discourse, Measurement, Diagnostic Tools.

INTRODUCTION

Since decades it is known that the characteristics of the instructional content have a direct influence on students' learning (Shavelson, 1972; Geeslin & Shavelson, 1975; Fischer, Labudde, Neumann, & Viiri, 2014). It has been found that the number of connections between the content structure elements is positively related to students' learning gains, the number of important topic-related concepts is significantly correlated with students' learning gains (Müller & Duit, 2004; Klieme, Pauli, & Reusser, 2009; Drollinger-Vetter, & Lipowsky, 2006).

In the QuIP project Helaakoski and Viiri (2014) coded the lesson videos manually, produced concept networks and calculated network measures. They found that the number of different physics concepts and connected concept pairs had correlations with students' learning gains.

Since manual coding is time consuming, our aim in this study is to make the lesson analysis automatic. Our research question (RQ) is:

RQ: What network measures correlate with students learning gain?

METHOD

Data Collection

Our data consists of 25 videotaped lessons from the QuIP project. The topic of the lessons was the introduction to the relation between electrical energy and power in ninth grade.

Participants. Each of the 25 videotaped lessons matches with one teacher and his/her students. In total, a sample of 328 students from 25 teachers from different schools of Finland are considered for the analysis. The average student age was 15.6 years.

Instruments. To measure the change of students' content knowledge in terms of quality, an instrument was developed by the researchers of QuIP project. The main topic of the test was the concepts of electrical energy and power. The test consisted of multiple-choice tasks, open-ended questions and calculations with a six-level complexity model. The process of the development of the instrument involved several steps: (1) selection, adaption and authoring of items, (2) expert review of items, (3) revision of items and (4) compilation of test booklets utilizing the final set of test items (see Geller, Neumann, Boone, and Fischer, 2014). The booklets for the Pre-test had 18 items and the booklets for the Post-test had 36 items. Each of the items was evaluated as correct (1 point) or incorrect (0 points). As general overview, the Pre-test had a mean of 7.9 points, whereas the Post-test has a mean of 15.67 points.

Procedure. Every teacher of the project performed a lesson with the same topic: introduction to the relation between electrical energy and power. There was no guidelines or materials given by the researchers to the teachers: they were supposed to teach the topic with their normal practice. On the other hand, the lesson was performed in between the Pre- and Post- test.

Data Analysis

Data analysis involved a process of different steps with several intermediate outputs. During this process a concept network was generated from each lesson recorded. Then, measures describing the concept networks were used to explain the students' learning gains. The main focus was to automatize as much as possible and reduce the manual work as shown in Caballero, Araya, Kronholm, Viiri, Mansikkaniemi, Lehesvuori, … & Kurimo (2017). Figure 1 gives a simple pipeline of the process.

For all the videotaped classes, an Automatic Speech Recognition (ASR) algorithm was used to automatically convert the teacher speech into text (class transcriptions). The ASR process was performed with the system developed by the Aalto University (Kronholm, Caballero, Araya, & Viiri, 2016).

Once the class transcriptions were done, a pre-process of stemming was performed in order to extract the root of the words. With the stemming we obtain the group of words that have the same root and therefore are related to the same concept. Text Data Mining (TDM) process was run to find keywords and their connections in a 10 seconds window time. In order to do so, a keyword list of 450 physics concepts was used as input. The keyword list was done manually by a physics teacher. If the teacher mentioned two concepts in a 10 seconds window time, then the two concepts were related each other. The edge has the direction of time, which means the first concept mentioned "goes" to the second one.

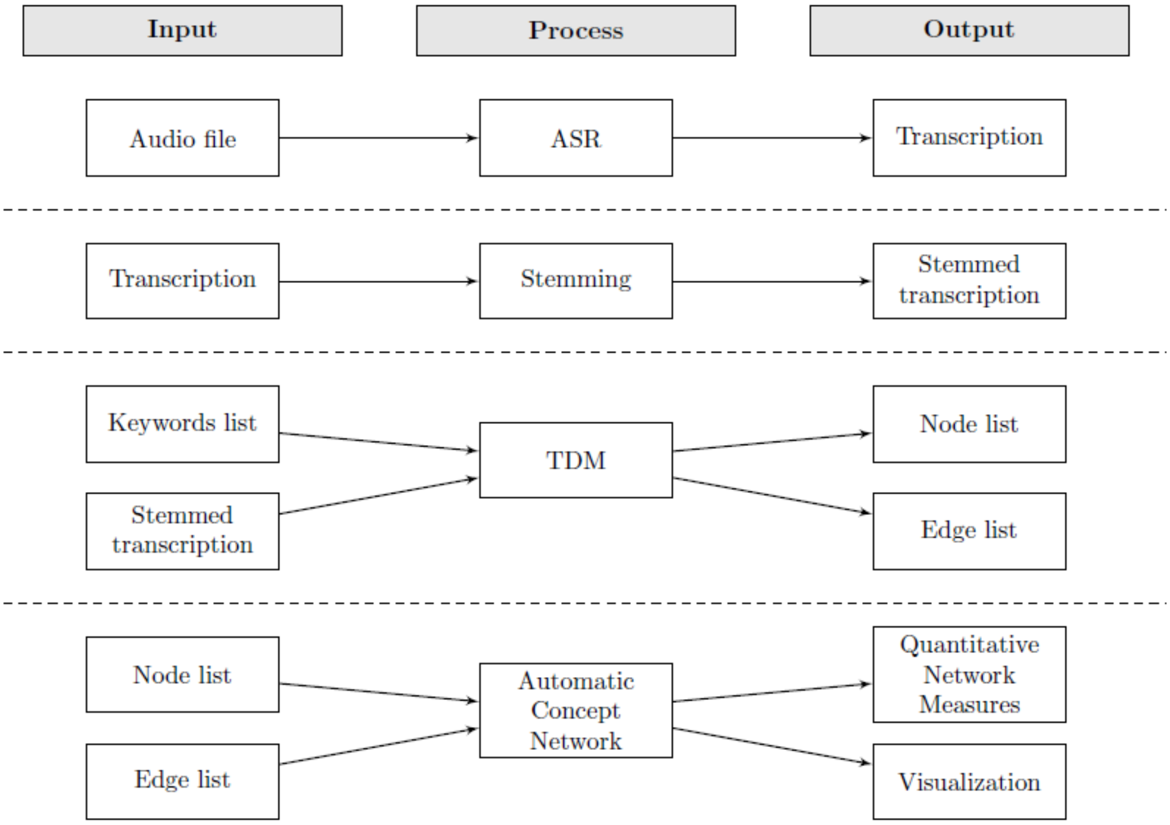
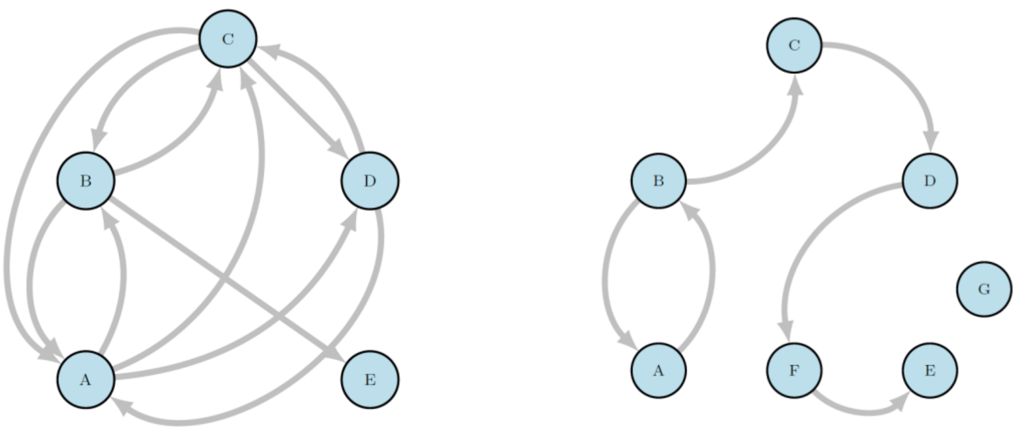


Figure 1. Pipeline for data analysis

With the keywords and keywords connections, an automatic concept network was generated (see Figure 2 for two examples of the Visualization output shown in Figure 1). In the concept network, nodes are concepts and the edges between two concepts mean that the concepts were said in the same 10 seconds window time.



(a) Network A (b) Network B

Figure 2. Example of two concept networks with different network measures

Afterwards, network measures were calculated. These are measures of Social Network Analysis applied to the concept network to see whether there is a relationship between the measures and students' learning gains. The measures are taken from Vargas et al. (2018). Table 1 shows the meaning we give to the network measures (Quantitative Network Measures output in Figure 1) and the results of them in the example networks shown in Figure 2.

Table 1. Network measure description and values for examples given in Figure 2

Network Measure	Meaning	Network A	Network B
Number of Nodes	How many different concepts the teacher said and related with other concepts. In Network A, the teacher said 5 different concepts: A, B, C, D, and E but teacher in Network B mentioned two more: F and G	5	7
Number of Edges	How many concepts were said in the same time window. Teacher of Network A had more connections between the 5 concepts than teacher of Network B. The arrows indicate which concept was mentioned first (e.g. in Network A, concept B was said before concept E)	11	6
Density	Proportion between number of edges and number of all possible edges. Network A is more dense than Network B. A network with no edges has a Density of 0 and a complete network has a Density of 1	0.55	0.14
Diameter	The greatest distance between any pair of concepts of the network. For Network A, the greatest distance is 3 (from concept D to concept E), whereas the greatest distance in Network B is 5 (from concept A to concept E)	3	5
Average Clustering	The average tendency of the concepts' neighbors to cluster together. In Network A, neighbors of concepts tend to cluster together more than in Network B.	0.5	0
Average degree	The average of how many linked concepts has each concept of the network. Teacher of Network A connected, in average, each concept to other 4.4 concepts, meanwhile Teacher of Network B connected, in average, each concept to 1.7 concepts.	4.4	1.7
Average Degree Centrality	The average of the proportion of how many neighbors does a concept has, normalized by dividing by the maximum possible degree in a simple graph n-1 where n is the number of nodes in the network.	1.1	0.28

The students learning gain (LG) was calculated as

$$\mathrm{LG} = \frac{\mathrm{Post} - \mathrm{Pre}}{\mathrm{Total}_{\mathrm{post}} - \mathrm{Pre}}$$

Where Post is the score of Post-test, Pre is the score of Pre-test and $\mathrm{Total}_{\mathrm{post}}$ is the maximum possible score for Post-test.

To answer the research question, a robust regression (Li, 2006) was run. In the model, the independent variables are the networks' measures and the dependent variable is the LG.

RESULTS

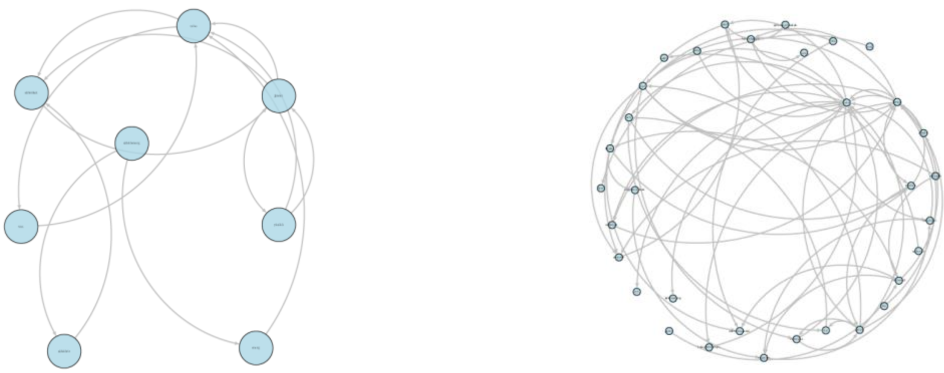
From the results shown in Table 2, we conclude that the variables Density, Diameter and Average Degree Centrality resulted to be significant for the LG. Density is related with LG in negative way: as more dense the network is, less LG for the students.

Table 2. The results of the robust regression, with the p-value of each of the measures

	Value	Std. Error	t – value	p - value
(Intercept)	-9.547	7.220	-1.322	0.188
NODES	0.510	0.300	1.701	0.091
EDGES	-0.146	0.138	-1.058	0.291
DENSITY	-4.193	1.864	-2.249	0.027
DIAMETER	0.939	0.389	2.653	0.016
CLUSTERING	2.269	7.770	0.292	0.770
AVG_DEGREE	1.461	1.723	0.848	0.398
AVG_DEGREE_CENTRALITY	25.277	9.865	2.563	0.010

Residual standard error: 5.286 on 307 degrees of freedom.

To analyse a concrete example, the lessons from two teachers are compared. Figure 3 shows their respective network visualization and Table 3 shows the network measures that turned to be significant.



(a) Lesson Teacher A (b) Lesson Teacher B

Figure 3. Two networks of two real lessons, with different network measures

Students in Teacher B lesson had higher LG (mean = 0.44) compared with students in Teacher A lesson (mean = 0.29). Moreover, students in Teacher B lesson had higher minimum and maximum values of LG. As Table 3 shows, the lesson of Teacher B has less density and less Average Degree Centrality, but higher Diameter.

Table 3. Network measures for the lessons shown in Figure 3

Network Measure	Lesson Teacher A	Lesson Teacher B
Density	0.20	0.05
Diameter	3	6
Average Degree Centrality	0.4	0.11

DISCUSSION AND CONCLUSION

Previous studies have shown that the characteristics of the instructional content have a relationship with students' learning. Particularly, the connections between content structure and the number of topic-related topics. The analysis of teachers' discourse is time consuming. In this proposal we take the advantage of Automatic Speech Recognition algorithms performance to automatically analyse the teachers' lesson through network analysis.

Social network analysis metrics are used to analyse the network created from teachers' talk. Those measures give the structure of the concept network of a teacher. Using the data of QuIP project, we studied 25 teachers and 328 students from Finland. The results show that the Density, Diameter and the average Degree Centrality of the concept network have a significant relationship with students' LG. This means that the greater the Diameter and the Degree Centrality, higher LG and the sparser the network is, greater LG. The results are coherent with previous results since we demonstrated that network measures relate significantly with students' learning as in Helaakoski and Viiri (2014).

On the other hand, automatic analysis was less time consuming than manual analysis. Automatic network analysis - starting from automatic speech recognition to automatic network generation and analysis - could help researchers in classroom talk analysis and could be used in teacher education as formative feedback tool. We will leave as future work which is the best way to give this kind of feedback in real-time.

In the future, we would like to find new ways of analysis, using other network measures like different centrality measures or cluster analysis to obtain a way of measuring the "importance" given to each concept during the class or how likely is the teacher to relate two specific concepts. Also, we expect in the future to gather more data from more teachers and students to test whether the results shown in this paper are robust and hold in other contents, subject matters beside physics, grade level, etc. Moreover, it could be interesting including in the analysis time series analysis so we could be able to identify which concept was being taught at any moment, and thus observe how the network changes from the start to the end of the lesson. This could lead to discover interesting time-related patterns that teachers might present when developing a lesson. Finally, we think it is imperative to consider students' talk to understand the class discourse as a whole, not only how the content is presented by the teacher.

ACKNOWLEDGEMENT

Funding from PIA-CONICYT Basal Funds for Centers of Excellence Project FB0003 is gratefully acknowledged and to the AKA-EDU-01 grant from CONICYT. The authors are also thankful for the funding provided to project No. 294218 by the Academy of Finland.

REFERENCES

Caballero, D., Araya, R., Kronholm, H., Viiri, J., Mansikkaniemi, A., Lehesvuori, S., Virtanen, T., & Kurimo, M. (2017). ASR in Classroom today: Automatic visualization of conceptual networks in science classrooms. In *European Conference on Technology Enhanced Learning* (pp. 541-544). Springer, Cham.

Drollinger-Vetter, B. & Lipowsky, F. (2006). Fachdidaktische Qualität der The-oriephasen. In E. Klieme, C. Pauli, & K. Reusser (Eds.) *Dokumentation der Erhebungs- und*

Auswertungsinstrumente zur schweizerisch-deutschen Videostudie "Unterrichtsqualität, Lernverhalten und mathematisches Verständnis". Material-ien zur Bildungsforschung (Vol. 15). Frankfurt am Main, Germany: GFPF.

Fischer, H. E., Labudde, P., Neumann, K., & Viiri, J. (2014) Quality of instruction in physics. Comparing Finland, Germany and Switzerland. Waxmann, Munster.

Geeslin, W. E. & Shavelson, R. J. (1975). Comparison of content structure and cognitive structure in high school students' learning of probability. *Journal for Research in Mathematics Education, 6* (2), 109–120.

Geller, C., Neumann, K., Boone, W.J., Fischer, H.E. (2014). What makes the Finnish different in science? Assessing and comparing students' science learning in three countries. *International Journal of Science Education, 36* (18), 3042-3066.

Helaakoski, J. & Viiri, J. (2014) Content and content structure of physics lessons and students' learning gains. In H.E. Fischer, P. Labudde, K. Neumann, & J. Viiri, (2014) *Quality of instruction in physics. Comparing Finland, Germany and Switzerland*. Waxmann, Munster. Pp. 93-110.

Klieme, E., Pauli, C., & Reusser, K. (2009). The Pythagoras study. Investigating effects of teaching and learning in Swiss and German mathematics classrooms. In T. Janík & T. Seidel (Eds.) *The power of video studies in investigating teaching and learning in the classroom* (pp 137– 160). Münster: Waxmann.

Kronholm, H., Caballero, D., Araya, R., Viiri, J. (2016). A smartphone application for ASR and observation of classroom interactions. Presented in *Finnish Mathematics and Science Education Research Association (FMSERA) annual symposium.*

Li, G. (2006). Robust regression. In D. C. Hoaglin, F. Mosteller, & J. W. Tukey (Eds.), *Exploring data tables, trends, and shapes* (pp 281 – 343). Hoboken: John Wiley & Sons.

Muller, C. T. & Duit, R. (2004). Die unterrichtliche Sachstruktur als Indikator fur Lernerfolg – Analyse von Sachstrukturdiagrammen und ihr Bezug zu Leistungsergebnissen im Physikunterricht. *Zeitschrift für Didaktik der Natur-wissenschaften, 10*, 146–160.

Shavelson, R. J. (1972). Some aspects of the correspondence between content structure and cognitive structure in physics instruction. *Journal of Educational Psychology, 63* (3), 225–234.

Vargas, D. L., Bridgeman, A. M., Schmidt, P. B., Wilcox, B. R., & Carr, L. D. (2018). Correlation between student collaboration network centrality and academic performance. *Physical Review Physics Education Research, 14*(2), 020112

UNPACKING THE PROMISES OF THE MAKER MOVEMENT IN STEM EDUCATION: THE DEVELOPMENT OF SCIENTIFIC AND ENGINEERING PRACTICES THROUGH TINKERING

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Tinkering, a subset of Making, is newly delineated as a specifically process-focused approach to learning through physical/digital creation and characterized by a creative and improvised way of solving problems. Advocates argue that it holds great promise as a means of STEM learning, though few empirical studies yet exist. In this research, we analyse the impact of Tinkering activities with regard to children's participation in scientific and engineering practices. Our results confirm preliminary expectations of learning through Tinkering, however, they suggest that while specific engineering practices can be easily seen through learner participation, scientific practices do not emerge spontaneously despite the existence of potential situations to promote them.

Keywords: STEM education, informal learning, primary school

INTRODUCTION

Making (or Maker movement), a grassroots movement related to digital and physical fabrication, has increasingly been embraced by formal and informal education (Bevan, 2017; Marshall & Harron, 2018; Martin, 2015). Characterized by the creative design, the construction and customization of objects, artefacts and other constructions with a fun or useful purposes, the playful nature and multiple entry points that characterize a Maker activity is seen by advocates as a powerful approach for helping students to gain confidence in their own ability to undertake new scientific and technological challenges (DiGiacomo & Gutiérrez, 2015). In the current era were design is seen as a new literacy (Blikstein, 2013), Making environments are seen as rich contexts for acquainting young people with STEM practices that will empower them to change their world (Project Zero, 2015). Moreover, the multidisciplinary nature of the Maker movement is championed as a potential context in which to tackle new STEM standards which place science and engineering practices at the forefront of STEM education (Duschl & Grandy, 2008; Grandy & Duschl, 2007; National Research Council, 2012; Osborne, 2014).

In this context, Tinkering, as newly-defined approach to learning framed in Making, has grown in popularity, educational interest, and specificity in the last few years (Bevan, Gutwill, Petrich, & Wilkinson, 2015; Vossoughi & Bevan, 2014). In a Tinkering activity, participants are invited to explore several material and phenomena to build their own creations (Petrich, Wilkinson, & Bevan, 2013) which can be easily tested in order to get an immediate feedback about their results (Resnick & Rosenbaum, 2013). While research on Tinkering has surfaced 'learning dimensions' as well as theoretical learning potentials (Bevan et al., 2015; Wardrip & Brahms, 2015), scant evidence exists regarding the real impact of Tinkering on scientific and engineering learning of both concepts and practices. In this context, our study seeks to interrogate the impact of Tinkering in STEM education. Specifically, it seeks answers to the following question:

- Which scientific and engineering practices are promoted through a Tinkering activity in an informal learning context?

METHOD

Our research is based on Creactivity, a Tinkering space located in the CosmoCaixa Museum in Barcelona, Spain. It is addressed to families with children between 7 and 12 years old and to school groups from 2nd to 6th grade. Inspired by Exploratorium's Tinkering Studio in San Francisco, it includes four areas (some with more than one space): Mechanics (with gears' corner and marble and pinball machines), Wind, Electricity and Light (with shadows and stop motion) (Figure 1).

Figure 1. The four Creactivity areas, which their corresponding spaces

Each session at Creactivity was attended by two facilitators, who received participants and made a brief introduction of the space, offer their support during the activity (giving materials, proposing challenges, etc.) and take care of making the closure of the session. No direct instructions were given to students, although implicit objectives (examples, drawings…) were present in all four areas. The study was carried out during a school year, focusing on the sessions with schools and including the activities carried out in the four areas of Creactivity.

Data gathering and analysis

The study was designed as a qualitative research with video and audio-recording as main data sources together with researcher's field notes. A total of 13 Tinkering sessions (26 hours) were observed. In each observation, two cameras and three audio recorders were placed in a Creactivity area, chosen randomly. Data analysis was based on the selection of 12 cases which were considered rich in content according to the information gathered in the field notes. Video and audio were edited for each case, in order to guarantee good sound quality and the best camera angle images. Edited videos were analysed using the qualitative data analysis software Atlas.Ti. Following a qualitative approach based on multimodal discourse analysis (Gee, 2011; Jones, 2013), relevant clips were identified. Each clip was first coded following an inductive categorization, describing the tasks carried out during a Tinkering activity (see Table 1) In a second round, these tasks were deductively coded - based on an adaptation of the NRC (2012) list of engineering and scientific practices- seeking to classify the identified tasks with the corresponding practices.

Table 1. Emerged categories regarding participants' tasks.

Student tasks- Emerging categories
To propose several assemblies/creations and choose one to carry it out
To do partial tests of parts of the assembly
To assemble/build their creations
To test creations
To analyze the result of the tests done (works / does not work)
To justify their creation
To explain a phenomenon
To investigate a phenomenon

RESULTS

Results confirm the development of some engineering practices and, to a lesser extent, of scientific practices. Specifically, our results confirm that engineering practices (blue/green scale) related to the *Materializing the solution* (33%), *Planning and carrying out tests* (32%), *Identifying multiple solutions and selecting the optimal one* for its realization (20%) and *Analysing and interpreting of data to identify points of improvement* (13%) were the most relevant during Tinkering activities (Figure 2). However, in most cases practices were usually shallow. For instance, when carrying out tests, students were directly testing, using the mechanisms included in the Tinkering space for having immediate feedback regarding the creations, without a thorough planification of the investigation, (e.g.: button for turning on the wind tube). Only in some cases, this testing evidences planification, focusing on testing some of the variables at play. As for the materialization of the solution, there is a certain difference between the participants: while some boys and girls make a deliberate choice of materials in order to make their creation real, others follow a more exploratory choice just picking one of the available materials and trying to use it.

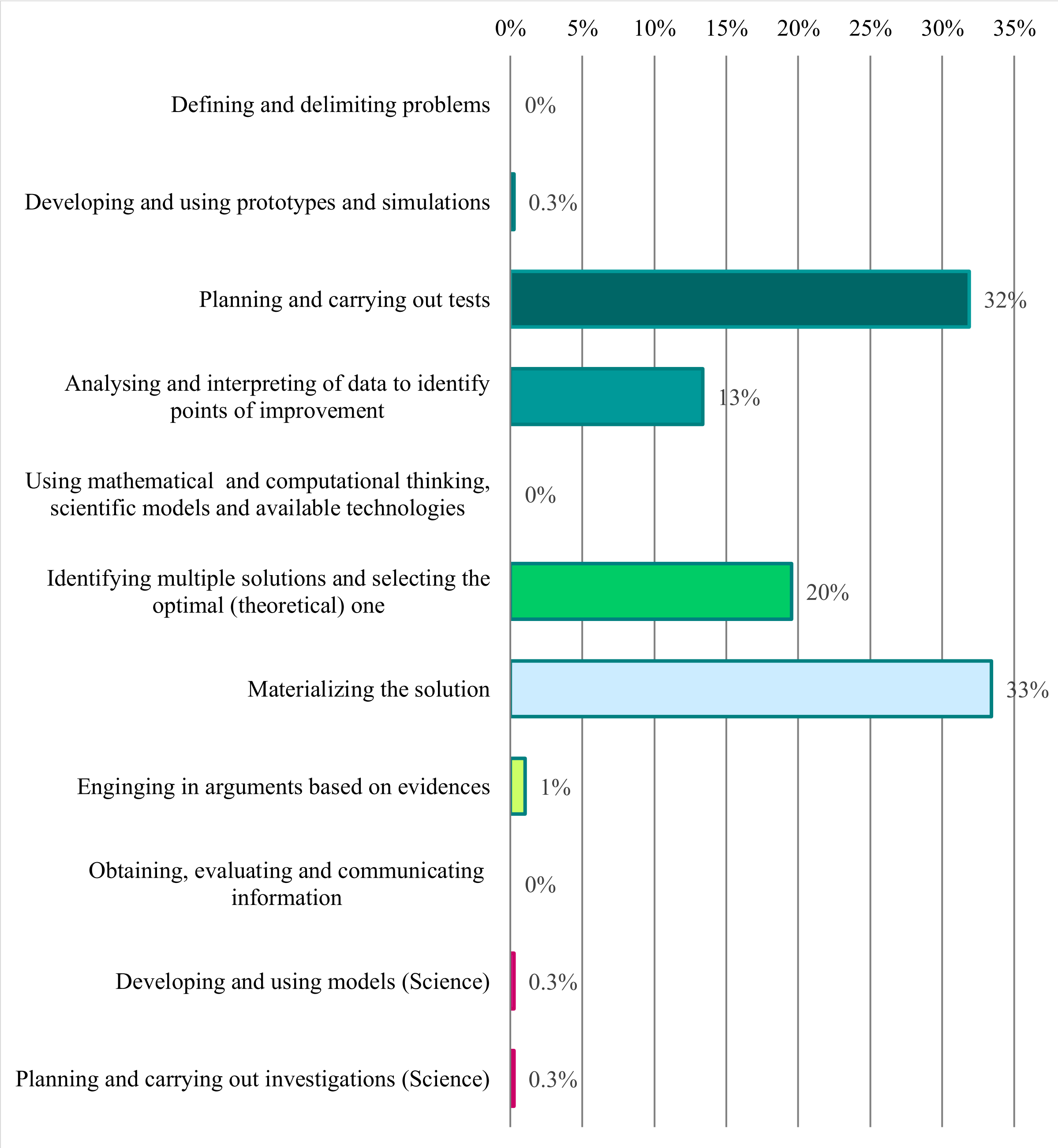

Figure 2. Engineering and scientific practices evidenced in Study 1 cases. Percentage of total observed practices.

Finally, beyond this construction and testing of creations, the other practice that seems to be encouraged in is the selection of an optimal solution. This practice involves identifying several possible solutions before selecting a specific one. In this sense, it is common to see students engaging in a kind of brainstorming in order to evaluate the different options that emerge or to look at the solutions made by others to get ideas among possible solutions.

Regarding scientific practices (pink scale), they seem to have a residual presence and are basically reduced to *Developing and using models* and *Planning and carrying out investigations.* Again, these practices are shallow, and students tend to devote little time to them moving easily to the engineering ones.

DISCUSSION AND CONCLUSIONS

Our study shows that students in a Tinkering activity are engaged in practices relevant to engineering and, to a lesser extent, to science. In both cases, most practices are usually shallow: there is testing but no test is planned, there is analysis of test results but it is not based on data,... The nature of the space (e.g.: the type of material with no measurement tools) and the methodological proposal that accompanies it (e.g.: a type of test for each space, few restrictions given to students, ...) could explain this lack of depth while also promote the greater or lesser presence of the various practices.

Regarding engineering practices, our study suggests that Tinkering activities promote certain practices that often play a residual role in engineering education or technology (i.e.: identification multiple solutions). As Mader and Dertien (2016) point out, the idea of making decisions about design is usually relegated to a pre-established decision, focusing most of the activities on framing the problem and building the solution. Hence, giving to students the opportunity to participate in Tinkering activities helps them to develop creative practices which are central for engineering.

On the other hand, the results show that throughout a tinkering activity there are situations in which scientific practices can be promoted but which do not seem to be maintained. The nature of the context and the methodology used by facilitators, much focused to engineering, would explain this result. These findings confirm what King and English (2016) argue: a STEM approach based on engineering design does not need to promote the development and learning of scientific practices and concepts. Unless the work around scientific practices is explicitly stated, they will not be given in a context where the practice of engineering is primarily promoted, however multidisciplinary the space may be.

ACKNOWLEDGEMENT

This research was funded by the Spanish Government (grant number EDU2015-66643-C2-1-P) and carried out within the ACELEC research group, acknowledged by the Catalan Government (grant number 2017SGR1399).

REFERENCES

Bevan, B., Gutwill, J. P., Petrich, M., & Wilkinson, K. (2015). Learning Through STEM-Rich Tinkering: Findings From a Jointly Negotiated Research Project Taken Up in Practice. *Science Education*, *99*(1), 98–120. http://doi.org/10.1002/sce.21151

King, D., & English, L. D. (2016). Engineering design in the primary school: applying stem concepts to build an optical instrument. *International Journal of Science Education*, *38*(18), 2762–2794. http://doi.org/10.1080/09500693.2016.1262567

Petrich, M., Wilkinson, K., & Bevan, B. (2013). It looks like fun, but are they learning? In *Design, make, play: Growing the next generation of STEM innovators* (pp. 50–70). Routledge.

Resnick, M., & Rosenbaum, E. (2013). Designing for tinkerability. In *Design, make, play: Growing the next generation fo STEM innovators* (pp. 163–181). Routledge.

Vossoughi, S., & Bevan, B. (2014). *Whitepaper - Making and Tinkering : A Review of the Literature*. Retrieved from http://sites.nationalacademies.org/cs/groups/dbassesite/documents/webpage/dbasse_089888.pdf

Wardrip, P. S., & Brahms, L. (2015). Learning Practices of Making : Developing a Framework for Design. In *Proceedings of the 14th International Conference on Interaction Design and Children* (pp. 375–378). http://doi.org/10.1145/2771839.2771920

EYE MOVEMENTS DURING DETERMINATION OF BUTTERFLIES WITH IDENTIFICATION KEY

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The purpose of the present research was to observe pre-service teacher's eye movements during the determination of butterfly species with a simplified dichotomous key containing illustrations, photographs, and written descriptions. Our aim was to explore if they prefer to use illustrations or photographs in the determination of butterfly species? The eye-tracking measures showed that students (n=58) used more illustrations than photographs of butterflies. Students reporting having more experiences with keys and butterflies had a significantly higher percentage of total fixation duration on illustrations in comparison to less experienced students. Achievements in tasks were not significantly correlated with visual attention towards different elements in identification steps. Implications for teaching biology are discussed in the conclusion.

Keywords: biological key, eye tracker, butterfly, observational skills

INTRODUCTION

Dallwitz, Paine, and Zurcher (2002) wrote that the identification of organisms is a process in determining which taxon species belong to and represents a basic skill for understanding nature. In biology, an identification key is a tool that aids the identification of biological entities (e.g., plants, animals, animal tracks). Thus, one of the most fundamental objectives in biology teaching is to strive for developing students' skills and abilities to use biological identification keys (Randler and Zehender, 2006). Each identification step in simplified identification keys requires from learner to choose between two options (dichotomous keys) or multiple ones; consisting of text, graphics or both. Simplified keys mostly contain organisms from the student's local environment and which gives them the opportunity to get to know these organisms more closely through identification (Bajd, 2016). There is an increasing number of studies (e.g., Anđić, Cvijetićanin, Maričić, and Stešević, 2018; Laganis, Prosen, and Torkar, 2017; Stagg, Donkin, and Smith, 2013; Randler, 2008; Bromham and Oprandi, 2006; Randler and Bogner, 2006) investigating the effectiveness of identification keys. Most of these studies were done with primary and secondary school students. In the present study, we focus our attention on pre-service teachers, who are going to teach students to use simplified identification keys in primary and lower secondary school. The results indicate that using identification keys in biology teaching is an effective educational tool to explain scientific principles (Randler and Bogner, 2006). Through the process of determination with identification key students improve their observational skills (Laganis, Prosen, and Torkar, 2017) and can work independently, without the teacher's help (Bromham and Oprandi, 2006). Students are more motivated for learning about plants when working with identification keys, although botanical content is not attractive for students (Silva et al., 2011).

Nowadays, loads of identification keys are available, usually using words, illustrations and/or photographs that guide a learner through the identification of the organism. For a review on the use of images in field guides and identification, keys see Leggett and Kirchoff (2011). Authors exposed best practices in image use in guides and keys, based on their review e.g., multiple images should be included to illustrate the taxon descriptions (characters indicated with arrows to direct the user's attention); an observed organism in the photograph should be pointed out from the backgrounds, where possible, the background should be of a standard color; the use of drawings is reasonable than photographs when representing a typical example of an organism; when used, illustrations should be prepared by professional botanical illustrators, and clearly labeled. However, little is known what type of visual representations (illustrations or photographs) users prefer to use.

Eye-tracking is a technique for studying various visualizations because it makes it possible to monitor cognitive processes due to the links between eye movements and cognition. Eye movements indicate where attention is being directed and total fixation time (i.e. cumulative duration of fixations within a region) is considered as a sign of the amount of total cognitive processing engaged with the fixated information. Data gathered with eye tracing provides information about the cognitive process of the student, such as reading, scene perception, visual search and other information on processing the problem (Rayner, 1998, 2009). The eye-tracking technique has been used in many studies, analyzing the learning process and problem-solving (e.g. Lai et al., 2013). For detecting information about students' procession of various visualizations, the eye-tracking is also efficiently used (e.g., Ferk Savec, Hrast, Devetak, and Torkar, 2016). With regard to this fact, collecting eye movements can provide important information in investigating students' identification of organisms with simplified keys.

Research goal and questions

The goal of the present research was to observe pre-service teacher's eye movements during the determination of butterfly species with a simplified dichotomous key containing illustrations, photographs and written descriptions that guide a learner through the identification step.

The main questions underlying this research were therefore threefold:

(1) Do pre-service teachers prefer illustrations or photographs through identification steps?

(2) Are there any differences between students with more or less prior experiences with identification keys and butterflies?

(3) What are the differences between students who identified organisms correctly and those who were not able to answer correctly?

RESEARCH METHOD AND DESIGN

Slovenian pre-service teachers (n = 58) participated in the study. They will teach science or biology subjects in primary or lower secondary school. Education staff at school level have to hold relevant educational qualification (ISCED 7 for primary school and lower secondary school teachers) and they have to pass the state professional examination for education staff

(Eurydice, 2019). Even though the curriculum varies among universities, pre-service teachers typically take content knowledge courses, pedagogical content knowledge courses, and general education courses. Pre-service teachers learn how to create and use simplified identification keys in general biology or science courses. Participating pre-service teachers were in the second, third or fourth year of studies at the University of Ljubljana's Faculty of Education. They all learned how to use simplified dichotomous identification keys before the study in the field of systematic botany and zoology.

Eight tasks were presented on a computer screen in the form of text and images. Each task was presented with one identification step: two different written descriptions (A and B), an illustration and a photograph of an organism (for example see Figure 1). Students had to identify which description (A or B) correctly describes the organism on the images. On four out of eight tasks illustrations were placed on the left side and photographs on the right side of the slide. The remaining four slides had the opposite pattern.

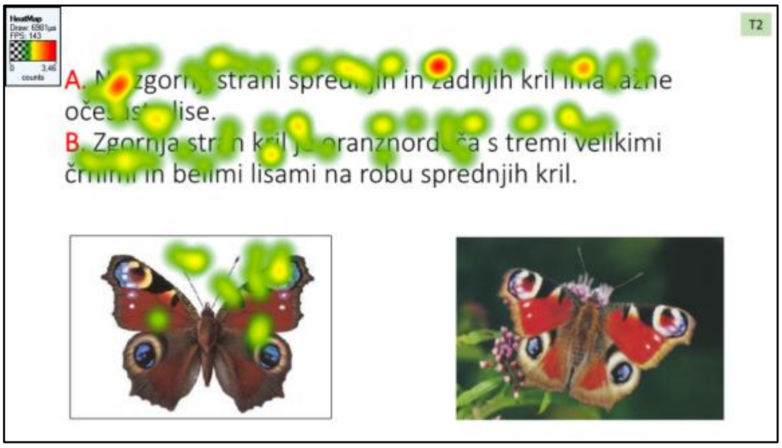

Figure 1. An example of a student focusing on illustration, placed on the left side when identifying the butterfly species (represented with heat map).

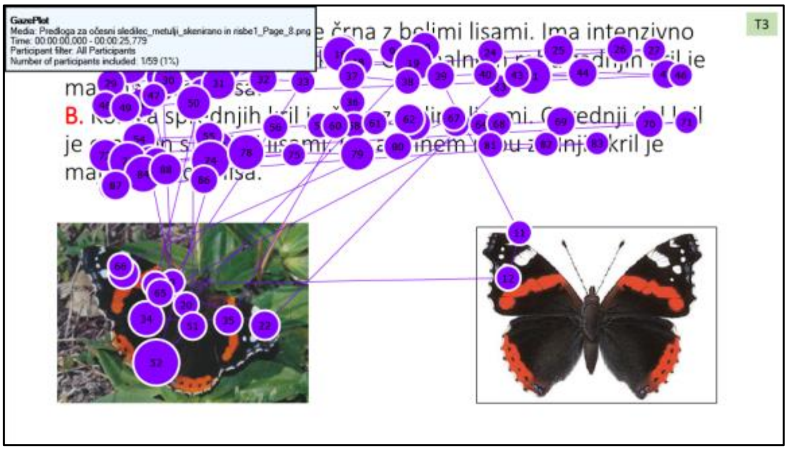

Figure 2. An example of a student focusing on the photograph of the organism, placed on the left side, when identifying the butterfly species (represented with gaze plot). Through the representation with the gaze plot, the many integrations between images and text could be observed.

To determine students' visual attention towards different elements of the slides while solving the tasks, we focused on the total amount of time (total fixation duration) spent in particular areas of interest (AOI). The tasks displayed on the computer screen were divided into several AOIs with regard to the placement of the images/texts investigated. Fixations refer to maintaining the visual gaze on a certain location (Figure 1), and fast eye movements from one location to another are called saccades (Figure 2). The identification of saccades or fixations is based on the motion of gaze during each sample collected. When both the velocity and acceleration thresholds (in our case: 30 degrees per second and 8,000 degrees per second squared) are exceeded, a saccade begins; otherwise, the sample is labeled as a fixation.

Data entry and analysis were conducted using the Statistical Package for the Social Sciences (SPSS). Basic descriptive statistics for numerical variables (mean, standard deviation, and frequency) were employed. The inferential statistical methods used were the Pearson product-moment correlation and the Student's t-test. In addition, effect sizes (Cohen's d) were calculated.

FINDINGS

Findings show that 41.40% of pre-service teachers solved correctly all eight tasks, 27.60% seven, 22.40% six, 6.90% five and 1.70% four tasks. Table 1 shows students' success in solving specific tasks. On average they solved 7.00 (SD = 1.04) tasks correctly. They spent on average 18.19 seconds (SD = 6.95) on each slide (tasks 1-8). While solving the tasks they devoted on average 26.17% of the time on images and the rest of the time on written descriptions of butterflies. Those that spent on average more total time on the slide, focused more attention on images. Percent of integration of images and texts was calculated which represents the number of times a student looked on images while reading written descriptions, excluding the number of saccades between text A and B. Average percent was 68.94% (SD = 8.01). In problem solving students used more illustrations (13.86%, SD = 4.33) than photographs (12.31%, SD = 4.18) of butterflies (t = 1.966, df = 114, p = 0.05, Cohen's d = .364). Students showing higher percent integration of images and texts used significant more illustrations of butterflies.

Table 6. Correctly and incorrectly solved tasks.

	Task solved correctly		Task solved incorrectly		Total	
	f	*f%*	*f*	*f%*	*f*	*f%*
Task 1	49	84.5	9	15.5	58	100.0
Task 2	52	89.7	6	10.3	58	100.0
Task 3	41	70.7	17	29.3	58	100.0
Task 4	56	96.6	2	3.4	58	100.0
Task 5	52	89.7	6	10.3	58	100.0
Task 6	51	87.9	7	12.1	58	100.0
Task 7	58	100.0	0	0.0	58	100.0
Task 8	47	81.0	11	19.0	58	100.0

Students were asked about their experiences with butterflies and identification keys (Table 2). A great amount of them (79.3%) exposed they like observing butterflies in nature, but only 6.9% of students have sampled and determined butterflies so far. Most of the students (84.5%) mistakenly thought widespread butterfly species in Slovenia *Lycaena virgaureae,* has yellow-colored wings. Also, only 5.2% of students would recognize butterfly species clouded yellow *Colias croceus*. Students also reported about their knowledge on the biodiversity of butterflies. None of them answered knowing the biodiversity *excellent*; one of them responded his knowledge is *very good*. Most of the students (58.6%) exposed their knowing the biodiversity of butterflies is *fair*, and 25.9% tell their biodiversity knowledge is *poor*.

Table 7. Self-reported experiences with keys and butterflies.

Self-reported experiences with keys and butterflies	Experienced	Not experienced
	f%	*f%*
I like observing butterflies in the meadow.	79.3	20.7
I could recognize a butterfly species yellow clouded *Colias croceus*.	5.2	94.8
I have sampled and determined butterflies more than three times.	6.9	93.1
Butterfly species *Lycaena virgaureae* has yellow wings.	15.5	84.5

Results in Table 3 show that students spending more time on images also integrated more images and texts. Students reporting having more experiences with keys and butterflies had significantly higher percent fixation duration on images in comparison to less experienced students. To solve the tasks, students with more experiences focused more on illustrations. The eye-tracking measures in students that solved tasks correctly and in those that were not able to solve the tasks correctly did not differ.

Table 8. Correlations.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Correctly solved tasks (1)	1	-.236	-.144	-.056	-.204	.015	-.205
Average duration of fixation on slide (2)	-.236	1	.340**	.283*	.325*	.231	-.051
Percent fixation on images (3)	-.144	.340**	1	.894**	.887**	.506	.268*
Percent fixation on illustration (4)	-.056	.283*	.894**	1	.586**	.485	.261*
Percent fixation on photograph (5)	-.204	.325*	.887**	.586**	1	.415	.217

Percent integration of images and texts (6)	.015	.231	.506**	.261*	.217	1	.179
Self-reported experiences with keys and butterflies (7)	-.205	-.051	.268*	.261*	.217	.179	1

Statistically significant * $p < .05$, ** $p < .001$.

DISCUSSION

The use of identification keys in biology teaching is a great opportunity to develop the scientific skills of students (Randler and Bogner, 2006) and familiarize them with biodiversity (Bajd, 2016). Identification keys can be simplified at many points to make it more fitting for educational purposes. Wisniewski (2002) suggests that the taxon descriptions should be supported with multiple images to help students visualize the presentative features of an organism. The findings of the present research suggest that Slovene pre-service teachers, who are going to teach science and biology subjects in primary and lower secondary school, spent on average one-quarter of a total fixation duration on images (illustration and/or photograph of a butterfly) while solving the problem through the step of butterfly identification.

Students preferred more illustrations than photographs for the determination of butterfly species. Also, students reporting having more experiences with using identification keys used substantially more illustrations in the identification process. A possible explanation is that students dislike photographic backgrounds because they distract them from the subject (Leggett and Kirchoff, 2011). Leggett and Kirchoff (2011) recommend that backgrounds should be of standard color. A finding of the present research suggests that students rely more on illustration prepared by professional biological illustrators in comparison to a photograph even though later depicts butterfly more realistically. Those students that reported having more experiences with keys and butterflies were not more successful in problem-solving in comparison to less experienced students, which can be explained through the simplicity of examples presented in the tasks. Drawings that are prepared by a trained botanical illustrator show specimens typical of the species and focus on and emphasize their specific features (Meicenheimer, 2007, 2009).

CONCLUSION

The present research provides four main conclusions about the use of identification keys when teaching and learning about the biodiversity of butterflies. First, students report having very little prior experiences with identifying key for, and determining of, butterflies. Second, students have successfully determined butterflies with provided identification keys. Due to relatively small numbers of incorrectly solved tasks, it is difficult to make solid conclusions on the effect of visual attention towards different elements of identification keys. Therefore, further research is needed to find out if selective visual attention is in any interplay with students' achievements. Next, the number of accurately determined butterflies and the students' total fixation duration on images were positively correlated. Last but not least, students with more prior experiences relied more on illustrations when using the keys. These findings have important implications for the development of educational materials and instructions for observing and studying the biodiversity of butterflies. It is an important goal to teach pre-service teachers to prepare and use identification keys in order to enable school students can learn about biodiversity more actively and independently of teacher help.

REFERENCES

Anđić, B., Cvijetićanin, S., Maričić, M., & Stešević, D. (2018). The contribution of dichotomous keys to the quality of biological-botanical knowledge of eighth grade students. *Journal of Biological Education*, 1–17.

Bajd, B. (2016). Jednostavni biološki ključevi. *Educatio biologiae: časopis edukacije biologije*, *2*(1), 91-99.

Bromham, L., & Oprandi, P. (2006). Evolution Online: Using a Virtual Learning Environment to Develop Active Learning in Undergraduates. *Journal of Biological Education, 41*(1), 21–25.

Dallwitz, M. J., Paine, T. A., & Zurcher, E. J. (2002). Interactive Identification Using the Internet. Towards a Global Biological Information Infrastructure – Challenges, Opportunities, Synergies, and the Role of Entomology. *European Environment Agency Technical Report, 70*(3), 23–33.

Eurydice. 2019. Slovenia Overview. Avaliable at: https://eacea.ec.europa.eu/national-policies/eurydice/content/slovenia_en

Ferk Savec, V., Hrast, Š., Devetak, I., & Torkar, G. (2016). Beyond the use of an explanatory key accompanying submicroscopic representations. *Acta Chimica Slovenica, 63*(4), 864–873.

Laganis, J., Prosen, K., & Torkar, G. (2017). Classroom versus outdoor biology education using a woody species identification digital dichotomous key. *Natural sciences education, 46*(1), 1–9.

Lai, M.-L., Tsai, M.-J., Yang, F.-Y., Hsu, C.-Y., Liu, T.-C., Lee, S. W.-Y., ... Tsai, C.-C. (2013). A review of using eye- tracking technology in exploring learning from 2000 to 2012. *Educational Research Review, 10*, 90–115.

Leggett, R., & Kirchoff, B. K. (2011). Image use in field guides and identification keys: review and recommendations. *AoB Plants*, Accessed January 20, 2019. http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3077818

Meicenheimer, R. D. (2007). *Miami University dendrology expert system*. Oxford, OH: Miami University.

Meicenheimer, R. D. (2009). *Miami University dendrology expert system*. Oxford, OH: Miami University.

Randler, C. (2008). Teaching Species Identification — A Prerequisite for Learning Biodiversity and Understanding Ecology. *Eurasia Journal of Mathematics, Science & Technology Education*, *4*(3), 223–231.

Randler, C., & Bogner, F. X. (2006). Cognitive Achievements in Identification Skills. *Journal of Biological Education, 40*(4), 161–165.

Randler, C., & Zehender, I. (2006). Effectiveness of Reptile Species Identification – A Comparison of Dichotomous Key with an Identification Book. *Eurasia Journal of Mathematics, Science and Technology Education, 2*(3), 55–65.

Rayner, K. (1998). Eye movements in reading and information processing: 20 years of research. *Psychological Bulletin, 124*(3), 372–422.

Rayner, K. (2009). The 35th Sir Frederick Bartlett Lecture: Eye movements and attention in reading, scene perception, and visual search. *The Quarterly Journal of Experimental Psychology, 62*(8), 1457–1506.

Silva, H., Pinho, R., Lopes, L., Nogueira, A. J., & Silveira, P. (2011). Illustrated Plant Identification Keys: An Interactive Tool to Learn Botany. *Computers & Education, 56*(4), 969–973.

Stagg, B.C., Donkin, M.E., & Smith, A.M. (2015). Bryophytes for Beginners: The usability of a printed dichotomous key versus a multi-access computer-based key for bryophyte identification. *Journal of Biological Education*, *49*(3), 274–287.

Wisniewski, E.J. (2002). Concepts and categorization. In D. Medin (ed.), *Stevens' handbook of experimental psychology* (pp. 467–531). New York: Wiley.

DIGITISATION IN CHEMISTRY LESSONS

DEVELOPMENT AND EVALUATION OF AN EXPERIMENTAL DIGITAL LEARNING ENVIRONMENT WITH UNIVERSAL ACCESSIBILITY

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Today, learning with and about digital media is absolutely essential and explicitly demanded in the German strategy paper "Bildung in der digitalen Welt" (Education in the Digital World; KMK, 2016). At the same time, the digitisation offers great potential for teaching highly heterogeneous learning groups individually and comprehensively (Edyburn, 2010; Meyer, Rose, & Gordon, 2014). However, the use of digital media at German schools is still in its infancy (MPFS, 2018). In order to create a basis for the successful implementation of digital media in teaching, we intend to generate profound knowledge about the effectiveness of digital learning environments on the one hand and considering heterogeneous learning groups on the other hand.

Against this background, the aim of our project is to develop and evaluate a digital learning environment for lower grades in secondary education (age 13 to 14). Regarding the design of the teaching unit, we follow the concept of Universal Design for Learning (UDL; CAST, 2011), a model for joint learning of students with and without special needs. After a short introductory video, the teaching unit mainly consists of an experimental phase and a theoretical phase.

The aim of the study is to investigate the effects of the use of tablet computers in these different teaching phases on the students' learning outcome. To do so, we determine the content knowledge previous to the teaching unit and after every single teaching phase. Moreover, the students' attitudes towards the given teaching material as well as their cognitive load are retrieved after each teaching phase. With the help of a screen-capture-software, it is possible to retrace the steps of the students during their work with the devices. Additionally, the lessons are filmed to analyse the work behaviour of the learners using the tablet computers while experimenting.

Keywords: Computer Supported Learning Environments, Multimedia and Hypermedia Learning, Digital and post-truth era

INTRODUCTION

In addition to an abundance of various digital tools, tablets, in particular, are increasingly being used in teaching. They are seen as a valuable addition to the use of digital media, especially in secondary schools. The wide range of different applications (apps) available for tablets make them versatile learning companions, whose simple and intuitive operation is particularly suitable for children and young people (Rikala, Vesisenaho, & Mylläri, 2013). In addition, the devices enable the creation of digital learning environments in which students can learn at their own pace and via various sensory modalities (Huwer, Bock, & Seibert, 2018). Tablets thus also have the great potential of providing individualised and comprehensive support for students in heterogeneous or inclusive learning groups (Meyer et al., 2014). However, with regard to the effectiveness of digital learning environments, firstly in chemistry lessons and secondly in the context of a heterogeneous student body, there is still a need for research (Hughes, Ko, & Boklage, 2017).

THEORETICAL BACKGROUND

Digital learning

Compared to traditional analogue media, digital media offer a number of new potentials for teaching and learning at school. On the one hand, they facilitate storing, processing, distributing and organizing information. On the other hand, they expand existing media by various factors. Through their *interactivity*, digital media enable, for example, the development of collaborative and synchronously editable projects, which are accessible to all learners and can be constantly supplemented with comments, notes, images, etc. Due to their *adaptivity*, it is relatively easy to adapt information to the individual needs of learners using digital devices. Based on their *multimediality,* digital learning offers the possibility to mediate content through different forms of representation and sensory modalities. Since auditory and visual information are processed in different cognitive structures, the simultaneous activation of several channels allows a better use of the learner's brain receptivity (Mayer, 2014; Petko, 2014).

At the same time, however, there are also limitations of digital learning: For example, the use of digital media may pose the risk of overloading the working memory of students as digital learning content often has a higher information density and complexity. Multimedia learning material should therefore be designed in such a way that learners can use their cognitive resources as efficiently and effectively as possible (Sweller, Ayres, & Kalyuga, 2011). Moreover, through their dynamic transitions and linked contents, digital media might mislead learners to just skim through the content without gaining a deep understanding of the learning content (Girwidz & Hoyer, 2018). Finally, it should be pointed out that digital media should not only be used to replace their analogue predecessors, because in such cases their diverse applications would remain unused. In school practice, however, this can still be observed to a great extent. Summarising, it can be stated that digital media have great potential, but do not lead automatically to better learning (Puentedura, 2006).

Digital-supported experimentation

Experiments are an elementary part of teaching chemistry. Digital media offer possibilities to support experimentation at school in different ways. Starting with the introduction to the experiment, digital media can have a motivating and introductory function. Possible options are playing a trailer or video or using online articles or comics (Huwer, Seibert, & Brünken, 2018; Kuhn & Müller, 2014; Sieve & Schanze, 2015). Video instructions or animations can also be used to plan and guide experiments. At the same time, it is possible to compile overviews of the required materials and equipment as well as to present the construction of more complex experimental apparatuses both statically and dynamically (Ardac & Akaygun, 2004; Huwer, Bock et al., 2018; Sieve & Schanze, 2015). Moreover, there are different possibilities of using digital media regarding the experimental procedure. Nowadays, there are various providers offering so-called virtual labs in which experiments can be simulated. Digital devices such as computers, smartphones or tablets make it much easier to carry out a wide variety of measurements to collect and evaluate data extensively and have it graphically displayed. Experiments that cannot be carried out at school can be integrated by showing video demonstrations of these experiments. However, digital media can also have a supporting and differentiating character during the experiment, for example by offering learning aids and additional information (Bresges et al., 2014; Huwer, Bock et al., 2018; Irwansyah, Lubab, Farida, & Ramdhani, 2017; Kuhn & Vogt, 2013; Sieve & Schanze, 2015). Finally, there are useful application possibilities for the documentation of experiments. Smartphones or tablets can extend experimental protocols with the help of their photo function. The audio recording function provides auditive storage of experimental documentations. At the same time, phenomena that happen too fast for the human eye can be recorded and slowed down with the slow-motion function, just as particularly slow chemical processes can be recorded and shortened with the time lapse function (Vollmer & Möllmann, 2018).

Universal Design for Learning (UDL)

Even today, school lessons are usually planned for an imaginary average learner, which is why most of the times only one common access to learning is provided for all students. However, for some learners this may create barriers that cannot be overcome without additional support. In contrast, a learning environment with universal accessibility offers different ways of overcoming these barriers or creates alternatives so that each learner can individually choose their path to successful learning. In this context, the approach of Universal Design for Learning

Principles		Provide multiple means of Engagement	Provide multiple means of Representation	Provide multiple means of Action & Expression
Guidelines	Access	1. Recruiting Interest	4. Perception	7. Physical Action
	Build	2. Sustaining Effort & Persistence	5. Language & Symbols	8. Expression & Communication
	Internalize	3. Self Regulation	6. Comprehension	9. Executive Functions
Goals		Purposeful & Motivated	Resourceful & Knowledgeable	Strategic & Goal Directed

Figure 3: The Universal Design for Learning (cf.

(UDL; CAST, 2011) from the USA, which is a concept for the design of inclusive teaching, offers great potential. The UDL is particularly distinguished by the production of flexible and varied teaching materials. Its main aim is to minimise barriers that learners might encounter in the classroom. The UDL is divided into three principles, each of which is subdivided into three subordinate guidelines (see Figure 1). Thus, the UDL table can be used as a kind of checklist when designing inclusive lessons, whereby not all guidelines necessarily have to be observed. Furthermore, digital media are very helpful to implement the UDL guidelines, as they offer a higher degree of flexibility compared to analogue media. Thus, they have the potential ofincreasing the individually adaptable support in school education (Edyburn, 2010; Rose, Hasselbring, Stahl, & Zabala, 2007).

RESEARCH QUESTIONS

In the context of this project, we focus on the following research questions:

Expertise Knowledge

Q1: Do the students increase their expertise knowledge?

Q1.1: Is the use of digital teaching materials differently effective in particular teaching phases?

Q1.2: Are there differences regarding the increase of the expertise knowledge when learning with exclusively digital or analogue teaching materials?

Attractiveness

Q2: How do learners rate the digital teaching materials compared to the analogue ones?

Cognitive Load

Q3: What influence do digital teaching materials have on the cognitive load of learners compared to analogue teaching materials?

RESEARCH DESIGN & TEST INSTRUMENTS

The following research design was developed in order to investigate the research questions. As depicted in Figure 2, the intervention is carried out in form of a project day at schools. The students of a class are divided into two comparable groups according to their expertise knowledge and cognitive skills, which are determined in the pre-test. At first, both groups receive a motivating introductory video. Afterwards, G1 continues to work digitally in the following two teaching phases, while G2 works analogously. In this way, a comparison between digital learning and learning with analogue learning materials in different teaching phases can be realised.

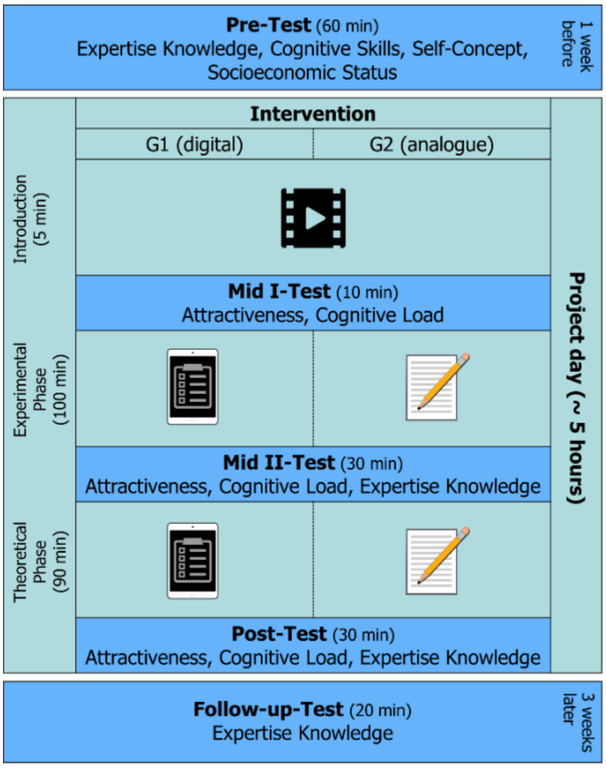

Figure 4: Research design.

The research questions are examined using various test instruments. One week before the intervention, an expertise knowledge test (24 items, α = .795) is carried out as part of the pre-testing in form of a multiple-choice test to assess the learners' prior knowledge. In addition to an intelligence test to determine the cognitive abilities (CFT 20-R; Weiß, 2006), a questionnaire to assess the school self-concept (Rost, Sparfeldt, & Schilling, 2007) and a questionnaire on the socioeconomic status (Torsheim et al., 2016) are carried out. Within the intervention, an attractiveness test (10 items, 6-point Likert scale, α = .871) as well as a cognitive load test (6-point Likert scale, 10 items, α = .834) in form of assessment sheets are used after the individual teaching phases. Moreover, the expertise knowledge test is conducted again after the experimental and theoretical phases in order to determine the effects of the individual phases on the learning growth of the students. Three weeks after the intervention, the follow-up test takes place in order to measure the long-term effects. Furthermore, the individual actions of the students working with the iPads are documented via screen recordings. Selected students working with the teaching materials are videotaped.

THE LEARNING ENVIRONMENT

Our study is conducted with students of the 8th grade of General schools (age group 13 to 14) on the subject of separating mixtures. The learning environment mainly consists of three phases: An introductory video, an experimental phase and a theoretical phase. Starting with the video, this is intended to provide a motivating leading-in to the topic, although no subject-related content is focused. After that, the experimental phase takes place, in which the learners carry out the different separation processes. The students work individually here. Each student receives an own experimental box and the corresponding teaching materials. After the experimental phase, the contents are taken up in more detail within the theoretical phase. Here the students are firstly provided with general information about the particular separation process. After this, the students can solve different tasks and finally have to summarise their newly acquired knowledge. In the theoretical and experimental phase, the students work with either an interactive iBook or with analogue paper pencil materials. These were designed in form of a workbook, which have identic content as the iBook.

FIRST RESULTS

In the course of this project, two pilot studies have been carried out so far, which is why in the following, we will contrast the results of both of them. Essential changes from pilot study I (PS I) to pilot study II (PS II) is the revision of the test instruments for evaluating the expertise knowledge, attractiveness and cognitive load. These have further improved with regard to their Cronbach's alpha values. In addition, within the framework of PS II, index cards were made available at the end of the theoretical phase for students who had finished this phase at an early stage. These index cards summarised the theoretical content.

Q1: Do the students increase their expertise knowledge?

Starting with the results for research question Q1 first regarding PS I, Figure 3 shows, that the expertise knowledge of both the digital and the analogue group has improved significantly in the pre-post-comparison (digital: $p < .001$, $\varphi = .75$, analogue: $p = .002$, $\delta = .62$). With regard to the increase within the individual phases, it can be observed that in the experimental phase, meaning from PRE to MID II, both groups learn significantly (digital: $p = .009$, $\varphi = .39$, analogue: $p < .001$, $\delta = .76$). In the theoretical phase, from MID II to POST, however, only the digital group learns significantly, while the analogue group stagnates (digital: $p < .001$, $\delta = .69$, analogue: $p = .618$, $\delta = .09$). In PS II, these findings cannot be observed. Here, both groups significantly improve their expertise knowledge in the experimental phase (digital: $p < .001$, $\delta = .81$; analogue: $p < .001$, $\delta = .70$) as well as in the theoretical phase (digital: $p < .001$, $\delta = .77$, analogue: $p < .001$, $\varphi = .57$).

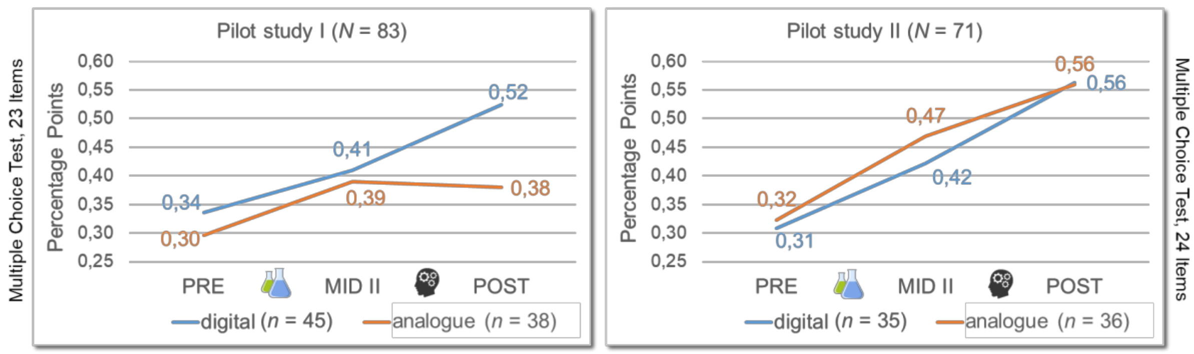

Figure 5: Results of pilot study I + II regarding expertise knowledge.

Comparing the digital and analogue groups, there is a significant difference between the two groups in the POST test of PS I ($p < .001$, $\delta = .76$). This difference, however, cannot be found in PS II ($p = .831$, $\varphi = .03$). It can be assumed that this is related to the use of index cards at the end of the theoretical phase of PS II, in which the analogue group could have learned a lot more from them compared to the digital group. As we took a closer look at these cards again, we noticed that the contents of the cards were very similar to the tasks of the expertise knowledge test, which could have led into "teaching to test". This might have concealed possible effects, which is why it can no longer be determined whether the increase in expertise knowledge is due to the learning environment or the final index cards. Furthermore, we suspect that the index cards were especially effective in the analogue group since they were an additionally provided medium to the workbooks. While the analogue group paid special attention to the new medium, the students working in the digital learning environment were only provided with additional pages containing digital index cards in the iBook. However, we can only confirm these results with certainty once we have evaluated the video and screen recordings. At MID II, after the experimental phase, there were no significant differences between the two groups in either of the two pilot studies (PS I: $p = .854$, $\varphi = .02$, PS II: $p = .233$, $\delta = .29$).

Q2: How do learners rate the digital teaching materials compared to the analogue ones?
In order to investigate research question Q2, an assessment sheet with a 6-point Likert scale was used to measure the attractiveness of the teaching materials, whereby the value 6 corresponds to the highest and 1 to the lowest attractiveness. As Figure 4 shows, both, PS I and PS II, show similar results: In principle, the students of both groups in both pilot studies rate the learning materials as attractive. Nevertheless, the experimental phase is rated slightly more attractive by all learners. In total, no significant differences between the digital and analogue groups could be identified, neither in PS I (MID I: $p = .853$, $\varphi = .02$, MID II: $p = .293$, $\varphi = .11$; POST: $p = .059$, $\varphi = .20$) nor in PS II (MID I: $p = .235$, $\varphi = .14$, MID II: $p = .085$, $\varphi = .21$; POST: $p = .916$, $\varphi = .01$).

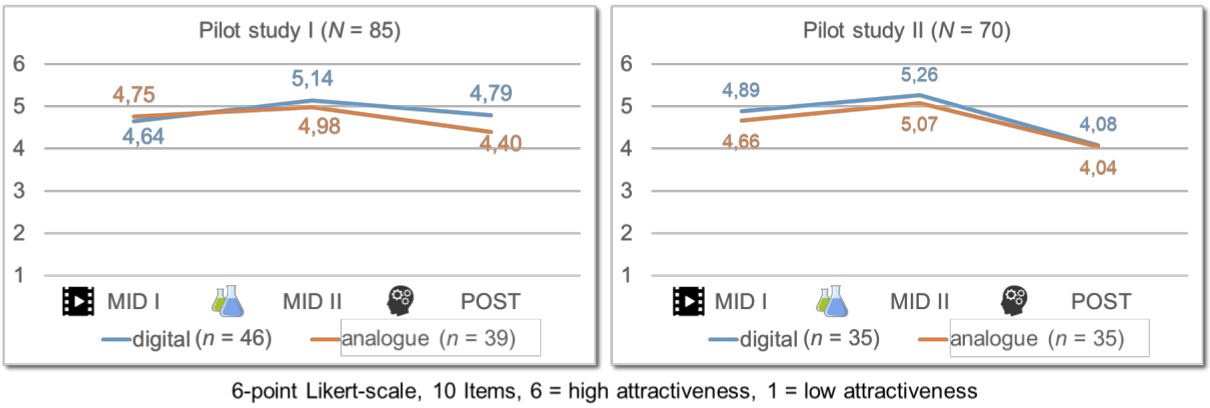

Figure 6: Results of pilot study I + II regarding attractiveness.

Q3: What influence do digital teaching materials have on the cognitive load of learners compared to analogue teaching materials?
Research question Q3 concerning the cognitive load was examined with a further assessment sheet, which was also based on a 6-point Likert scale, in which the value 6 corresponds to a low and 1 to a high cognitive load. Here, as well, the two pilot studies show similar results. Hence, Figure 5 shows that there are no significant differences between the digital and the analogue group in PS I (MID I: $p = .885$, $\delta = .03$, MID II: $p = .996$, $\varphi = .00$; POST: $p = .233$, $\varphi = .13$) as well as in PS II (MID I: $p = .953$, $\delta = .01$, MID II: $p = .165$, $\varphi = .17$; POST: $p = .725$, $\varphi = .04$). Both groups in both studies rate the experimental part as the least stressful part, followed by the theoretical part and the introductory video.

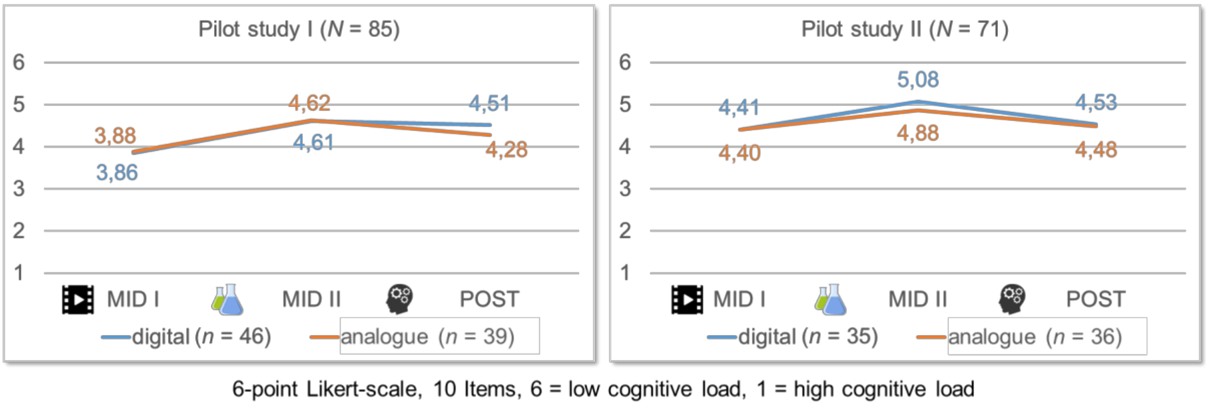

Figure 7: Results of pilot study I + II regarding cognitive load.

CONCLUSION

In summary, it can be stated that in terms of expertise knowledge, a significant increase could first be ascertained through the learning environment within both groups and in both pilot studies. What is striking is the very significantly better result of the digital group in the post test of PS I, which does not occur in PS II. This is probably related to the use of the mentioned index cards. As a consequence, the index cards are not used in the following main study. Furthermore, no significant differences were found between the two groups with regard to both the attractiveness of the teaching materials and the cognitive load when working with the materials.

Overall, these first results suggest that the use of digital media in both pilot studies did not have any negative effects in either case, but tend to have a positive influence on the learning outcome of the students. Regarding the increasing digitisation of German schools, this may dispel initial concerns about a decline in the quality of teaching. On the basis of these first findings, future projects can investigate how the potential of digital media can be fully exploited and how digitally supported chemistry teaching can be further optimised.

After the revision of the developed learning environment of the second pilot study, we have begun the main study of the project with a sample size of about 250 students, which will be concluded in February 2020. Moreover, the development of coding manuals for evaluating the screen and video recordings as well as the final analysis of the collected data after the main study are still pending.

ACKNOWLEDGEMENT

We would like thank to the participating chemistry teachers and the learners.

REFERENCES

Ardac, D., & Akaygun, S. (2004). Effectiveness of multimedia-based instruction that emphasizes molecular representations on students' understanding of chemical change. *Journal of Research in Science Teaching*, *41*(4), 317–337. https://doi.org/10.1002/tea.20005

Bresges, A., Beckmann, R., Schmoock, J., Quast, A., Schunke-Galley, J., Weber, J., & Firmenich, D. (2014). Tablets beim physikalischen Experimentieren: - zur Unterstützung des Kompetenzaufbaus. *Praxis der Naturwissenschaften - Physik in der Schule*, *63*(5), 11–16.

CAST (2011). Universal Design for Learning Guidelines version 2.0. Retrieved from http://www.udlcenter.org/aboutudl/udlguidelines/downloads

CAST (2018). Universal design for learning guidelines version 2.2 [graphic organizer]. Retrieved from http://udlguidelines.cast.org/more/downloads

Edyburn, D. L. (2010). Would You Recognize Universal Design for Learning if You Saw it? Ten Propositions for New Directions for the Second Decade of UDL. *Learning Disability Quarterly*, *33*(1), 33–41. https://doi.org/10.1177/073194871003300103

Girwidz, R., & Hoyer, C. (2018). Didaktische Aspekte zum Einsatz digitaler Medien - Leitlinien zum Lehren mit Multimedia, veranschaulicht an Beispielen. In J. Meßinger-Koppelt & J. Maxton-Küchenmeister (Eds.), *Naturwissenschaften / Joachim Herz Stiftung. Naturwissenschaften digital: Toolbox für den Unterricht* (1st ed.). Hamburg: Joachim Herz Stiftung Verlag.

Hughes, J. E., Ko, Y., & Boklage, A. (2017). iTeachSTEM: Technological Edgework in High School Teachers' iPad Adoption. *RESEARCH IN THE SCHOOLS*, *24*(1), 45–62.

Huwer, J., Bock, A., & Seibert, J. [Johann] (2018). The School Book 4.0: The Multitouch Learning Book as a Learning Companion. *American Journal of Educational Research*, *6*(6), 763–772. https://doi.org/10.12691/education-6-6-27

Huwer, J., Seibert, J. [J.], & Brünken, J. (2018). Multitouch Learning Books als Versuchsanleitungen beim Forschenden Experimentieren am Beispiel von Süßungsmitteln. *Der mathematische und naturwissenschaftliche Unterricht*, *2018*(03), 181–186.

Irwansyah, F. S., Lubab, I., Farida, I., & Ramdhani, M. A. (2017). Designing Interactive Electronic Module in Chemistry Lessons. *Journal of Physics: Conference Series*, *895*, 12009. https://doi.org/10.1088/1742-6596/895/1/012009

KMK (2016). Strategie der Kultusministerkonferenz "Bildung in der digitalen Welt": Beschluss der Kultusministerkonferenz vom 08.12.2016. Retrieved from https://www.kmk.org/fileadmin/Dateien/pdf/PresseUndAktuelles/2017/Strategie_neu_2017_datum_1.pdf

Kuhn, J., & Müller, A. (2014). Context-based science education by newspaper story problems: A Study on Motivation and Learning Effetcs. *Perspectives in Science*. (5), 5–21.

Kuhn, J., & Vogt, P. (2013). Smartphones as experimental tools: Different methods to determine the gravitional acceleration in classroom physics by using everyday devices. *European Journal of Physics Education*, *4*(4), 16–27.

Mayer, R. E. (Ed.). (2014). *Cambridge handbooks in psychology*. *The Cambridge handbook of multimedia learning* (Second edition). New York: Cambridge University Press. https://doi.org/10.1017/CBO9781139547369

Meyer, A., Rose, D. H. [D. H.], & Gordon, D. (2014). *Universal design for learning: Theory and practice*: CAST Professional Publishing. Retrieved from http://udltheorypractice.cast.org/home?2

MPFS (2018). JIM 2018 - Jugend, Information, (Multi-)Media. Basisuntersuchung zum Medienumgang 12- bis 19-Jähriger. Retrieved from https://www.mpfs.de/fileadmin/files/Studien/JIM/2018/Studie/JIM_2018_Gesamt.pdf

Petko, D. (2014). *Einführung in die Mediendidaktik: Lehren und Lernen mit digitalen Medien*. *Pädagogik: Vol. 25*. Weinheim: Beltz. Retrieved from http://www.vlb.de/GetBlob.aspx?strDisposition=a&strIsbn=9783407256782

Puentedura, R. R. (2006). Transformation, Technology, and Education. Retrieved from http://hippasus.com/resources/tte/

Rikala, J., Vesisenaho, M., & Mylläri, J. (2013). Actual and Potential Pedagogical Use of Tablets in Schools. *Human Technology: An Interdisciplinary Journal on Humans in ICT Environments*, *9*(2), 113–131. https://doi.org/10.17011/ht/urn.201312042736

Rose, D. H. [David H.], Hasselbring, T. S., Stahl, S., & Zabala, J. (2007). Assistive Technology and Universal Design for Learning: Two Sides of the Same Coin. Retrieved from https://pdfs.semanticscholar.org/75a2/2d319afce4e5323d0ed22abe27f2e913c841.pdf

Rost, D. H., Sparfeldt, J. R., & Schilling, S. R. (2007). *DISK-Gitter mit SKSLF-8: Differentielles Selbstkonzept-Gitter mit Skala zur Erfassung des Selbstkonzepts schulischer Leistungen und Fähigkeiten*. Göttingen: Hogrefe.

Sieve, B., & Schanze, S. (2015). Lernen im digital organisierten Chemieraum. *Praxis der Naturwissenschaften - Chemie in der Schule*, *64*(3), 2–7.

Sweller, J., Ayres, P., & Kalyuga, S. (2011). *Cognitive Load Theory* (1st ed.). *Explorations in the Learning Sciences, Instructional Systems and Performance Technologies: Vol. 1*. New York, NY: Springer New York.

Torsheim, T., Cavallo, F., Levin, K. A., Schnohr, C., Mazur, J., Niclasen, B., & Currie, C. (2016). Psychometric Validation of the Revised Family Affluence Scale: A Latent Variable Approach. *Child Indicators Research*, *9*, 771–784. https://doi.org/10.1007/s12187-015-9339-x

Vollmer, M., & Möllmann, K.-P. (2018). Slow speed—fast motion: time-lapse recordings in physics education. *Physics Education*, *53*(3), 35019. https://doi.org/10.1088/1361-6552/aaa954

Weiß, R. H. (2006). *Grundintelligenzskala 2 (CFT 20-R)*. Göttingen: Hogrefe.

ARE SIGN LANGUAGE EQUIVALENTS FOR TECHNICAL TERMS REQUIRED FOR DEAF SCIENCE EDUCATION?

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Many technical terms are used in university lectures. However, the terminology of scientific disciplines is not often used in the common vernacular of the hearing-impaired community. We chose 100 technical terms related to information science. Of these, fifty nine percent of these terms were authorized.", but the remaining 41% did not have a sign language equivalent, or sign language expressions were not yet established. Therefore, in this study, by first focusing on the technical terms of information science, we created a Japanese sign language video dictionary for learning the technical terms used in science information. We continued the study with the following steps: 1) Identification of the technical terms used in information science. 2) Investigation of the common sign language signs for technical terms. 3) Filming of these signs. 4) Proposal of appropriate representation for classifier. 5) Building of the web video dictionary site. 6) Evaluation of the video dictionary site by users. 7) Improvement of the video dictionary site. Twenty-three sign language users evaluated the sign language video dictionary. Around 70% of participants answered that the sign language video dictionary for technical information science terms was necessary, and about 80% of respondents said that it was useful. Furthermore, many people (about 90%) answered that they could learn new technical terms in sign language. The sign language video dictionary of technical terms would be highly effective in science education for students who are deaf or hard-of-hearing. Sign language and CL (classifiers) can express invisible logic and the mechanical characteristics of objects. For that reason, sign language and CL can encourage anyone to understand science. A knowledge of technical terms in sign language and CL may lead to a scientific education based on a universal design perspective.

Keywords: Information Science, Sign Language, Video Dictionary, Universal Design

BACKGROUND

Despite the widespread use of sign language, the number of native signers in the world has not been accurately counted. The WHO said that "around 466 million people worldwide have disabling hearing loss, and 34 million of these are children" (WHO, 2019). Additionally, Michael (2006) reported that there are 250,000 to 500,000 American Sign Language users. The Japanese Ministry of Health announced that there are 60,000 Japanese sign language users (2008). We must seriously consider education and communication for people with hearing impairment.

Many technical terms are used in university lectures. Higher education institutions that target the hearing impaired in Japan have lectures conducted in sign language. However, the specific terminology of scientific disciplines is not often used in the common vernacular of the hearing-impaired community. The hearing-impaired students who attend a specialized class may not be able to understand the lecture. Alternatively, various sign language expressions may be made using the same technical term, and this may cause confusion.

Therefore, in this study, by first focusing on the technical terms used in information science, we create a sign language video dictionary for learning information science terminology through self-study before and after the lecture.

Similar projects have focused on American Sign Language (the ASL STEM Forum in 2019) and British Sign Language (the BSL Glossary project in 2019). Several specialized areas were covered, including mathematics; information and communication technology; physical science and physics, and meteorology. However, these kinds of international resources cannot be transferred to Japan, because Japanese sign language is very different. There is not yet a sign language video dictionary to contribute to science education for hearing-impaired students in Japan.

RESEARCH QUESTIONS

1. How many technical terms from scientific disciplines are there in Japanese sign language?
2. Do deaf students need the sign language video dictionary to aid in their science education in Japan?

PRODUCTION OF THE SIGN LANGUAGE VIDEO DICTIONARY

Design procedure

Science education has a very wide range; therefore, we limited this study to information science terms only. We carried out our research as follows:

1. Identification of the technical terms used in information science.
2. Investigation of the common sign language signs for technical terms.
3. Filming of these signs.
4. Proposal of appropriate representation for classifier.
5. Building of the web video dictionary site.
6. Evaluation of the video dictionary site by users.
7. Improvement of the video dictionary site.

1. Identification of the technical terms used in information science.

We selected 92 technical science terms using materials from information science and mathematics lectures. Deaf or hard-of-hearing students from the Department of Information Science at Tsukuba University of Technology were required to fill out the questionnaire. They decided on which technical terms to include in the dictionary and added the missing technical terms. In total, we selected 100 technical terms on information science.

2. Investigation of the common sign language signs for technical terms.

As a result, we found that 37 of these signs were posted in a dictionary, and 22 expressions were published on the Internet. These results indicated that 59% of all the technical terms were approved, while the remaining 41% had no equivalent sign, or no sign language expression had been established (Figure 1).

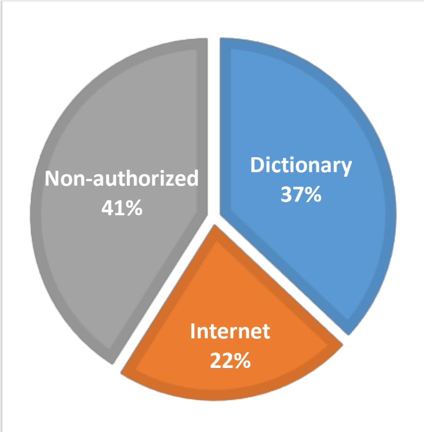

Figure 1. How many technical terms do we have in Japanese sign language?

3. Filming of sign language.

We represented the generic words in sign language dictionaries, but we needed to create the non-generic words by CL (classifier). To make the sign language easy to see, the performer wore a long-sleeved back shirt against a white background. Both M4V and MP4 file formats were prepared. MP4 made one file 8 MB or less. We edited the videos in both normal speed and slow motion. These videos were prepared from a front view and a side view.

4. Proposal of appropriate representation for classifier.

We needed to create the non-generic words by CL. What is CL? CL means classifier. The sign containing "handshapes in particular orientations to stand for certain semantic features of noun arguments" (Frishberg, 1975) came to be called classifier predicates (Lindell, 1977). The commonly recognized handshapes that are typically used to show different classes of things, shapes, and sizes are called "classifiers." Classifiers are basic elements of sign language, and they are widely used in deaf education. Classifiers share some limited similarities with the gestures of hearing non-signers. Those who do not know sign language can often guess the meaning of these constructions.

We assigned the following task to deaf students: express the technical terms "xx" with your fingers and arms. We recorded their ideas, discussed them together, and narrowed them down to one idea.

We give specific examples below (Figure 2). The definition of an electric circuit is "a complete electrical network with a closed-loop giving a return path for current. (Wikipedia)" The student said, "The CL on the left looks like paper. On the other hand, the CL on the right represents the path through which the current from the battery flows."

After narrowing them down to one idea, we conducted a questionnaire on the clarity of the proposed CL. An idea that received a rating of at least 3 points was adopted (Figure 3).

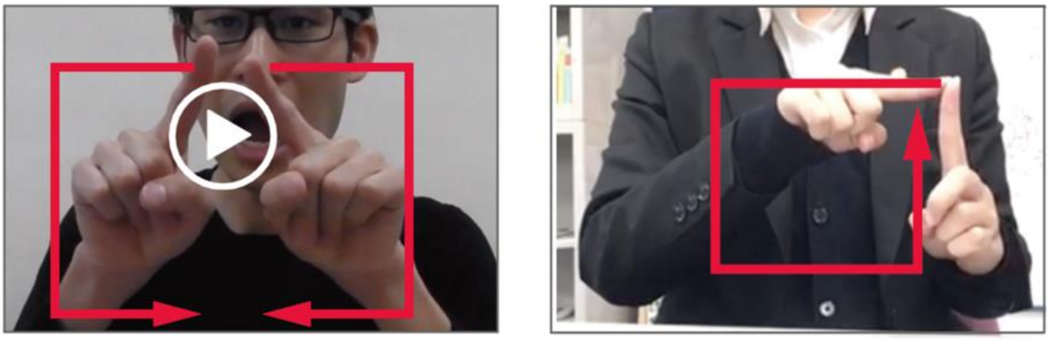

Figure 2. Proposed expression of "electric circuit"

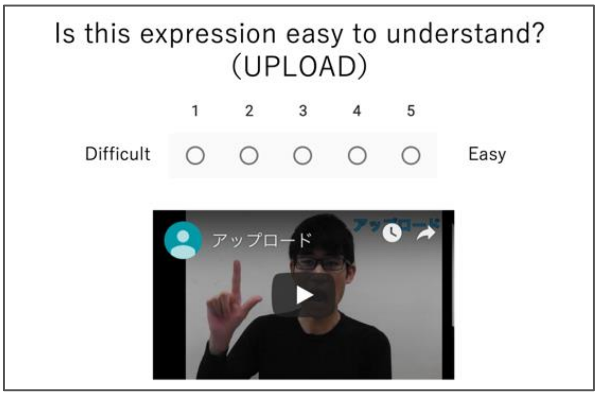

Figure 3. Screenshot of evaluation questionnaire.

5. Building the web video dictionary site.

We designed web pages where students could search the targeted sign language from a list of the Japanese alphabet. We explained how to sign particular words and the origin of the movements used to sign them.

6. Evaluation of the sign language video dictionary.

From November 16th to 30th, 2018, we conducted an online questionnaire using Google Form in order to evaluate the site prototype. In total, 23 students and teachers participated in this evaluation (14 university students, six junior high school students, and three junior high school teachers). All participants were sign language users.

7. Improvement of the video dictionary site.

The following revisions have been made in response to advice from participants. In addition to the Japanese alphabet list, an English alphabet list was created. Icons that were referred from Microsoft Word were also added to allow users to identify at a glance whether the sign language term was quoted from the dictionary or the original-CL (Figure 4, 5).

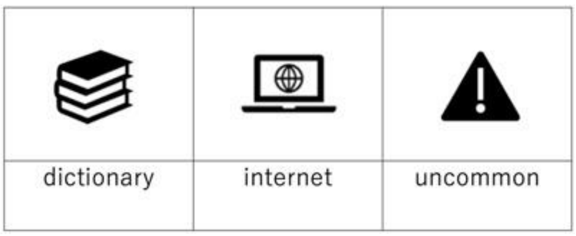

Figure 4. **Icons for citation sources**

Figure 5. Design of the web video dictionary

RESULTS OF THE EVALUATION

The results of user evaluation indicated that 78.3% of participants thought the sign language video dictionary was useful, 69.6% thought it was necessary, and 60.9% said they would like to use it (Figure 6).

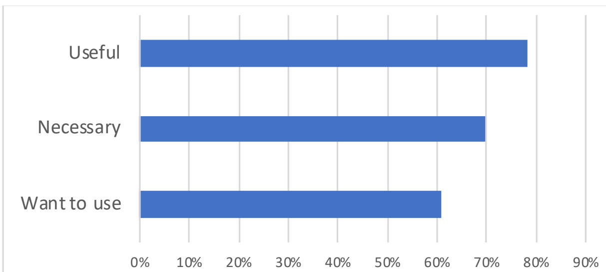

Figure 6. Comprehensive evaluation of the sign language video dictionary.

In evaluating the efficiency of the site, 95.7% of participants responded that its "operation was easy," while 78.3% of participants answered that it was "easy to see on-screen information" and 69.6% of participants answered that "I was able to find the necessary information at once." As for its effectiveness, 91.3% of participants answered: "I was able to learn new technical terms in sign language," and 82.6% of participants answered that "I could acquire new knowledge." Overall, 56.5% of participants were satisfied, and 65.2% of participants answered: "I would like to introduce this site to someone else (Figure 7)."

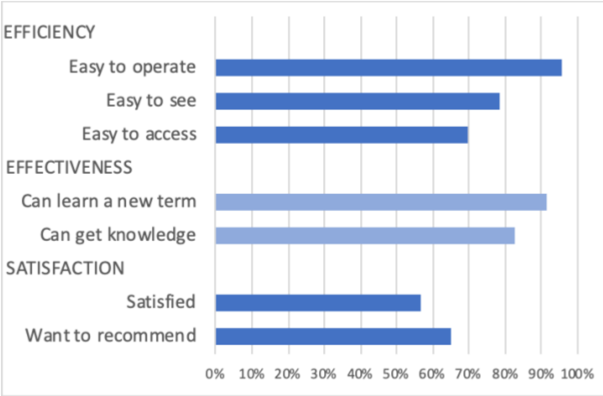

Figure 7. Evaluation of the usability of the sign language video dictionary.

To confirm that the site was easy to understand, the following three questionnaires were set. The results showed that 82.6% of participants answered that "the explanation of technical terms in the sign language video was easy to understand," 82.6% of participants answered that "the explanation of the motion and handshape were easy to understand," and 78.3% of participants answered that "the sentences about how to express sign language were easy to understand (Figure 8; Left)."

In response to the animated expression of the sign language terms, 47.8% of participants answered that "the slow-motion version is necessary" and 47.8% answered that "the voice data is necessary." Furthermore, 73.9% of participants answered that "the side view of the motion is necessary (Figure 8; Right)."

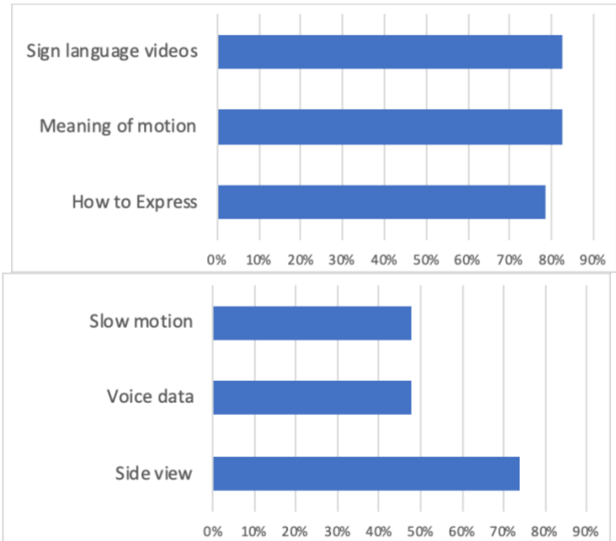

Figure 8. Left: Information on understandability / Right: Information on necessary elements

DISCUSSION

Around 70% of participants answered that the sign language video dictionary for technical information science terms was necessary, and about 80% of respondents said that it was useful. The results show that the sign language video dictionary was both necessary and useful for students who are deaf or hard-of-hearing. Furthermore, many people (about 90%) answered that they could learn new technical terms using sign language. This sign language video dictionary would be highly effective for hearing impaired students.

The sign language video dictionary we created was easy to operate and could provide information relatively efficiently. This dictionary was fine from a usability and information accessibility perspective. The level of understanding of information in sign language, including the original CL, was also high. However, as the satisfaction level was 57%, we think that there is a need for improvement. We understand that the slow-motion videos in sign language were unnecessary. Unfortunately, we do not know what caused the lack of satisfaction. Elucidating points for improvement need to be addressed as a future task. We plan to hold workshops to create a robust language while incorporating research from previous studies (O'Neill, 2016).

CONCLUSION

In Japan, 59% of technical terms for information science in Japanese Sign Language were authorized and 41% were not. Therefore, we designed the Japanese Sign Language video dictionary site using the original CL. Sign language video dictionaries for scientific information have proved necessary and effective for deaf and hard-of-hearing students. We were convinced that the development of a large-scale Japanese sign language science dictionary would be needed.

The sign language video dictionary of technical terms can be highly effective in science education for students who are deaf or hard-of-hearing. Sign language and CL (classifier) can express invisible logic and the mechanical characteristics of objects. For that reason, sign language and CL can encourage anyone to understand science. A knowledge of technical terms in sign language and CL may lead to science education based on a universal design perspective.

ACKNOWLEDGEMENT

This work was supported by JSPS KAKENHI Grant Numbers JP18H03660.

REFERENCES

Gottardis, L., Nunes, T. And Lunt, I (2011). A synthesis of research on deaf and hearing children's mathematical achievement. Deafness and Education International, vol. 13 (3), 131-150.

ASL Stem Forum (2019). Enabling American Sign Language to grow in Science, Technology, Engineering and Mathematics, https://aslstem.cs.washington.edu/info/about, date accessed 31th. Jan 2019.

BSL Glossary project (2019). British Sign Language Glossaries of Curriculum Terms, http://www.ssc.education.ed.ac.uk/bsl/, date accessed 1st. Jan. 2020.

Japanese Ministry of Health (2008). Fact-finding survey on disabled children and people. https://www.mhlw.go.jp/toukei/saikin/hw/shintai/06/dl/01_0001.pdf, date accessed 31th. Jan 2019.

K.P. O'Neill, A. Cameron, G. Quinn, R. O'Neill and F. McLean (2016), British Sign Language Glossary for Mathematics and Statistics. IMA International Conference on Barriers and Enablers to Learning Maths: Enhancing Learning and Teaching for All Learners, 1-7. https://www.researchgate.net/publication/309476603_British_Sign_Language_Glossary_for_Mathematics_and_Statistics.

Mitchell, Ross; Young, Travas; Bachleda, Bellamie; Karchmer, Michael (2006). "How Many People Use ASL in the United States?: Why Estimates Need Updating" (PDF). Sign Language Studies. 6 (3). ISSN 0302-1475. Retrieved November 27, 2012.

World Health Organization (2019). Fact Report: Deafness and hearing loss. https://www.who.int/news-room/fact-sheets/detail/deafness-and-hearing-loss, date accessed 1st. Jan. 2020.

Wikipeadia, Circuit, Electrical circuit. https://en.wikipedia.org/wiki/Circuit, date accessed 19th. Jan. 2020.

Our site (only Japanese and Japanese sign language): http://is-sign-language.sub.jp/

HOW STUDENTS COMBINE REPRESENTATIONS FROM DIFFERENT MEDIATIONS TO UNDERSTAND THE ELECTRIC FIELD CONCEPT IN ELECTROSTATICS.

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The use of simulations in Physics Teaching is effective in aiding the visualization and the correct understanding of the physical models, for example, in electrostatics. Therefore, with the use of a computer simulation (GeoGebra), this work aims to investigate the preferred mediation chosen by five undergraduate Engineering students when solving a problem of the intensity of the electric field. The Cognitive Mediation Networks Theory (CNMT) was used as theoretical referential. We used as methodology a qualitative analysis of the speech and depictive gesture produced by the students. Thus, our results indicated that through computer simulation, all five students appropriated the hypercultural representation of the software, establishing a relation between the distance of the charge and the electric field point. Nonetheless, the psychophysical mediation and social mediation is preferred to describe the concept of charge.

Keywords: Computer Based Learning, Physics, Video Analysis.

INTRODUCTION

It is argued that the study of physical phenomena related to electromagnetism is more prone to be an abstract than a mechanical, “hands-on” problem (Lopez & Silva, 2015). However, students' understanding of the physical phenomena involved still causes discomfort, due to some complex elements of visualization and the difficulty that students have in creating and using representations of the application of physics (Gire, 2014). In this sense, Kneubil & Ricardo (2014) point out that students may fully understand the theory, but there seems to be a great distance between formalism and reality.

According to Guisasola et al. (2008), there are few papers that analyze the phenomena of the electric charge whose focus is on the interpretation of the students in relation to the electric charge processes in a body, or that actually is interested in the understanding of the knowledge and cognitive skills that the students need to have to interpret these phenomena.

The students use common sense, being characterized by the lack of consistency in the analyzes in relation to different situations, and that the explanations have a lack of consistencies and scientific interpretations to describe the phenomena related to electrostatics (Furió, Guisasola and Almudí, 2004). According to Boss et al. (2009), although students have worked on the concept of electric charge in high school, they have confused conceptions and difficulties in explaining the concept when they encounter the discipline of General Physics in higher education.

The didactic use of computer visualization of eletromagnetic phenomena is reported to increase students' understanding and their ability to internally visualize microscopic and macroscopic electromagnetic representations, as is well-known in the science education literature (Pieper, F. C. & Serrano, A., 2016, did a review on the topic). In this article, we aims to investigate the preferred mediations evidenced by five students when solving a problem of electrostatics using the Cognitive Mediation Theory as theoretical referential. Do they have different preferred mediations when learning different concepts within electromagnetism?

THEORETICAL REFERENTIAL

In his Cognitive Networks Mediation Theory, Campello de Souza, Silva, Silva, Roazzi, & Carrilho (2012) indicates that cognitive development involves the interaction of an individual with objects and systems that have the ability to perform computations, being a process that involves the simultaneous emergence of internal and external mechanisms of mediation. The individual not only allocates the same computational resources, but also gains new concepts, where the new internal mechanisms present in the cognitive structure of the individual are named *drivers* (as employed in computation) that make possible the use of external mechanisms. The brain, to guarantee cognitive mediation with an external mechanism, formulates new specific competences that allow communication. For an integration between information processing carried out by the brain and external mechanisms to occur, computational devices that translate inputs and outputs are necessary, as if software were installed, "*device drivers*" that recognize and program external hardware. Cognitive mediation occurs by relating internal and external processes to the cognitive structure through internal mechanisms through individual knowledge and access and use of external mechanisms, enabling the acquisition of knowledge and development of the cognitive structure. In relation to mental images they can be static and can be dynamic, and drivers are associated with dynamic mental images, while static mental images are much more related to representations.

Regarding the levels of mediation, in Campello de Souza, Silva, Silva, Roazzi & Carrilho (2012), also detailed in Serrano et al. (2018), there are essentially four major levels of mediation: Psychophysical Mediation, related to the physiological characteristics of the subject with the composition of the object; Social Mediation, when interaction occurs with different people in the same environment; Cultural Mediation, implying the language and the capacity of society to report events involving categorizations of ideas and concepts; And Hypercultural Mediation, which uses access to technology, to the computer, to simulations, that is, there is use of technological tools. Therefore, when learning a new concept, students may make use of one or more mediations to make sense of it. Our research question is then: How students combine representations from different mediations to understand the electric field concept in electrostatics?

METHODOLOGY

The study was done in the first half of 2017, with five students of the Civil Engineering under graduation course. The methodology consisted of six stages that were explained below.

Pre-test: performed individually with four open problems, involving electric field concepts before computer simulation, aiming to investigate the students' initial knowledge about concepts related to the conceptual field of electrostatics. Essentially we progressively proposed problems that grow in complexity regarding the value of an electric field in a specific point of space (bidimensional), starting with a single charge and adding a second charge so the student had to calculate the resulting field at a given point, changing the charges signal.

Computer Simulation Guide: The activity guide was intended to guide pairs of students, performing the simulation while talking to each other, in the development of the proposed activity in GeoGebra, referring to the electric field. The activity was based on the P.O.E. (Predict-Observe-Explain) methodology, where the students had to first discuss on how to compute the electric field, then, which means to predict-observe-explain (Tao & Gunstone, 1999).

Simulation: The chosen simulation is available at <https://www.geogebra.org/m/eHyU8ZmU> according to figure 1, it refers to the content of Electrostatics, which is the study of charges at rest. In this simulation it is possible to visualize the electric field vector generated by the charges, which indicate the intensity and direction of the field.

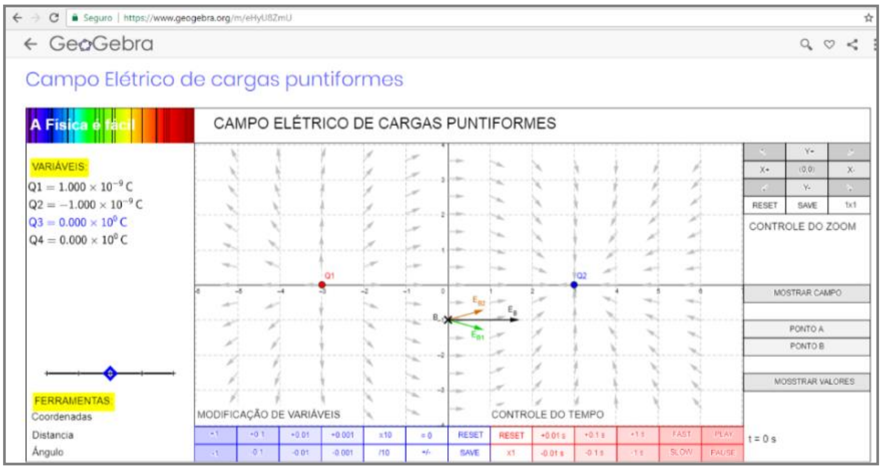

Figure 1. Computer similation used in the didactic activity. The charges can be changed and the student can interact with the position of the test point (X at the middle), while watching the resulting electric field changing. Source: https://www.geogebra.org/m/eHyU8ZmU

Post-test: the problem situations were similar to those of the pre-test, however, our objective was to find evidence in the construction and / or modification of mental images associated with the use of different external mediation mechanisms in the domain of problem situations.

Interview: Were recorded and were individual, we use the Report Aloud technique in which the student reports his thought process while answering questions, associated with the analysis of descriptive gestures. Ramos (2015), Wolff (2015), Trevisan (2016), Veloso (2017) and Meggiolaro (2019) used the Report Aloud technique, that is fully explained in Trevisan, Serrano, Wolff and Ramos (2019). and observed that even with a few days between the activity with the resolution of the questions and the interview, the student remembered the triggers he applied in the activity.

Transcription and gestures: Each student was renamed in order to identify them and preserve their original names. The interviews were transcribed and the images of the gestures were coded.

With the intention of analyzing the verbal language present in the production of data, we use the Discursive Textual Analysis proposed by Moraes & Galiazzi (2007), which involves identifying and isolating statements from the materials submitted to analysis, categorizing these statements and producing texts, integrating them into the description and interpretation, using the constructed category system as the basis for its construction.

Descriptive Gestural Analysis in relation to students' gestures, based on Mornaghan & Clement (1999) and Clement & Stephens (2010), in which they state that when students use hand movements they are suggesting dynamic images of mental simulations during the resolution of relative motion problems.

RESULTS

Our first main result is that the mental image that the electric field varies with distance is established by hypercultural mediation. More specifically, students 5, 6, 7, 8 and 9 internalized the hypercultural mediation derived from computational simulation to understand the relationship between distance and intensity of the electric field vector.

Evidence: The conception that student 5 (Figure 2) describes was incorrect (in the pre-test) in relation to the intensity of the vector, since, when we approach the electric charge, the module of the electric field vector is larger, not smaller: "*when I approached the point of charge (Figure 2), the vector diminished* "; "[...] That I understood, because I would take ... If I had a point here and a positive charge here, the positive charge, it repels. I departed off the (infinitesimal) point (charge). Then I learned that the vector departs off the charge". Making gestures to show the point and the charge at a certain distance.

Figure 2. Student 5 showing a depictive gesture referring to charge and point.

The mediation that the student employed to understand this relation was the hypercultural mediation because the student associates with the computer simulation, pointing out earlier in the interview "*the field line started from the charge. That's what I learned most from GeoGebra.*"

What student 5 indicated is explained by CNMT principles, when this theory concludes that brain capacity is limited and the brain naturally uses external tools that make it more capable to perform tasks. By using GeoGebra the student, to interact with the software, had to understand the graphic representation of the electric field vector while manipulating the position of the test point. By moving the test point (Figure 2) the student could see, in the simulation, the resulting electric field changing as it gets closer to each point charge. The essence of the CNMT is that, by interacting with the hypercultural tool, the student internalizes the operations made by the simulation (albeit partially), as *drivers*, and is able to use those *drivers* even without the presence of the simulation.

Student 6 responds that "it would be larger, the value of the intensity greater" (Figure 3); "... because the closer, the greater the electric field." We can see that the mediation was from the GeoGebra simulation - hypercultural mediation: "*I saw in GeoGebra, according to the charge a little higher, according to the slightly smaller charge.*"

Figure 3. Student 6 showing a depictive gesture referring to a vector.

Our second main result is that the mental image of charge is acquired by psychophysical, cultural and social mediation, depending on the student. Students 6, 8 and 9 internalized a psychophysical mediation taken from day-a-day objects while students 5 and 7 internalized a social mediation and/or cultural mediations from their previous classes.

Student 6 (Figure 4) describes the charge by relation to a truck: “for example, what is the load (charge and load are synonyms in Portuguese) of a truck? It is the weight of the truck! The load that the truck carries, the weight, is a value that it has assigned. A charge, a particle, is the little weight it has"

By means of gestures, the student 6 represented the displacement of the truck on the table. This comparison of the electric charge with a truck points to evidence of psychophysical mediation. Student 6 referred to her routine or common sense to relate the electric charge to the weight (load), that is, the electric charge is a property of the particle and the weight is related to the truck's load carrying capacity. Student 8 in a similar way associates the concept of charge to the representation of a quick animal (rabbit) while student 9 associate charge to the popular electrostatic experiment of using piece of papers being repelled after electrisation.

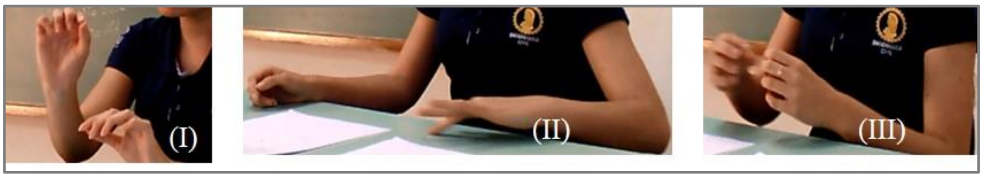

Figure 4. Student 6 showing (I) Gesture representing charge and point; (II) Dynamic gesture representing a truck running; (III) Static gesture representing weight.

Student 5 describes charges using representations that he developed from (high school) chemistry classes, social mediation from a teacher: “Charge, I think, an electron or a charge that has a ... A positive and negative, has sense of ... Charge, for me, it is ... It may be so. Charge, for me, are three types: the positive, the negative and the zero, right? Hence because I know that the positive donates and that the negative receives; the null is when it has the same level, same number of cations and ions.”

When asked whether this concept of charge is positive, negative or null, the student refers: “from the chemistry class, but then, I used knowledge of chemistry to do this”. In this fragment, we realized that the concept of charge was established by the chemistry class, possibly being a social mediation due to this interaction and evidence of hypercultural mediation by studying videos “Ah, I also watch videos, so I’ve already watched a lot of atomic bomb videos”, on YouTube.

Student 7 describes that an electrical charge can have “excess electrons or lack of electrons” and that, “if the two are lacking or excess, they will not interact; otherwise if it was a positive or negative charge. One has, the other does not ”. "Anything has a charge", and "it is like property, it has a material or a particle, [...] of each one". During the interview, when asked where we found electrical charges, he says:

Student 7: Oh, like, a stick like that, let's say there's a lot in the books ...

Researcher: Great. Do you remember any book where you saw that?

Student 7: Yeah, I remember a photo, a little bit over the top, a little thing with a ball, like this, fully charged.

Researcher: Great. Do you remember what book this is? In what book did you see this image?

Student 7: I don't remember the book.

Researcher: Yes, but when did you study this? Now, or when you were doing physics in high school?

Student 7: In high school.

Researcher: High school, the little stick with ..?

Student 7: Yes, with a ball.

Probably, the mental image that student 7 describes, with the stick, and, at the end, a ball with charges around it – is a classic representation commonly printed in Didactic Physics books, referring to the electrification processes by contact or by induction. We observed that the student used mental images acquired from cultural mediation, like a book, to explain the electric charge. And Social mediation, referring to High School Physics teachers.

DISCUSSION AND CONCLUSION

Our objective was to investigate the mediation evidenced by five students of higher education when solving a problem situation related to the intensity of the electric field. From the results aforementioned, answering the research question, we observed that different mediations – psychophysical and hypercultural or social and hypercultural are used combined to conceptualized the electric field produced by a charge. While the concept of charge is acquired by psychophysical and social mediations, the comprehension of the electric field is acquired using the hypercultural mediation. One could argue that the students, by using a concept of charge that is not related to electric field domain is "wrong" or showing an alternative conception, but the student can employ different representation and yet be able to correctly predict the qualitative behaviour of the electric field.

GeoGebra, used in this research, proved to be an excellent computational resource, being adequate to achieve the objective of this work, providing an effective tool in the visualization and in the correct understanding of the concepts involved in the resulting electric field vector, allowing to analyze and conjecture establishing hypotheses contributing for the student in expanding his knowledge.

And the interpretation of the gestures provided information that was not identified only through speech, since we found in the analysis the importance of the gestural and verbal association in the transmission of information, and through gestures it was feasible to analyze the actions expressed by the students in relation to to the concepts of electric charge, electric field lines, electric field vector, resulting electric field vector and electric force.

In the analysis of the electric charge, knowing that the intensity of the electrical interactions of a particle depends on the electric charge, we conclude that the articulated use of the external mechanisms of psychophysical, cultural, social and hypercultural mediation proved to be important, but social mediation stood out. learning the concept of electric charge, pointed out by four students.

ACKNOWLEDGEMENT

This work was partially supported by FULBRA, FAPERGS and CAPES.

REFERENCES

Boss, S. L. B., Souza Filho, M. P., Caluzi, J. J. (2009). Fontes primárias e aprendizagem significativa: aquisição de subsunçores para a aprendizagem do conceito de carga elétrica. In: *Encontro Nacional de Pesquisa em Educação em Ciências,* VII., 2009, Florianópolis. Anais eletrônicos. Florianópolis: Associação Brasileira de Pesquisa em Educação em Ciências.

Campello de Souza, B., Silva, A. S., Silva, A. M., Roazzi, A., & Carrilho, S. L. S. (2012). Putting the Cognitive Mediation Networks Theory to the test: Evaluation of a framework for understanding the digital age. *Computers in Human Behavior*, 28(6), 2320-2330.

Clement, J. J. & Stephens, A. L. (2010). Documenting the use of expert scientific reasoning process by high school physics students. *Physics Education Research*, 6(2), 20122-1-20122-15.

Erickson, F. (1998). Qualitative research methods of Science Education. In: Fraser, B.; Tobin, K. G. *International Handbook of Science Education.* London: Kluber Academic Publishers, 1155-1173.

Furió, C., Guisasola, J., Almudí, M. (2004). Elementary Electrostatic Phenomena: Historical Hindrances and Students' Difficulties. Canadian Journal of Science, *Mathematics and Technology Education*. 4(3), p. 291-313.

Gire, E. (2014). Arrows as anchors: An analysis of the material features of electric field vector arrows. *Physical review special topics*. 10, 020112.

Guisasola, J., Zubimendi, J., Almudí, J., Ceberio, M. (2008). Dificultades persistentes en el aprendizaje de la electricidad: Estrategias de razonamiento de los estudiantes al explicar fenómenos de carga eléctrica. *Enseñanza de Las ciencias*. 26(2), p. 177-192.

Kneubil, F. & Ricardo, E. (2014). The relevance of teaching on science: Report of an experience in a university course on electromagnetism. *Experiences in Science Teaching*. v.9, nº. 2.

Lopez, E; & Silva, R. (2015). Transformation of mental models on the concepts of force and electric field through the WebQuest methodology, in university students of Engineering. *Brazil Physics Teaching Notebook*, v. 32, n. 1, p. 2-31.

Meggiolaro, G. (2019). An investigation between the external mediation mechanisms and the problem situations, in the study of the conceptual field of electrostatics with students from the engineering. (PhD Thesis, Lutheran University of Brazil, Canoas, 2019). *PhD Thesis in Science and Mathematics Teaching*, 187f.

Monaghan, J. M., & Clement, J.J. (1999). Use of a computer simulation to develop mental simuations for understanding relative motion concepts. *International Journal of Science Education*. 21(9), 921-944.

Moraes, R., & Galiazzi, M. C. (2007). *Discursive Textual Analysis*. Ijuí, Editora Unijuí.

Pieper, F. C., & Serrano, A. (2016). The 'state of art' of the research on Magnetic Field teaching: A review of Physics education literature between 1995 and 2015. *Acta Scientiae, 18(3),* 779-819.

Ramos, A. F. (2015). Study of the Internalization Process of Chemistry Concepts Using Molecular Modeling Software: A Proposal for High School and Higher Education. (PhD Thesis, Lutheran University of Brazil, Canoas, 2015). *PhD Thesis in Science and Mathematics Teaching*, 230f.

Tao, P. K.; & Gunstone, R. F. (1999). A process of conceptual change in force and motion during computer-supported Physics instruction. *Journal of Research in Science Teaching*, v.3 7, n. 2, p. 859-882.

Trevisan; R. (2016). The study of the relationship between mental images used by students of quantum mechanics and their epistemological profile: an investigation by methodology Report Aloud. (PhD dissertation, Lutheran University of Brazil, Canoas, 2016). *PhD dissertation in Science and Mathematics Teaching*, 143f.

Serrano, A., Trevisan, R., Meggiolaro, G., Anjos, J., Freitas, S., & Moreira, L. P. (2018). Where do representations and drivers for solving physics problems come from? an analysis of four experiments In Finlayson, O.E., McLoughlin, E., Erduran, S., & Childs, P. (Eds.), Electronic Proceedings of the ESERA 2017 Conference. *Research, Practice and Collaboration in Science Education*, Part 4 (co-ed. Juuti, K., Kyza, E. A.), (pp. 622-629). Dublin, Ireland: Dublin City University. ISBN 978-1-873769-84-3.

Veloso; M. S. O. (2017). An investigation of the process of (re) construction of physics concepts in experimental activities in distance physics courses. (PhD Thesis, Lutheran University of Brazil, Canoas, 2017). *PhD Thesis in Science and Mathematics Teaching*, 206f.

Wolff, J. F. S. (2015). The modifications of previous drivers through the use of computer simulations: significant learning of the collision concepts verified through the analysis of the mental images of university students. (PhD Thesis, Lutheran University of Brazil, Canoas, 2015). *PhD Thesis in Science and Mathematics Teaching*, 260f.

Trevisan, R., Serrano, A., Wolff, J., Ramos, A. (2019) Peeking into students' mental imagery: the Report Aloud technique in Science Education research. *Ciência & Educação*, v. 25(3), p. 647-664.

INVESTIGATING STUDENTS' ACTIONS AND DISCUSSIONS WHEN EXPERIMENTING WITH PHYSICAL AND VIRTUAL MANIPULATIVES IN SCIENCE

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Many studies investigating the effectiveness of the use of physical and virtual manipulatives (PM, VM) and their combination for experimentation purposes revealed varying learning outcomes, which were attributed to PM and VM differing affordances. We examined how students' actions and discussions differed when they experimented with PM, VM, and a blended combination (PM&VM). An introductory science course on Light and Color was used. The participants were 22 undergraduate students of a university in Cyprus who were randomly separated into three conditions (PM condition, 7 students; VM condition, 7 students; PM&VM condition, 8 students). Data sources included whole group videotaped conversations (discussion between peers and between students and instructors), instructors' reflective/observation journals and screen captured data. A total of 12 meetings were analyzed (two meetings in each group of each condition). Data analysis involved both quantitative and qualitative methods and focused on coding and analyzing students' actions and discussions during experimentation. The qualitative analysis of actions/discussions in all conditions was combined with a Wilcoxon sign rank test, a Kruskal Wallis test and a correspondence analysis for comparing the three conditions. The analysis showed that students' actions and discussions appeared to be influenced by the means of experimentation in specific aspects. Specifically, the PM&VM condition enabled students to confirm and extend their observations because it offered them a wider range of affordances when experimenting, which in turn resulted in more rounds of experimentation. This implies that the means of experimentation were crucial for optimizing the actions that need to take place during experimentation and for establishing productive conversations among peers and between students and the instructors.

Keywords: Physical, Virtual, Experimentation

PHYSICAL AND VIRTUAL EXPERIMENTATION IN SCIENCE: THEORETICAL PERSPECTIVES

The extant research of the domain has documented the value of using Physical Manipulatives (PM) and Virtual Manipulatives (VM). In this line of research we define PM as real-world physical material and apparatus, whereas VM are defined as virtual apparatus and material in computer-based simulations (Brinson, 2015; Chen, Chang, Lai and Tsai, 2014; de Jong, Linn and Zacharia, 2013; Hovardas, Xenofontos and Zacharia, 2017; Hmelo-Silver, Liu, Gray and Jordan, 2015; Hsu and Thomas, 2002; Kapici, Akcay and de Jong, 2019; Zacharia and Anderson, 2003; Zacharia, 2007; Zacharia, Olympiou and Papaevripidou, 2008; Zacharia and Olympiou, 2011; Zacharia and de Jong, 2014). Olympiou and Zacharia (2012) studied prior comparative studies between PM and VM and attributed the differences in outcomes to their differing affordances (assets that offer the opportunity for an interaction with PM or VM in accordance with the ability of a learner to interact).

A series of PM and VM affordances are reported in the literature as unique affordances. For example, in the case of PM, physicality (kinesthetic use and active touch of concrete material) is reported as one unique affordance that the VM could not offer in a virtual learning environment (Zacharia, Loizou and Papaevripidou, 2012). On the other hand, a large number of unique affordances exist in the case of VM compared to PM (for examples see Smetana and Bell, 2012 and Zacharia, 2015). In an effort to resolve issues resulting from the deficiencies of PM experimentation in physical learning environments, a number of VM unique affordances were developed and implemented in VM manipulatives. Parameters and variables from the physical world that couldn't be altered, simplified or augmented through PM, could now become a reality and be manipulated through the use of VM (e.g. studying the consequences of the greenhouse effect under extreme temperatures and gas emissions). Based on a gamut of affordances offered both from PM and VM, many researchers argued in favor of blending the affordances of the two means of experimentation in an effort to take advantage of the maximum number of benefits (for example see Olympiou and Zacharia, 2012).

Despite the fact that research has shown that the presence of PM and VM can be vital for studying complex scientific phenomena/systems (e.g., Brinson, 2015; Zacharia, 2015) and has revealed a positive impact on their content knowledge performance, we know very little about how PM and VM affect students' actions and discussions while experimenting and how these in turn relate to their learning. In other words, researchers have not yet thoroughly examined the experimental procedures/actions that students follow and their discussions during experimentation and how these relate to their science learning. Any effort in understanding science laboratory experimentation's effect on student learning must involve, among others, an understanding of how PM and VM affect students' actions and discussions.

THIS STUDY

The main purpose of this study was to investigate students' actions and discussions, who used either PM alone, VM alone or a combination of PM with VM (PMVM) for conducting the same experiments and compare those, while having in mind the counteractive results emerging from the literature regarding the effectiveness of both PM, VM and their combination. The students' actions while experimenting, were coded and analyzed, based on three main axes, namely: a) the type of activity that is customarily defined by the curriculum material or at some point, defined by the inquiry or procedural issues the students tend to follow, e.g. experimentation, completion of worksheets etc., b) students' interactions, and c) student-teacher interactions.

The study followed the Physics by Inquiry curriculum (McDermott and The Physics Education Group, 1996) in order to compare students' actions and discussions along PM, VM and a blended combination of PM and VM experimentation, in the domain of Light and Color.

The main purpose of this study was to examine: *How do student actions and discussions compare, when experimenting with the PM or VM alone, or with the use of a blended combination of PM and VM?*

METHODS

The sample of the study comprised of undergraduate students of a university in Cyprus, who enrolled in an introductory science course. The sample was drawn randomly. In total, 22 out of 70 participants were randomly selected and separated into three conditions: PM condition (7 students); VM condition (7 students); and PM&VM blended combination condition (8 students). These participants had never taken college physics prior to this study. The students in all conditions worked collaboratively, after they were randomly assigned to subgroups of three or four persons, as suggested by the curriculum of the study (McDermott *et al.*, 1996).

The study's curriculum focused on the colored light section by McDermott et al. (1996). For the purposes of this study, two experiments were analyzed. The first experiment was on mixing colored light and colored paint. The second experiment focused on having colored light passing through color acetates and prisms. The rationale behind the selection of these two experiments was for the students to develop an understanding of the nature of the colored light.

PM involved the use of physical materials and instruments in a regular physics laboratory, whereas VM involved the use of the virtual laboratory *Optilab* (Hatzikraniotis, Bisdikian, Barbas, & Psillos, 2007). The blending of PM and VM followed the Olympiou and Zacharia (2012) framework.

Procedure

All participants were familiarized with the materials and the instruments, either PM or VM, before engaging in any of the experiments. During experimentation, the role of the instructor was supportive in terms of engaging students in dialogues and enacting their experiments (actions). All conditions shared the same instructors. The duration of the whole study was 13 weeks, whereas, the duration of the two experiments at task was 2 weeks. All students, regardless of condition, worked in a science laboratory that included both the PM and VM needed for the study.

Data Collection and Analysis

The study's data sources involved group videotaped conversations, instructors' reflective journals and screen-captured data. The unit of analysis was single utterances, derived from students' and student-teachers' conversations, which were first examined and analyzed separately and, second, each utterance received a single code. A total of 744 minutes of conversations were analyzed, corresponding to 12 meetings overall. Data analysis focused on coding and analyzing qualitatively students' actions and discussions during experimentation. The video data analysis involved the open-coding scheme of Chin (2006). A quantitative analysis was also conducted using the categories that emerged through the qualitative analysis (i.e., Wilcoxon sign rank test; Kruskal Wallis test; correspondence analysis).

RESULTS

Students elicited different actions across conditions (e.g., during experiment observations) and discussions. In particular, the PMVM students were found to have made more direct observations during the first experiment than the other two conditions. Our analysis also revealed that PM&VM students discussed longer than their peers in the other conditions in the first experiment. In the second experiment, no such differences were found. The same pattern emerged during the discussions between instructors and students.

The qualitative analysis revealed differences among the three conditions in students' actions during both experiments. Specifically, our analysis revealed that students using both means of experimentation would compare their direct observations, conducting each mixture of colored light with both manipulatives and then reaching to a result, which was noted down before proceeding to the next test/observation. Using both means in conducting each mixture of colored light was mostly evident during the first experiment, despite the fact that this was observed to a lesser extent during the second experiment also. In particular, when secondary colored light beams were mixed, students of the blended combination condition used both VM and PM, despite the fact that they were called to use only VM for that specific part of the experiment. Additionally, when PM students experimented with setting up the first experiment, in terms of arranging the colored light beams in front of a screen, certain difficulties emerged which called for the instructors' assistance. Students using VM did not confront any of these difficulties. Interestingly, PMVM students, despite the fact that they were using both manipulatives, managed to solve such difficulties emerging from the concrete use of PM on their own, by just watching how the set up was arranged at the virtual environment. Again, this was not called for by the curriculum used. For the purposes of this study, the discussion analysis between the three conditions was quantitative.

The quantitative analysis further revealed a pattern in favour of the PMVM condition, which presented highest counts in several variables (see Table 1). For instance, students in the PMVM condition made more observations (*Kruskal-Wallis Chi-square* = 14.38, $p < 0.001$), formulated more scientifically valid (*Kruskal-Wallis Chi-square* = 12.63, $p < 0.01$) and invalid statements (*Kruskal-Wallis Chi-square* = 13.46, $p < 0.001$), and had more questions on content for their peers (*Kruskal-Wallis Chi-square* = 13.81, $p < 0.001$) and instructors (*Kruskal-Wallis Chi-square* = 14.62, $p < 0.001$). These variations disappeared after the first experimentation. No statistical difference among conditions was computed in the second experimentation, which seemed to come along with a homogenization of student performance and behaviour across conditions (see Table 2). Indeed, Wilcoxon signed ranks tests revealed a number of significant trends, which reflected such a convergence among conditions. For example, there was a decrease in the number of observations (*Wilcoxon Z* = -2.10, $p < 0.05$) questions on content (*Wilcoxon Z* = -2.52, $p < 0.05$) and experimentation for peers (*Wilcoxon Z* = -2.20, $p < 0.05$) in the PMVM condition.

Table 1. Variables depicting student performance and interaction with peers and teachers across conditions for the first experiment

Variable	Students accessing PM (N = 7)	Students accessing VM (N = 8)	Students accessing both PM and VM (N = 8)	Chi-square of the *Kruskal-Wallis* test
Total number of utterances (count)	138.86	139.88	212.25	7.76^{ns}
Total time used (in seconds)	702.00	483.75	923.50	5.94^{ns}
Mean time per utterance (in seconds)	5.06	3.46	4.35	6.69^{ns}
Total number of observations (count)	26.86	32.63	103.13	14.38***
Completing the worksheet (count)	16.71	12.13	37.38	7.84^{ns}
Student interaction				
Comment on the procedure (count)	31.86	54.25	55.00	5.02^{ns}
Scientifically valid statement (count)	13.14	13.63	34.75	12.63**
Scientifically invalid statement (count)	12.43	4.00	16.88	13.46***
Question on content (count)	11.71	10.88	29.13	13.81***
Scientifically valid response on content (count)	9.00	9.88	16.38	8.89^{ns}
Scientifically invalid response on content (count)	7.00	3.13	9.63	10.98^{ns}
Question on experimentation (count)	8.43	8.75	13.88	2.95^{ns}
Scientifically valid response on experimentation (count)	3.43	2.88	7.88	10.14^{ns}
Scientifically invalid response on experimentation (count)	0.86	0.13	0.63	2.83^{ns}
Student-teacher interaction				
Question on content (count)	1.29	0.25	6.13	14.62***
Question on experimentation (count)	3.43	3.38	3.25	0.19^{ns}

Note: All variables have a scale measure; ns = non-significant; ** $p < 0.01$; *** $p < 0.001$; levels of significance presented after Bonferroni correction.

Table 2. Variables depicting student performance and interaction with peers and teachers across conditions for the second experiment

Variable	Students accessing PM (N = 7)	Students accessing VM (N = 8)	Students accessing both PM and VM (N = 8)	Chi-square of the *Kruskal-Wallis* test
Total number of utterances (count)	144.57	162.50	168.63	0.77^{ns}
Total time used (in seconds)	646.43	575.13	842.50	2.05^{ns}
Mean time per utterance (in seconds)	4.47	3.54	5.00	10.92^{ns}
Total number of observations (count)	19.14	14.88	54.13	9.80^{ns}
Completing the worksheet (count)	8.71	23.63	31.63	7.01^{ns}
Student interaction				
Comment on the procedure (count)	45.00	62.88	35.75	3.90^{ns}
Scientifically valid statement (count)	18.29	22.25	34.00	4.54^{ns}
Scientifically invalid statement (count)	10.29	5.88	7.38	2.19^{ns}
Question on content (count)	17.00	17.63	17.75	0.19^{ns}
Scientifically valid response on content (count)	19.86	18.75	26.25	0.91^{ns}
Scientifically invalid response on content (count)	7.57	3.25	5.88	3.81^{ns}
Question on experimentation (count)	4.86	9.88	9.00	5.36^{ns}
Scientifically valid response on experimentation (count)	8.00	5.50	5.13	0.53^{ns}
Scientifically invalid response on experimentation (count)	1.57	0.75	0.75	2.85^{ns}
Student-teacher interaction				
Question on content (count)	14.14	3.38	2.88	3.23^{ns}
Question on experimentation (count)	5.43	7.00	1.25	5.94^{ns}

Note: All variables have a scale measure; ns = non-significant; levels of significance presented after Bonferroni correction.

Characteristic Features for PM, VM and their Combination

To examine which variables were singled out as characteristic features for each condition, we performed a correspondence analysis. The biplot of the correspondence analysis is presented in Figure 1. Conditions are shown in black cycles and variables describing student performance and behavior are portrayed with white cycles. A first remark is that both experiments were placed quite close along the plane for each condition. To explain the positioning of conditions relative to variables, we need to take into account the projections of each point on the axes (i.e., coordinates). In this regard, conditions are characterized by the variables, which have the largest projection on the axis along which conditions have been positioned.

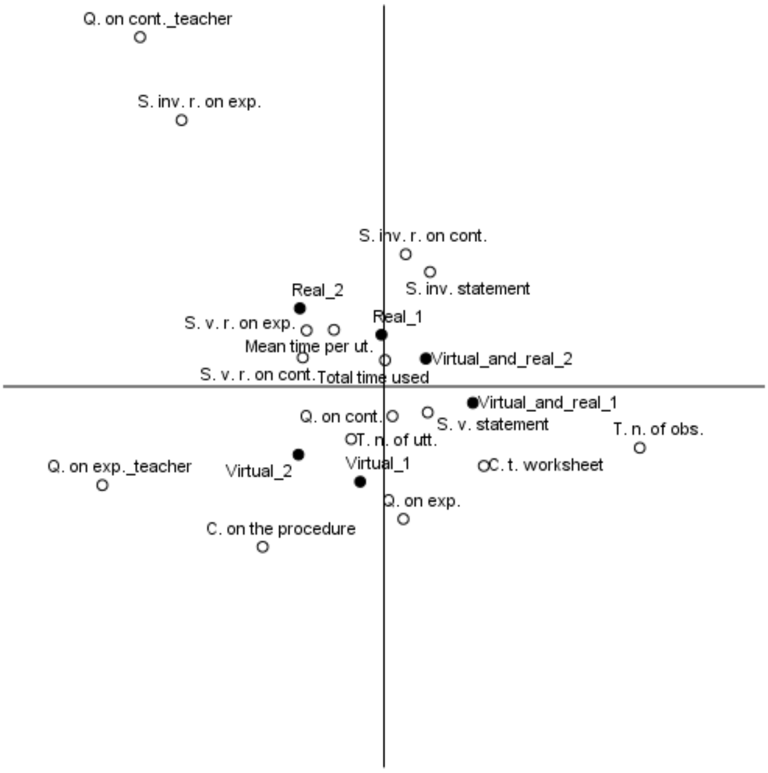

Figure 1. Biplot displayed by the correspondence analysis. The horizontal axis explained 45.3% of variance in data, while the vertical axis explained another 26.3% (cumulative variance explained = 71.6%). Black cycles depict conditions in the first and second experiment (denoted by numbers), while white cycles depict variables examined: T. n. utt. = Total number of utterances; Total time used; Mean time per utt. = Mean time per utterance; T. n. of obs. = Total number of observations; C. t. worksheet = Completing the worksheet; C. on the procedure = Comment on the procedure; S. v. statement = Scientifically valid statement; S. inv. statement = Scientifically invalid statement; Q. on cont. = Question on content; S. v. r. on cont. = Scientifically valid response on content; S. inv. r. on cont. = Scientifically invalid response on content; Q. on exp. = Question on experimentation; S. v. r. on exp. = Scientifically valid response on experimentation; S. inv. r. on exp. = Scientifically invalid response on experimentation; Q. on cont._teacher = Question on content addressed to the teacher; Q. on exp. teacher = Question on experimentation addressed to the teacher.

Despite the homogenization among conditions after the second experiment, which has been underlined in the previous section, there were still a number of dimensions, which were relatively more pronounced in each condition. For instance, the condition that involved both virtual and real experimentation was placed on the positive part of the horizontal axis and it was characterized by an increased number of observations. The conditions including PM or VM only were allocated to the negative part of the horizontal axis and they were marked by questions addressed to the teacher, either on content (upper left quartile) or on experimentation (lower left quartile), respectively. Overall, the horizontal axis may be conceptualized as distinguishing student interaction with the learning environment, which was indicated by number of observations for the condition using both PM and VM, from student interaction with instructors, which was pronounced for students who have used PM or VM only.

Students engaged in real experimentation seemed to have voiced an increased number of invalid statements or invalid responses on experimentation and content (positive part of vertical axis). On the negative part of the vertical axis, students performing virtual experimentation seemed to have focused on procedural aspects (comments on the procedure; questions addressed to peers and the teacher on experimentation). Taken together, the vertical axis distinguished invalid statements of responses, associated with the condition that included PM only, from elaborating on the procedure (linked to the condition that used VM only).

CONCLUSIONS/SIGNIFIGANCE

The most important aspect of this study was that the PMVM condition was found to cause more rounds of experimentation. Given this, we conjecture that this repetition may have increased student confidence in terms of the validity of their results, since the same results emerged using different means of experimentation. Additionally, students in the PMVM condition raised more questions concerning the conceptual aspects of the topic at task and spent more time elaborating on them in peer discussions or discussions with the instructor. The latter when combined with the former appears to portray a pattern, in which more rounds of experimentation result in more actions and more discussions related with the learning objectives at task. One explanation could be that the presence of VM in the PMVM condition may have worked as a catalyst in resolving procedural issues (e.g., set-up issues) and thus allowed students to focus on the conceptual aspects at hand (see also Olympiou and Zacharia, 2012). This kind of findings are in line with research studies advocating in favor of VM, based on their unique affordances and their effect on conceptual understanding (Olympiou, Zacharia and de Jong, 2013). On the other hand, students in the PM condition, were found to spent their time mostly on procedural than conceptual issues. Thus, valuable discussion time was spend on non-important issues.

The homogenization of student performance and behaviour among conditions in the second experiment may imply that the distractions found in the first experiment, were resolved for all three conditions. This means that the actions and, especially, the discussions followed in experiment 2 were about the same. This underlines the necessity to resolve any possible distractions for the students as early as possible during their experimentation journey.

Overall, this study showed that different means of experimentation have a different effect on student actions during experimentation (e.g. making more observations, enacting more inquiry cycles) and for establishing productive conversations among peers and between students and instructors (Olympiou and Zacharia, 2012; 2014), at least when the affordances of the manipulatives do not support the students in resolving and handling distractions that relate to the enactment of their experiments (e.g., the messy nature of PM). Of course, additional research is required to reaffirm these results across several science domains.

REFERENCES

Brinson, J. R. (2015). Learning outcome achievement in non-traditional (virtual and remote) versus traditional (hands-on) laboratories: A review of the empirical research. *Computers & Education*, 87, 218-237.

Chen, S., Chang, W. H., Lai, C. H., & Tsai, C. Y. (2014). A comparison of students' approaches to inquiry, conceptual learning, and attitudes in simulation-based and microcomputer-based laboratories. *Science Education*, *98*(5), 905-935.

Chin, C. (2006). Classroom Interaction in Science: Teacher questioning and feedback to students' responses. *International Journal of Science Education*, *28*(11), 1315–1346.

de Jong, T., Linn, M. C., & Zacharia, Z. C. (2013). *Physical and virtual laboratories in science and engineering education. Science, 340*(6130), 305-308.

Hmelo-Silver, C. E., Liu, L., Gray, S., & Jordan, R. (2015). Using representational tools to learn about complex systems: A tale of two classrooms. *Journal of Research in Science Teaching*, *52*(1), 6-35.

Hsu, Y. S., & Thomas, R. A. (2002). The impacts of a web-aided instructional simulation on science learning. *International Journal of Science Education*, *24*(9), 955-979.

Hatzikraniotis, E., Bisdikian, G., Barbas, A., & Psillos, D. (2007). Optilab: Design and development of an integrated virtual laboratory for teaching optics. In C. P. Constantinou, Z. C. Zacharia, & M. Papaevripidou, *Proceedings of the 7th International Conference on Computer Based Learning in Science*. Crete, Greece: Technological Educational Institute of Crete.

Hovardas, T., Xenofontos, N. A., & Zacharia, Z. C. (2017). Using Virtual Labs in an Inquiry Context: The Effect of a Hypothesis Formulation Tool and an Experiment Design Tool on Students' Learning. In *Optimizing STEM education with advanced ICTs and simulations* (pp. 58-83). IGI Global.

Kapici, H. O., Akcay, H., & de Jong, T. (2019). Using Hands-On and Virtual Laboratories Alone or Together ― Which Works Better for Acquiring Knowledge and Skills? *Journal of Science Education and Technology*, 1-20.

McDermott, L. C., and the Physics Education Group at the University of Washington, (1996). *Physics by Inquiry*, Volume II. Wiley : New York.

Olympiou, G., & Zacharia, Z. C. (2012). Blending physical and virtual manipulatives: An effort to improve students' conceptual understanding through science laboratory experimentation. *Science Education*, *96*(1), 21-47.

Olympiou, G., Zacharia, Z. C., & de Jong, T. (2013). Making the invisible visible: Enhancing students' conceptual understanding by introducing representations of abstract objects in a simulation. *Instructional Science*, *41*(3), 575-596.

Olympiou, G., & Zacharia, Z. C. (2014). Blending physical and virtual manipulatives in physics laboratory experimentation. In Topics and trends in current science education (pp. 419-433). Springer, Dordrecht.

Smetana, L. K., & Bell, R. L. (2012). Computer simulations to support science instruction and learning: A critical review of the literature. *International Journal of Science Education, 34*(9), 1337-1370.

Zacharia, Z. C., & Anderson, O. R. (2003). The effects of an interactive computer-based simulation prior to performing a laboratory inquiry-based experiment on students' conceptual understanding of physics. *American Journal of Physics*, *71*(6), 618-629.

Zacharia, Z. C. (2007). Comparing and combining real and virtual experimentation: an effort to enhance students' conceptual understanding of electric circuits. *Journal of Computer Assisted Learning*, *23*(2), 120-132.

Zacharia, Z. C., Loizou, E., & Papaevripidou, M. (2012). Is physicality an important aspect of learning through science experimentation among kindergarten students? *Early Childhood Research Quarterly, 27*(3), 447-457.

Zacharia, Z. C., Olympiou, G., & Papaevripidou, M. (2008). Effects of experimenting with physical and virtual manipulatives on students' conceptual understanding in heat and temperature. *Journal of Research in Science Teaching*, *45*(9), 1021-1035.

Zacharia, Z. C., & Olympiou, G. (2011). Physical versus virtual manipulative experimentation in physics learning. *Learning and instruction*, *21*(3), 317-331.

Zacharia, Z. C., & de Jong, T. (2014). The effects on students' conceptual understanding of electric circuits of introducing virtual manipulatives within a physical manipulatives-oriented curriculum. *Cognition and instruction, 32*(2), 101-158.

Zacharia, Z. C. (2015). Examining whether touch sensory feedback is necessary for science learning through experimentation: A literature review of two different lines of research across K-16. *Educational Research Review*, 16, 116-137.

INVESTIGATING ONLINE OPEN FORUMS AS EDUCATIONAL SPACES FOR HAZARDS LITERACY LEARNING

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Research has begun to investigate how discourse on social media sites influences risk perceptions and decision-making surrounding natural hazards like hurricanes, but little work has been done to define these spaces as learning environments where natural hazards literacy can be developed. In this study, qualitative interviews and comprehensive content analyses of two hurricanes-centered forums on the social media site Reddit were conducted. With a focus on discourse and communication surrounding hurricane-related imagery, this paper provides insight on Reddit as an informal learning environment and documents common inaccurate information and gaps in public knowledge related to disaster impacts.

Keywords: weather, public science, informal education

The ability to accurately interpret probabilistic information like forecast models and other weather visualizations is one of the factors, along with socioeconomic constraints, demographic patterns, and cultural preferences that influence public decision-making about the risks associated with hurricanes (Morss et al., 2017). However, many of the technical images that depict a storm's potential path, like spaghetti models or the cone of uncertainty model, are easily misunderstood (Broad et al., 2007). Misinformation can be easily misjudged and, in cases where it is re-communicated in social settings, can lead to a cascading spread of distorted interpretations from person to person resulting in under or over inflated perceptions of risk within groups or communities (Morss et al., 2017). An example of this was seen in the public communications about the risks associated with Hurricane Florence in 2018. The hurricane became a national example of the shortcomings of the Saffir-Simpson Hurricane Wind Scale which categorizes hurricanes by wind speed (de la Garza, 2018). This measurement alone supplies little information about the strength of the storm or potential to cause damage, yet is most often conflated with perceived risk (Agdas & Webster, 2012). Though it made landfall as a Category 1 storm, Florence dropped over 35 inches of rain causing nearly $17 billion dollars in damages in North Carolina alone (Stradling & Bennett, 2018). The storm's track was well-forecasted by the National Hurricane Center, but its intensity, and consequently the magnitude of its impacts, proved to be a challenge (Stewart & Berg, 2019). These factors — the storm's long life over the ocean, its potential for landfall in the Carolinas, and the uncertainties with its intensity and impacts sparked a social media frenzy and sent waves of viral misinformation surging ahead of the storm (Bonazzo, 2018). Florence-related posts on social media sites like Facebook and Twitter ranged from doctored images of sharks swimming up flooded highways, to the more alarming re-communication of erroneous risk-related interpretations of the forecasts and models which consequently downplayed the potential for damage to life and property (Bonazzo, 2018).

Rationale

Though researchers have begun to investigate how evolving information and social interactions on social media platforms influence people's risk interpretations and decision-making (Morss et al., 2017), little work has been conducted to explore or define these social media spaces as learning environments where knowledge and literacy surrounding natural hazards and environmental risks can be fostered. By investigating the way hazards like hurricanes are communicated via social media, this research examines how social media platforms, particularly open online forums like Reddit (described further below), act not only as spaces where social communication of information exists, but also as venues of social learning where conversations about particular topics contribute to both individual learning and group practice (Haythornthwaite et al., 2018).

This comparative case study analyzed the ways in which communities of users engaged with visual content in two hurricanes-related subreddits. Through content analysis of user engagement with hurricane-related imagery, this study a) supports and draws additional conclusions about the platform's categorization as a learning environment, b) assesses the accuracy of public interpretations of hurricane related imagery, c) identifies common themes in erroneous information presentation, and d) documents evidence of correction or amplification of misinformation. Qualitative interviews conducted with Reddit participants yielded further insight about user preferences for information seeking and image sharing. The following research questions were asked in order to investigate the roles that online social learning environments like Reddit play in facilitating hurricane and hazard-related image literacy learning:

1. What patterns of discussion, knowledge-seeking, and knowledge dissemination exist in hurricanes-specific subreddits?
    a. Do these patterns differ from patterns of online discourse previously established by the literature?
2. Can specific learning outcomes be documented within these conversations?
3. How do Reddit users determine the validity of visual information on Reddit and what are their preferences and rationales for types of images sought and shared?

CONCEPTUAL FRAMEWORKS

Social learning on Reddit

Online communities constructed within social media platforms like Twitter and Facebook that have greatly influenced not only learning environments, but the roles and behaviors of learners and educators who construct learning experiences (Gruzd et al., 2016). Social media has become a space where users can seek new learning experiences under their own direction and in collaboration with others. User-constructed learning spaces like the online open forum Reddit offer information-seekers an opportunity to come together to solicit and supply resources related to shared interests. Reddit in particular has been established as a platform for examining learning practices because its "user-generated and participatory online culture" (Haythornthwaite et al., 2018, p. 1936), allows individuals to engage in sense-making through connecting resources and actively constructing "learner-generated contexts" (Luckin, 2010 as cited in Haythornthwaite, et al. 2018, p. 1934) that support individual and group knowledge (Gunawardena, Lowe, and Anderson, 1997).

Within subreddits, the questions solicited and the answers supplied form the basis of a participant-led discussion structure that is contributed to, and moderated by, members of the site. Posts are organized categorically by way of user-created discussion boards called subreddits. These subreddits or "subs," can be created for nearly any conceivable topic. Redditors (users of Reddit) subscribe to subreddits of interest and contribute content or commentary. User posts within each subreddit are not sorted and presented based on chronology or by a computational algorithm like Twitter, Facebook or Instagram. Instead, Reddit relies on Redditors to vote posts up or down. This creates a hierarchical presentation of the most popular posts and rewards users who submit high-impact content and adhere to the appropriate social rules and norms of the site, or "reddiquette" (Anderson, 2015). Users not only have the ability, but the expectation, to comment on, correct, and argue about information presented by others and to then further group knowledge and learning by providing citations to sources and further additional resources (Anderson, 2015; Haythornthwaite et al., 2018; Moore and Chuang, 2017).

METHODOLOGY

This cross-case analysis focused on two weather-related subreddits as unique cases in which user-developed hazards literacy learning occurs. The data collection process consisted of two dual-part phases: 1) a two-part comprehensive content analysis to investigate a) social learning processes and b) outcomes, followed by 2) a series of a) structured and b) semi-structured interviews. Together, these procedures provided an in-depth understanding of the ways the Reddit community communicates, interprets, and engages with images associated with hurricane-related risks.

Data Collection

Content analysis. A purposive sample of publicly available comments within two subreddits, HurricaneFlorence and TropicalWeather, was selected. Within each subreddit, new, or parent, posts consist of either an image and corresponding title or text and corresponding title. Because this research investigated communication and outcomes related to visual imagery, only comments nested within parent posts containing an image were selected for comment coding. Qualifying images included ''iconic'' representations, such as maps of impact, and ''indexical'' images, such as photographs of on-the-ground conditions (Messaris, 1997 as cited in Rickard et al., 2017, p. 472). Memes were excluded from this analysis. Because the TropicalWeather subreddit contains posts related to a number of storms, only those that directly referenced Hurricane Florence were included. Additionally, posts were constrained by date from the time that Hurricane Florence became a sustained hurricane (September 9, 2018) to the date it was downgraded from a tropical depression to a post-tropical cyclone (September 18, 2019). Based on the precedent set forth by Haythornthwaite et al. (2018), one percent of the total number of comments for HurricaneFlorence (*n*=99) and TropicalWeather (*n*=582) were coded.

Table 1. Subreddit descriptive statistics

Subreddit Community	Number of Moderators	Number of Subscribers (at the time of data collection)	Number of Total Comments in Purposive Sample	Coded Sample (1%)

HurricaneFlorence	3	2,300	9,894	99
TropicalWeather	10	62,200	58,167	582

Interviews. Due to the open nature of Reddit and its structure as a discussion and resource board, the interview protocol for this study was centered around the forum model of computer-mediated communication (Salmons, 2012). An invitation to participate in this study was posted in each subreddit along with an initial set of structured, exploratory questions centered around the types of images being shared. A semi-structured follow-up procedure was pursued with all participants who responded to the initial query. In total, ten users responded to the questions in the initial post, with nine agreeing to take part in a second stage that included an interview. Methods of response varied between users, with three responding to initial posts via private message (one of these requesting to conduct the interview via email), and the other six answering the initial and follow-up questions within the thread of the original public post.

Analyses

In the first stage of content analysis coding, comments were evaluated for communication and discourse patterns according to the 'learning in the wild' coding schema established by Haythornthwaite et al. (2018). In the second stage, the same comments were coded for the accuracy and validity of scientific claims or explanations. Two researchers (one a university climatologist and the other an education/communication researcher) independently coded the online social discourse for processes and patterns, and 2) accuracy and validity of hazards-related scientific claims or explanations. Interrater reliability testing was conducted for 20% of the comments with Krippendorf's Cu-Alpha coefficients of 0.93 and 0.85 respectively. The thematic analysis of interview data was conducted by organizing excerpts from the interview transcriptions into thematic categories and utilizing a priori and emergent codes related to user's self-assessments of learning outcomes and processes. Participants were asked about their preferences and rationales for sharing iconic versus indexical images and how they determine validity in the information they both seek and find on Reddit.

Content Analysis for Learning Processes and Patterns. The 'learning in the wild' coding schema was developed with the purpose of describing the different types of discourse, exploratory talk, and conversational dialogue occurring in online open forums (Haythornthwaite et al., 2018). To develop the codes, researchers documented variation in conversation and discourse patterns across four 'Ask'-style Reddit domains: 'askscience,' 'Ask_Politics,' 'AskAcademia,' and 'AskHistorians.' These subreddits function as knowledge-focused informal learning environments where users seek and supply scholarly information and are generally comprised of both experts and non-expert subscribers (Moore and Chuang, 2017). Haythornthwaite et al. (2018) determined that comments on Reddit generally fall within three categories of purpose: Explanation, Socializing, or Information Exchange. Explanation and Socializing can be further subdivided around central trends of emotionally positive, negative, or neutral valence, while Information Exchange is described as pertaining to either seeking or providing resources. A final code for Rules and Norms describes communications related to internal Reddit culture or "reddiquette." The full codebook included: Explanation with *Disagreement*, *Agreemen*t, or *Neutral Presentation*; Socializing with *Negative* or *Positive Intent*; *Information Seeking*; *Providing Resources*; and *Subreddit Rules and Norms*.

The TropicalWeather forum examined here functions similarly to an 'Ask'-style subreddit where subscribers engage in ongoing discussions related to the general topic of tropical weather as well as event-specific topics like individual storms or phenomena. Weather events around the globe are featured in this subreddit, and storms are often discussed regardless of whether or not landfall is projected. Additionally, knowledgeable others and experts are encouraged to self-identify with Reddit flair (markers or 'tags' that can be attached to a post) as a way of adding additional validity to scientific claims or explanations. By comparison, the Hurricane Florence forum was created specifically for information-sharing related to the isolated weather event. The subreddit was created when the storm was forecasted to have impacts on the United States and remained active through the duration of the event and for some time after as post-storm impacts were still being observed. Although these subreddits have similar purposes and rules related to civil engagement and expectations of accurate information, differences in posts may exist due to the structure and function of the subreddits, particularly if those differences pertain to the initial development of the subreddit as a space for academically-focused inquiry, the presence of experts within the community (Moore and Chuang, 2017) or expectations for group maintenance and civic engagement (Haythornthwaite et al., 2018).

Content Analysis for Accuracy and Validity of Hazards-Related Information. In order to assess communication specifically related to image literacy, comments in the two subreddits were open coded for accuracy of scientific concepts or principles and common themes related to misconceptions or naive conceptions of scientific processes were identified. Correction or amplification of misinformation was also documented and coded for accuracy and validity.

RESULTS

Conversational Processes and Patterns

The analyses of the HurricaneFlorence and TropicalWeather subreddits revealed unique patterns in the types of discourse and engagement presented in each community (see Table 2). Explanations with Neutral Presentation, Information Seeking requests, and mentions of Subreddit Rules and Norms were similar across both HurricaneFlorence (7%; 11%; 0%) and TropicalWeather (8%; 12%; <1%). TropicalWeather contained a substantially larger percentage of comments with positive valence including Explanations with Agreement (32%), and Socializing with Positive Intent (30%). Patterns within HurricaneFlorence indicate a community that engages in positive (19%) and negative (24%) social discourse with similar frequency, but presents more counter arguments or disagreements to previous comments (21%) compared to subscribers of TropicalWeather.

Table 2. Results from "learning in the wild" content analysis schema application

	Frequency of comments in HurricaneFlorence	Frequency of comments in TropicalWeather
Sample Size	99	582
1. Explanation with Disagreement	21 (21%)	54 (9%)
2. Explanation with Agreement	14 (14%)	185 (32%)
3. Explanation with Neutral Presentation	7 (7%)	47 (8%)
4. Socializing with Negative Intent	24 (24%)	21 (4%)
5. Socializing with Positive Intent	19 (19%)	177 (30%)
6. Information Seeking	11 (11%)	71 (12%)
7. Providing Resources	12 (12%)	36 (6%)
8. Subreddit Rules and Norms	0 (0%)	4 (<1%)

Note: Counts represent the tabulated frequency of comments assigned to each code.

Accuracy and validation

Open coding of comments for accuracy of scientific concepts or principles led to the identification of four common themes: *Oversimplification; Size, Scale, and Measurement; Tropical Cyclone Physics or Dynamics;* and *Skepticism around Informational Resources*.

Oversimplification. Coders identified frequent occurrences of oversimplified explanations of weather forecasts and models with an identifiable trend of overreliance on individual factors or models as the basis of explanation or argumentation. In several cases, users posted images of the outputs from individual 'spaghetti' models (ex. 18Z GFS or 12Z European) and provided interpretations and forecast predictions about Florence's track or intensity based on these singular models. Spaghetti models, or spaghetti plots, are amalgamations of the individual outputs from various computer models around the world that predict the paths of hurricanes. When visualized together and laid over a map of a potentially impacted area, the models of the predicted storm paths resemble strands of spaghetti. When the strands or tracks cluster together, it is a general indication of consensus between the models. Models presented in isolation lack this context and therefore cannot display a high degree of confidence or accuracy. Posts of this nature occurred across both subreddits. However, the comments in both forums were a mixture of discussion about the implications of overreliance on singular models and the pitfalls of making predictions based solely on these visualizations alone. Subscribers also demonstrated an overreliance on or oversimplified understanding of individual physical factors generally reported during hurricane forecasts like wind speed, rain, storm surge, or forward motion. Discourse within posts and comment threads generally focused on one or two of these factors while either not considering or downplaying the importance of other factors and the interactions between them.

Interpretations of size, *scale, and measurement.* Misinformation or miscalculations appeared in discourse related to the influence of storm size; timing and duration; and local geography on predicted and actual impacts, particularly flooding. Within HurricaneFlorence, there were several instances of discourse surrounding images where perceptions of flood water depth were based on point perspective. For example, water in the foreground of photographs appearing shallower or deeper than water in the background. In nearly all cases, misinterpretations or incorrect inferences as to the magnitude of the flooding were later corrected on the basis of topographical variation and the lack of dimensionality in 2D images. Discourse in TropicalWeather centered around question-and-answer comments regarding what the storm surge height is measured against, and how risk from storm surge inundation relates to land elevation and inland distance. Explaining responses included references to other factors that influence risk of flooding from storm surge, such as tide levels, rainfall, and other local geographic factors. In both subreddits, discussions demonstrated evidence of connecting multiple factors acting at a variety temporal and spatial scales and that can amplify or reduce the magnitude of an impact.

Misinformation about tropical cyclone physics or dynamics. Misinterpretations of meteorological phenomena often appeared in comments related to characteristics of a tropical cyclone. These were often, but not always, corrected in subsequent discourse.

> "Is there any science to support my curiosity that once over land and then taking this turn, depending on where you are, like southern South Carolina for example, the storm actually blows the water off the coast out to sea, as opposed to causing a surge into the coast, like what's happening right now as it approaches?" (Redditor– Tropical Weather)

The first comment after this sought to provide an answer.

> "...the difference is the volume of water. Water gets spread around when it's small and will quickly dry up over dry land. When you are dealing with a massive amount of water like the ocean, the energy stays in the water, and overflows leading to the surges" (Redditor – Tropical Weather).

This response provided accurate information. However, this information does not adequately answer the original question, which could lead to misinformation that it is the relative volume of water on land vs. the ocean that is the primary factor in storm surge inundation. A subsequent comment in this thread offered a scientifically correct explanation.

Skepticism around Informational Resources. There were instances of general mistrust of image-based resources including maps, visualizations, and eyewitness photos and videos. This appeared within the HurricaneFlorence and TropicalWeather subreddits as a lack of familiarity with graphics leading to misinterpretations and also as misinterpretations related to out-of-context visual representations. A lack of familiarity with graphics was demonstrated by users who would frequently disagree with or challenge the validity of certain graphics presented in new posts, occasionally even accusing them of being doctored or hand drawn when they were in fact official government forecasts. This suggests that even graphics that are frequently produced by the NHC are not universally accepted or understood. In HurricaneFlorence, there were additional challenges made against indexical, or eyewitness images. Users were more skeptical of images that presented hurricane-related impacts without context, like photographs of floodwaters being taken without any other representation of scale. In both cases and without corrections, assumptions of falsehood on accurate information can spread misinformation information just as significantly as if the information was truly inaccurate.

Interviews

Interview participants were asked questions related to their preferences for seeking and sharing visual information related to hurricanes and how they determine validity and accuracy in the information sought or solicited.

Iconic versus indexical images. Both groups of subscribers indicated that visual information was the most helpful way to communicate hurricane-related risks. In both HurricaneFlorence and TropicalWeather, users who preferred indexical images like photos and videos cited the additional context and real-life depictions of impacts as being most helpful in developing risk perceptions. Those who preferred iconic, or graphical, representations of information did so with the caveat that in isolation these images have the highest risk of misinterpretation and that overreliance on models out of context can negatively impact public perception of the dangers associated with hurricanes.

Establishing accuracy and validity. When asked about the spread of misinformation, subscribers of both subreddits referenced the social rules and expectations of the forums as actively curtailing the intentional or unintentional spread of false or errant information. Moderators and knowledgeable others of both subreddits tended to self-identify as experts and gatekeepers, and expressed a desire to meet the expectations of non-experts by being sources of accurate and objective information.

DISCUSSION

The results of the first stage of content analysis describe the difference between the two subreddits on the basis of emotional valence. In general, HurricaneFlorence presented a greater number of eyewitness photographs and tended to be more personal and subjective in both socialization and explanations. By contrast, TropicalWeather functioned with greater similarity and followed discourse patterns similar to the to more objective and scholarly-focused AskAcademia, AskHistorians, and askscience subreddits described by Haythornthwaite et al. (2018). However, the second stage of content analysis that coded for the accuracy and validity of scientific claims and documented evidence of correction identified that misinformation was corrected in nearly almost every instance regardless of the subreddit. Though TropicalWeather provided opportunities for experts and knowledgeable others to self-identify, this did not necessarily impact the accuracy and validity of the information presented within the forums. In both cases, these subreddits were established as venues for information exchange and were held to equivalent standards. Users of both forums were expected and encouraged to engage in discourse that provided the most timely and relevant information related to Hurricane Florence. The analysis for accuracy in the HurricaneFlorence and TropicalWeather subreddits did however expose issues of oversimplification of scientific concepts; misconceptions related to size, scale and measurement; a limited understanding of tropical cyclone physics and meteorological phenomena amongst users; and also identified that many Redditors may lack a framework for assessing the validity or accuracy of visual imagery.

Not only do these results have implications for those who work to communicate and educate the public about the threats of hurricanes and other natural hazards, but also for formal and informal educators. As others have suggested, K-12 classrooms are a starting point for hazards education (Mitchell, 2009). However, research has shown that hazards education is not standard across curricula, and that instruction surrounding the physical and social impacts of hazards on people, communities, and infrastructure are underrepresented with respect to both standards and classroom texts (Mitchell, 2009).

FUTURE RESEARCH

More research is needed on who uses Reddit and how people make sense of the various types of science-related information that are communicated. Little is known about how people accept or reject Reddit information compared to information from other sources such as television or radio. The ways students and the public locate information about the natural world are changing rapidly and we need to know what and how information is being shared. This is particularly important when individuals must make sense of science related risks or hazards that can be life-threatening.

REFERENCES

Agdas, D., Webster, G. & Masters, F. (2012). Wind speed perception and risk. *PLoS ONE, 7*(11).

Anderson, K. E. (2015). Ask me anything: what is Reddit? *Library Hi Tech News, 32*(5), 8–11.

Broad, K., Leiserowitz, A., Weinkle, J., & Steketee, M. (2007). Misinterpretations of the "cone of uncertainty" in Florida during the 2004 hurricane season. *Bulletin of the American Meteorological Society, 88*(5), 651–667.

Bonazzo, J. (2018, September 12). Fake news about Hurricane Florence is flooding social media. *News & Observer*. https://observer.com/2018/09/hurricane-florence-fake-news-all-over-social-media/

Gruzd, A., Paulin, D., & Haythornthwaite, C. (2016). Analyzing social media and learning through content and social network analysis: A faceted methodological approach. *Journal of Learning Analytics, 3*(3), 46–71.

Gunawardena, C. N., Lowe, C. & Anderson, T. 1997. "Analysis of a global online debate and the development of an interaction analysis model for examining social construction of knowledge in computer conferencing." *Journal of Educational Computing Research 17(*4): 397–431.

Haythornthwaite, C., Kumar, P., Gruzd, A., Gilbert, S., Esteve del Valle, M., & Paulin, D. (2018). Learning in the wild: coding for learning and practice on Reddit. *Learning, Media and Technology, 43*(3), 219–235.

Luckin, R. 2010. *Re-designing Learning Contexts: Technology-rich, Learner-centered Ecologies*. New York, NY: Routledge.

Messaris, P. (1994). *Visual" literacy": Image, mind, and reality.* Westview Press

Mitchell, J. T. (2009). Hazards education and academic standards in the Southeast United States. *International Research in Geographical and Environmental Education, 18(*2), 134–148

Moore, C., & Chuang, L. (2017). Redditors revealed: Motivational factors of the Reddit community. *Proceedings of the 50th Hawaii International Conference on System Sciences*.

Morss, R., Demuth, J., Lazrus, H., Palen, L., Barton, C., Davis, C., Snyder, C., Wilhelmi, O., Anderson, K., Ahijevych, D., Bica, M., Fossell, M., Henderson, J., Kogan, M., Stowe, K., & Watts, J. (2017). Hazardous weather prediction and communication in the modern information environment. *Bulletin of the American Meteorological Society, 98*(12), 2653–2674.

Rickard, L. N., Schuldt, J. P., Eosco, G. M., Scherer, C. W., & Daziano, R. A. (2017). The proof is in the picture: The influence of imagery and experience in perceptions of hurricane messaging. *Weather, Climate, and Society,* 9(3), 471-485.

Salmons, J. (2012). *Designing and Conducting Research with Online Interviews*. In Cases in Online Interview Research (pp. 1–30). Thousand Oaks, California: SAGE Publications, Inc.

Stewart, S., & Berg, R. (2019). *National Hurricane Center tropical cyclone report: Hurricane Florence (AL062018)*. National Hurricane Center.

Stradling, R., & Bennett, A. (2018). Hurricane Florence damages in North Carolina near $17 billion. *News & Observer*. Retrieved from https://www.newsobserver.com/news/local/article220890905.html

EFFECTS OF DIGITAL MEDIA IN HETEROGENEOUS CHEMISTRY LESSONS

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Digital media play an increasingly important role in almost all areas of life. With the growing presence of laptops, smartphones, and tablets, daily life as well as professional needs are changing (Hanekamp, 2014). That means that mobile devices are becoming an important part in schools and classrooms (Frechette & Williams, 2016; Noonan, 2013). In particular, tablets are seen as a useful possibility to implement digital media in school (Rikala et al., 2013). Of particular importance regarding the use of digital media in classrooms are explanatory videos. Furthermore, with the digitisation at school, proven formats, such as tasks, can be realised with tablet support. Against this background, this project is analysing how to optimise the effect of a tablet-based learning environment for lower secondary education. The digital learning environment bases on a learning program for laptops. For this project, the contents of the learning program are modified to be used on iPads. The aim of this project is to investigate the effect of the use of tablets in two teaching phases: For the input phase, a laptop-based learning environment was modified and evaluated for the use on iPads. In the internalisation phase, the work with tablet-based tasks is compared with the creation of student explanatory videos regarding their effectiveness considering knowledge, attractiveness and cognitive load.

Keywords: Computer Based Learning, Multimedia and Hypermedia Learning, Differentiation

MOTIVATION

Over the last years, digital media have played an increasingly important role in almost all areas of life. The proceeding digitisation of everyday life is also evident in the use of media by students. Various studies, such as the Bitkom (Bitkom, 2017) or the JIM study (Medienpädagogischer Forschungsverbund Südwest, 2018), show that the smartphone use in Germany – especially among young people – has increased rapidly in recent years. Furthermore, the JIM study points out that the video portal YouTube is one of the most popular websites (Medienpädagogischer Forschungsverbund Südwest, 2018). This makes it clear that video use is extremely important for students. Due to this development, more and more schools try to get mobile devices. This is also reflected in the education policy guidelines in Germany as the strategy paper "Education in the digital world" by the Conference of Education Ministers explicitly calls for learning with and about digital media (KMK, 2017). In addition, the "*DigitalPakt Schule*" – under the leadership of the Federal Government and the Länder – provides financial support for schools (BMBF, 2019).

THEORETICAL BACKGROUND

With regard to the theoretical background, two aspects become important: Digital Learning and Universal Accessibility. Concerning digital learning, we will focus on possible applications and didactic functions. In regard to universal accessibility, the aim is to make teaching materials accessible, if possible, for all students, which is particularly important in heterogeneous learning groups. In this context, digital media have the advantage of offering a variety of possibilities for developing a learning environment with universal accessibility.

Digital Learning

When implementing digital learning technologies, it is essential to think about the specific way mobile devices are used. For this reason, we focus on the SAMR model by Puentedura (2006) (see Figure 8). This model consists of four levels: While at the substitution level digital media replace other tools, which means, for example, reading a text on the iPad instead of an analogue worksheet, functional enhancements can be achieved through the use of digital media at the level of augmentation (Bastian, 2017). For instance, when a written text is spell-checked. Both of these levels are summarised under the term enhancement, the next two levels indicate a transformation. At the level of modification, digital media allow tasks to be redesigned. An example would be the possibility for students to create video recordings (Bastian, 2017). However, digital media can be used for redifining learning, so that completely new methods, such as a collaborative writing tasks, are imaginable (Bastian, 2017).

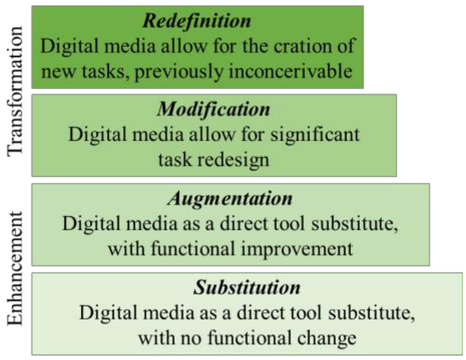

Figure 8. SAMR model (cf. Puentedura, 2006).

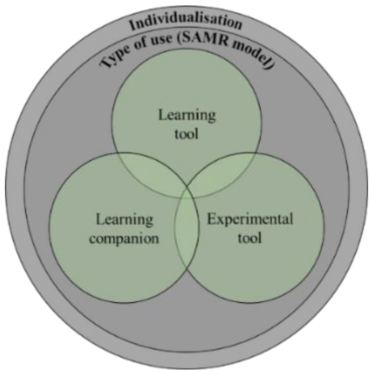

Figure 9. Didactical functions of digital media (cf. Huwer & Brünken, 2018).

If digital media are used in the classroom, the didactic functions in science teaching as a learning tool, experimental tool and learning companion should be considered as shown in Figure 9 (Huwer & Brünken, 2018). As a learning tool, digital media can support the learning process in a concrete learning situation, while, as an experimental tool, digital media can promote the conduction of experiments. If digital media are used as learning companions, they enrich the learning process over a longer period of time. The didactic functions are embedded in the type of use (Huwer & Brünken, 2018) that can be described with the SAMR model. Thus, all four levels of the SAMR model can be implemented for each didactic function. The last dimension is individualisation. With help of digital media, it is possible to achieve different levels of individualisation for a given learning setting (Huwer & Brünken, 2018).

One possibility for using digital media and especially tablets in the classroom is the use of explanatory videos. According to Wolf and Kratzer (2015) explanatory videos are self-produced short films that explain how to do something or how something works respectively in which concepts and relationships are explained. These videos have the advantage of meaningfully linking auditory and visual forms of presentation (Grodach, 2018). The effect and the value of explanatory videos can be differentiated according to which person produces the video and to who receives it (Kulgemeyer, 2018; Wolf, 2018). For instance, students can learn from professionals (producer: teacher, recipient: student), whereby the explanations can be repeated as often as needed. Another option of using explanatory videos in school is that the students create their own explanatory video in order to deal with the topic in more detail (producer: student, recipient: student or teacher) (Kulgemeyer, 2018; Wolf, 2018).

In the context of digital learning, proven teaching formats, such as working on tasks, should be considered for the use on digital devices. The great advantage of processing digitally prepared tasks is that students can receive direct and individual feedback on their given answer (van der Kleij et al., 2015).

Universal Accessibility

Since the ratification of the UN Convention on the Rights of Persons with Disabilities in Germany in 2009, people with disabilities have the right to equal participation in school life (United Nations, 2006). Overall, Germany has switched to an inclusive school system in which people with and without disabilities are taught together. As this goes hand in hand with the fact that the heterogeneity in school classes is increasing more and more, education needs to consider this aspect. Hence, teachers have to adapt their teaching in such a way that each student – regardless of age, gender, origin, level of performance, etc. – is able to participate in the classroom. To reach this goal, the Universal Design for Learning (UDL), developed in the USA, shows possibilities for planning a lesson with universal accessibility (CAST, 2018). The UDL is characterised by a high degree of flexibility. In addition, possible barriers to successful learning are reduced. The UDL is based on three principles, which are shown in Figure 10 as columns. Each principle is subdivided into three guidelines, giving a total of nine guidelines. The guidelines are explained in more detail by checkpoints. For example, the guideline 5 "Language & Symbols" is further described by the checkpoint "Clarify vocabulary and symbols". For reasons of clarity, the checkpoints in Figure 10 are not shown but can be found at the homepage of CAST (2018). The first principle addresses possibilities for supporting learning motivation. Moreover, the second principle of the UDL deals with different possibilities of information presentation. The third principle focuses on the support of learning activity and the presentation of learning outcomes. In general, the UDL can be used as a checklist. However, not all nine guidelines necessarily need to be implemented.

Principles		Provide multiple means of Engagement	Provide multiple means of Representation	Provide multiple means of Action & Expression
Guidelines	Access	1. Recruiting Interest	4. Perception	7. Physical Action
	Build	2. Sustaining Effort & Persistence	5. Language & Symbols	8. Expression & Communication
	Internalize	3. Self Regulation	6. Comprehension	9. Executive Functions
Goals		Purposeful & Motivated	Resourceful & Knowledgeable	Strategic & Goal Directed

Figure 10. The Universal Design for Learning (cf. CAST, 2018).

Various ways are possible to implement the UDL. On the one hand, for instance, many aspects of the UDL can be realised by implementing cooperative learning settings (Hall et al., 2003; Jiménez et al., 2007). On the other hand, the digitisation in schools makes a major contribution to the implementation of the UDL. In this context, digital media offer the possibility of individualisation and differentiation (Tulodziecki & Grafe, 2012). In addition, learning with digital media realises multichannel learning to support the internalisation of information

(Paivio, 1990). Moreover, digital media can provide individual support for the students, for example by helping to read, write and solve tasks (Hall et al., 2015; Rose et al., 2007).

AIM OF THE RESEARCH

Subject of this research is a learning environment for the use on iPads, which we modified based on a laptop-learning environment (Baumann & Melle, 2019). Simultaneously, we complemented the learning environment by two different forms of digitally supported internalisation methods as we compare the creation of explanatory videos and tasks with automated feedback on student performance. To evaluate the developed digital learning environment, we determine the increase in knowledge, the assessment of attractiveness as well as the impact of the learning materials on the cognitive load of the students. In addition, the usage behaviour of the learners when using the learning software is recorded and analysed. Based on this project, we aim to gain deeper insights into the effects of tablet use on knowledge conveyance and internalisation.

METHOD

Design

The following research design (cf. Figure 11) was developed to answer the research questions above. In this case, it is an intervention study, that is carried out as a project day at schools. The sample includes students of the 8th grade (age 13 to 15) in initial chemistry tuition at comprehensive schools in Germany. The advantage of conducting the study on a single day is that learners go through the whole intervention and then fill out the post-test. In this way, sample reduction due to the absence of learners can be avoided.

One week before the intervention, the students write the pre-test. Based on these test results, the class is divided into two parallelised groups. In the input phase, the students of both groups work with the same digital learning environment individually, followed by the internalisation phase in a cooperative pair work. The students in one of the two groups create their own explanatory videos, while the students in the other group work on tasks using the iPad. The project day ends with the post-tests. Three weeks later a follow-up knowledge test is conducted.

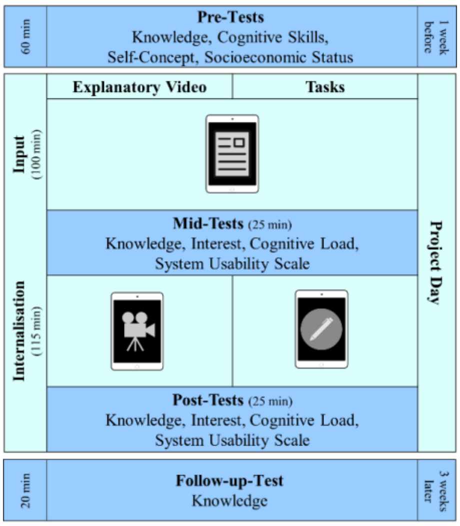

Figure 11. Research Design.

Instruments

The quantitative data are collected by various test instruments. For the pre-tests, we use a knowledge test with 28 items (Cronbach's $\alpha = .769$) to record previous knowledge (Baumann & Melle, 2019; cf. Michna & Melle, 2018), the CFT 20-R to determine cognitive abilities (Weiß, 2006), a questionnaire to determine the school self-concept (Rost et al., 2007), and a questionnaire on the socio-economic status of the students (Torsheim et al., 2016). On the project day itself, we run an assessment test (10 items, Cronbach's α = .865) to determine the attractiveness of the teaching materials (Kieserling & Melle, 2019) and an assessment test (10 items, Cronbach's α = .821) for the cognitive load (Kieserling & Melle, 2019; Leppink et al., 2013) after the input and after the internalisation phase. Furthermore, a test (10 items) is used to record the system usability scale (Brooke, 1996). At the same time, we also apply the knowledge test. In addition to these selective tests, the individual actions of the learners are documented by screen and video recordings.

THE LEARNING SOFTWARE

The learning environment, which was developed within this study, deals with the introduction to the basic concept of the chemical reaction and is a further development of a multimedia learning environment by Baumann and Melle (2019). This learning program by Baumann and Melle (2019) is designed for the use on laptops for the initial tuition of chemistry at comprehensive school. In this laptop-based learning environment, universal accessibility was achieved by implementing various aspects of the UDL. For our project, we modified the multimedia learning environment for the use on iPads. The digital implementation was carried out with iBooks Author (Apple Inc., 2019) and further developed with regard to the implementation of more aspects of the UDL. A detailed description of the transfer of the laptop-based learning environment for the use on iPads is given by Greitemann and Melle (accepted). The structure of the iPad-based learning environment is shown in Figure 12. First, the students work through an introductory chapter in which the functions and the handling of the learning environment are described. This is followed by an information input phase. The students work on the chapters Chemical Reaction, Chemical Equation, Physical Process and Oxide Formation. Afterwards, a practical phase in the form of experiments follows. In the final internalisation phase, the students either create own explanatory videos or work on tasks.

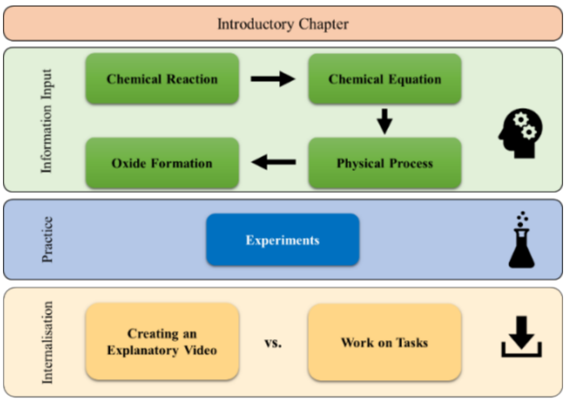

Figure 12. Structure of the iPad-based Learning Environment.

In the input phase, the learning environment serves as a learning tool. The contents of the learning environment are differentiated into three levels. While at the lowest level one reminders of previous knowledge are embedded, additional information is displayed at the highest level three. The students are free to choose the level and can switch between the levels at any time. Moreover, an interactive information presentation is realised so that, for example, short video sequences can be watched as well. Furthermore, the students are given the option to have the texts in the learning environment read aloud. The visual presentation of the contents supports the students iconically. At the end of each chapter, the content is summarised in short sentences, in which the important information is emphasised in bolded letters.

Furthermore, the learning environment serves as experimental tool in the practical phase. In total, the students carry out four experiments. The experimental instructions are offered in form of a text, in form of an image as well as in form of video instructions. Futhermore, the documentation is carried out by using the photo function so that the students' observations can be recorded by a before-and-after comparison. During the evaluation, the students have to answer one closed and one open question. For the closed question, they receive a direct feedback and a sample solution for the open question.

In the subsequent internalisation phase in cooperative pair work, both groups get an additional structuring to support the work process. The students of the explanatory video group start by watching an explanatory video, in which a fictive person serves as motivating strategy: Mario is doing an exchange year and does not understand the topic chemical reaction. Therefore, he asks his friends to send him a video explaining this topic. Afterwards, the students are asked to first work on their own and then with their partner on the content again. The next step is the creation of a storyboard in pair work. With the help of the storyboard, the students plan their video by making drawings of the image sequences and noting down the speaker text. In the final phase, the video is implemented on the iPad using the screencast-based app doceri (SP Controls, 2019). The presentation phase of the videos is done in the chemistry lessons outside of the research. In the task group, the students first watch a video. Subsequently, the students work on tasks for the four theoretical chapters of the learning environment one after the other. Here, the students first work on some tasks individually in order to clarify open questions and work on further tasks in a subsequent pair work phase.

FIRST RESULTS

In the following chapter, the results of the first pilot study are presented. As this is a pilot study with a small sample ($N = 48$), the results should be considered as preliminary.

How do (1) the digital learning environment, (2a) the creation of explanatory videos and (2b) the digitally supported task processing affect the knowledge growth of the students?

The results of the knowledge test are presented in Table 9. The graphic representation is shown in Figure 13. It should be noted that the two groups do not differ with regard to the tasks in the input phase (Pre to Mid). All in all, it becomes clear that both groups learn significantly and with a very high effect size in the input phase. Considering the internalisation phase, there is no significant increase in knowledge in either group. Differences between the two groups cannot be detected at any point in time.

Table 9. Results of the Knowledge Test.

	n	M^*_{pre}	M^*_{mid}	M^*_{post}	Pre - Mid		Mid - Post	
					p	d	p	d
Explanatory Video Group	26	.29	.50	.50	< .001	1.504	.780	.030
Task Group	22	.29	.50	.51	< .001	1.565	.719	.051

*percentage

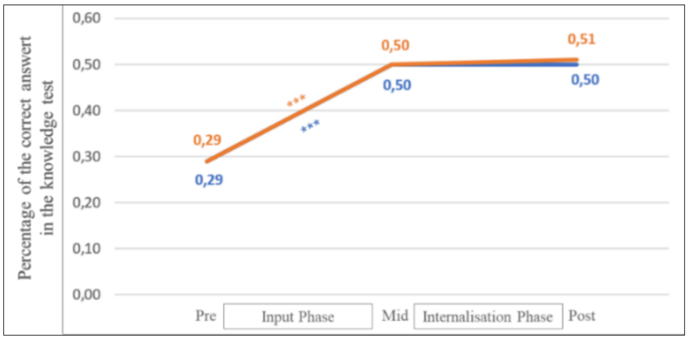

Figure 13. Means of the Knowledge Test (Explanatory Video Group = blue, Task Group = orange).

How are (1) the digital learning environment, (2a) the creation of explanatory videos and (2b) the digitally supported task processing assessed from the students in terms of attractiveness?

The results of the attractiveness test are presented in Table 10 and Figure 14. Both groups rate the digital learning environment on a 6-point Likert scale from 1 = negative to 6 = positive as very attractive in the mid-test. In the post test, this attractiveness decreases significantly for the students of the task group with a medium effect. In contrast, the attractiveness of the explanatory video group after the internalisation phase does not differ significantly from the attractiveness after the input phase. Moreover, the residual comparison between the two groups shows no significant differences between the two groups. Nevertheless, a medium effect indicates that the students of the explanatory video group rate the internalisation phase more attractive than the students of the task group.

Table 10. Results of the Attractiveness Test.

	n	M^*_{mid}	M^*_{post}	Mid - Post		Residual comparison	
				p	d	p	d
Explanatory Video Group	26	4.96	5.03	.609	.093	.076	.550
Task Group	21	5.11	4.75	.040	.524		

*6-point Likert scale from 6 = positive to 1 = negative

How do (1) the digital learning environment, (2a) the creation of explanatory videos and (2b) the digitally supported task processing affect the cognitive load of the students?

The third question deals with the effect of the teaching materials on cognitive load (see

Table 11, Figure 15). For this, a 6-point Likert scale was used, with value 1 corresponding to a high cognitive load and value 6 to a low cognitive load. The students of the task group perceive the internalisation phase more cognitive burdensome than the input phase (significant effect, medium effect size). The cognitive load of the students in the explanatory video group remains constant. However, the residual comparison shows no significant differences between the two groups.

Table 11. Results of the Cognitive Load Test.

	n	M^{*}_{mid}	M^{*}_{post}	Mid - Post		Residual comparison	
				p	d	p	d
Explanatory Video Group	25	5.15	5.11	.873	.028	.079	.522
Task Group	22	5.38	4.95	.007	.669		

*6-point Likert scale from 6 = Low Cognitive Load to 1 = High Cognitive Load

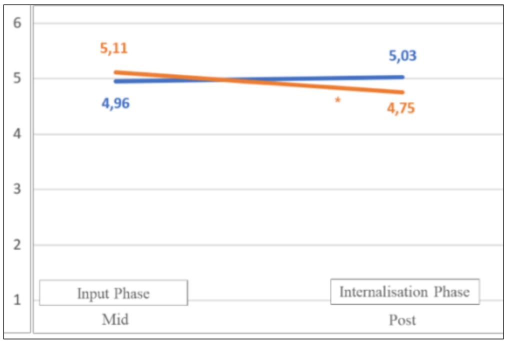

Figure 14. Means of the Attractiveness Test (Explanatory Video Group = blue, Task Group = orange; 6-point Likert Scale from 1= negative to 6 = positive).

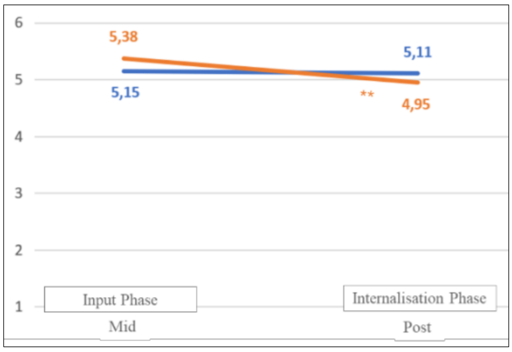

Figure 15. Means of the Cognitive Load Test (Explanatory Video Group = blue, Task Group = orange; 6-point Likert Scale from 1 = high cognitive load to 6 = low cognitive load).

DISCUSSION AND CONCLUSION

Based on the results presented above, it can be stated that the expertise of the students in both groups can be significantly increased by the input phase, while no additional increase in knowledge can be detected after the internalisation phase. Furthermore, both, the input phase and the internalisation phase are considered to be attractive for the students of both groups. However, there are tendencies that the creation of an explanatory video is rated more attractive by the students than the work on iPad-based tasks. The cognitive load is not too high for both groups.

Following the pilot study, the teaching materials and the test instruments will be revised. As a consequence of the results just presented, the knowledge test will be optimised. To this end, the cognitive level of the test is to be raised in order to determine differences between the two groups on the higher cognitive level of application. In addition, we will add open questions to the knowledge test in order to check if there are any differences between the two groups regarding these more difficult questions. Further, we will optimise the learning environment (e.g. due to curricular changes renaming the chapter "Oxidation" to "Oxide formation"). Moreover, the usage behaviour has not yet been evaluated. Hence, an evaluation using specific coding manuals is planned. Furthermore, possible differences between the different cognitive levels of the students will be analysed. Consequently, another pilot study will be carried out with a sample of $N \approx 80$ students. Finally, the main study with a sample of about $N \approx 275$ students will take place.

ACKNOWLEDGEMENT

We thank the participating students and teachers. The learning software was developed as part of the project DoProfiL. This project is part of the "*Qualitätsoffensive Lehrerbildung*", a joint initiative of the Federal Government and the *Länder* which aims to improve the quality of teacher training. The programme is funded by the Federal Ministry of Education and Research.

REFERENCES

Apple Inc. (2019). *iBooks Author*. https://www.apple.com/de/ibooks-author/

Bastian, J. (2017). Tablets zur Neubestimmung des Lernens? Befragung und Unterrichtsbeobachtung zur Bestimmung der Integration von Tablets in den Unterricht. In J. Bastian & S. Aufenanger (Eds.), *Tablets in Schule und Unterricht: Forschungsmethoden und -perspektiven zum Einsatz digitaler Medien* (pp. 139–168). Springer VS.

Baumann, T., & Melle, I. (2019). Evaluation of a digital UDL-based learning environment in inclusive chemistry education. *Chemistry Teacher International*, 1–13.

Bitkom. (2017). *Zukunft der Consumer Technology – 2017: Marktentwicklung, Trends, Mediennutzung, Technologien, Geschäftsmodelle*. https://www.bitkom.org/sites/default/files/pdf/noindex/Publikationen/2017/Studien/2017/CT-Studie/170901-CT-Studie-online.pdf

BMBF. (2019). *Wissenswertes zum DigitalPakt Schule*. https://www.bmbf.de/de/wissenswertes-zum-digitalpakt-schule-6496.php

Brooke, J. (1996). SuS: a 'quick and dirty' usability scale. In P. W. Jordan, B. Thomas, B. A. Weerdmeester, & I. L. McClelland (Eds.), *Usability Evaluation in Industry* (pp. 189–194). Taylor and Francis.

CAST. (2018). *Universal design for learning guidelines version 2.2 [graphic organizer].* http://udlguidelines.cast.org/more/downloads

Frechette, J. D., & Williams, R. (2016). Introduction. In J. D. Frechette & R. Williams (Eds.), *Routledge research in cultural and media studies: Vol. 74. Media education for a digital generation* (pp. 1–20). Routledge Taylor & Francis Group.

Greitemann, L., & Melle, I. (accepted). Transferring and Optimizing a Laptop-based Learning Environment for the Use on iPads. *World Journal of Chemical Education*.

Grodach, C. (2018). Video Learning in Community Planning. *Journal of Planning Education and Research*, *113* (2).

Hall, T. E., Cohen, N., Vue, G., & Ganley, P. (2015). Addressing Learning Disabilities With UDL and Technology. *Learning Disability Quarterly*, *38* (2), 72–83.

Hall, T. E., Vue, G., Strangman, N., & Meyer, A. (2003). *Differentiated instruction and implications for UDL implementation*.

Hanekamp, G. (2014). Zahlen und Fakten: Allensbach-Studie 2013 der Deutschen Telekom Stiftung. In J. Maxton-Küchenmeister & J. Meßinger-Koppelt (Eds.), *Digitale Medien im naturwissenschaftlichen Unterricht* (pp. 21–28). Joachim-Herz-Stiftung Verl.

Huwer, J., & Brünken, J. (2018). Individualisierung mit Tablets im Chemieunterricht. *Computer + Unterricht*, *110* (30), 7–10.

Jiménez, T. C., Grad, V. L., & Rose, E. (2007). Gaining Access to General Education: The Promise of Universal Design for Learning. *Issue in Teacher Education*, *16* (2), 41–54.

Kieserling, M., & Melle, I. (2019). An experimental digital learning environment with universal accessibility. *Chemistry Teacher International*, 1–9.

KMK. (2017). *The standing Conference's "Education in the Digital World" strategy Summary*. https://www.kmk.org/fileadmin/Dateien/pdf/PresseUndAktuelles/2017/KMK-Strategie_Bildung_in_der_digitalen_Welt_Zusammenfassung_en.pdf

Kulgemeyer, C. (2018). A Framework of Effective Science Explanation Videos Informed by Criteria for Instructional Explanations. *Research in Science Education*, *26* (1), 435–456.

Leppink, J., Paas, F., van der Vleuten, C. P. M., van Gog, T., & van Merriënboer, J. J. G. (2013). Development of an instrument for measuring different types of cognitive load. *Behavior Research Methods*, *45* (4), 1058–1072.

Medienpädagogischer Forschungsverbund Südwest. (2018). *JIM 2018: Jugend, Information, (Multi-) Media*. https://www.mpfs.de/fileadmin/files/Studien/JIM/2018/Studie/JIM2018_Gesamt.pdf

Michna, D., & Melle, I. (2018). Inclusion in Chemistry Education in Secondary School. In O. E. Finlayson, E. McLoughlin, S. Erduran, & P. Childs (Eds.), *Proceedings of the ESERA 2017 Conference.: Research, Practice and Collaboration in Science Education.* (pp. 1433–1440). Dublin City University.

Noonan, L. (2013). Talking tablets in school. *SecEd*, *2013* (2).

Paivio, A. (1990). *Mental representations: A dual coding approach*. *Oxford psychology series: Vol. 9*. Oxford University Press; Clarendon Press.

Puentedura, R. R. (2006). *Transformation, Technology, and Education*. http://hippasus.com/resources/tte/

Rikala, J., Vesisenaho, M., & Mylläri, J. (2013). Actual and Potential Pedagogical Use of Tablets in Schools. *Human Technology: An Interdisciplinary Journal on Humans in ICT Environments*, *9* (2), 113–131.

Rose, D. H., Hasselbring, T. S., Stahl, S., & Zabala, J. (2007). *Assistive Technology and Universal Design for Learning: Two Sides of the Same Coin*. https://pdfs.semanticscholar.org/75a2/2d319afce4e5323d0ed22abe27f2e913c841.pdf

Rost, D. H., Sparfeldt, J. R., & Schilling, S. R. (2007). *DISK-Gitter mit SKSLF-8: Differentielles Selbstkonzept-Gitter mit Skala zur Erfassung des Selbstkonzepts schulischer Leistungen und Fähigkeiten*. Hogrefe.

SP Controls, I. (2019). *doceri*. https://doceri.com/

Torsheim, T., Cavallo, F., Levin, K. A., Schnohr, C., Mazur, J., Niclasen, B., & Currie, C. (2016). Psychometric Validation of the Revised Family Affluence Scale: A Latent Variable Approach. *Child Indicators Research*, *9*, 771–784.

Tulodziecki, G., & Grafe, S. (2012). Approaches to Learning with Media and Media Literacy Education: Trends and Current Situation in Germany. *Journal of Media Literacy Education*, *4* (1), 44–60.

United Nations (2006). UN-Convention on the Rights of Persons with Disabilities and Optional Protocol. http://www.un.org/disabilities/documents/convention/convoptprot-e.pdf

Van der Kleij, F. M., Feskens, R. C. W., & Eggen, T. J. H. M. (2015). Effects of Feedback in a Computer-Based Learning Environment on Students' Learning Outcomes. *Review of Educational Research*, *85* (4), 475–511.

Weiß, R. H. (2006). *Grundintelligenzskala 2 (CFT 20-R)*. Hogrefe.

Wolf, K. D. (2018). Video statt Lehrkraft? Erklärvideos als didaktisches Element im Unterricht. *Computer + Unterricht*, *28* (109), 4–7.

Wolf, K. D., & Kratzer, V. (2015). Erklärstrukturen in selbsterstellten Erklärvideos von Kindern. In K.-U. Hugger, A. Tillmann, S. Iske, J. Fromme, P. Grell, & T. Hug (Eds.), *Jahrbuch Medienpädagogik. Jahrbuch Medienpädagogik* (Vol. 3, pp. 29–44). Springer VS.

EXPLORING DIFFICULTIES IN THE USE OF MOBILE DEVICE SENSORS IN THE SCIENCE CLASSROOM: THE CASE OF ACCELEROMETERS

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In recent years, the educational community has shown a keen interest for the use of mobile devices (smartphone and tablets) in the school science lab, and particularly for exploiting the potentialities offered by the sensors of these devices. The present paper reports parts of the findings from a broader study into the difficulties that a teacher might encounter when trying to implement proposals from the physics education literature. These difficulties are primarily related with the variation in technological capabilities of the different models. Specifically, we investigated whether the variety of students' personal mobile devices may cause significant differences in the results of experiments, utilizing the acceleration sensor of those devices. Details of smartphones model belonging to 1,083 students were recorded, and the most popular devices of this population were identified, with the seven of them selected for use in the study. The selected smartphones simultaneously recorded the acceleration of a moving body to which they all were attached. The findings indicated that the differences in the values of the acceleration measured by the various devices are not statistically significant in the context of experimentation in the school lab. Therefore, in our view, students' use of their personal mobile devices would in no case be a deterrent to a lesson plan involving the measurement of acceleration.

Keywords: Technology in Education, Laboratory Work in Science, Teaching Practices

INTRODUCTION

The use of smartphones and tablets seems to provide, for science teachers, an easy solution both for real-time data collection (via the various sensors available in all mobile devices), and the on-site processing of these data as well. The literature on this subject is rapidly expanding (e.g. Kearney et al., 2012; Kuhn &Vogt, 2013; Zacharia et al., 2016; Gonzalez & Gonzalez, 2016; Iliaki et al., 2018), but it does not address yet all aspects of this technology in the classroom. Most of the papers describe experiments in which the use of mobile devices is required, and only few of the studies deal with technical problems involving the mobile device sensors (e.g. Monteiro 2015). However, there are no significant studies on the practical problems that may arise in the classroom when using these devices.

As a first step in our research, we considered that it would be useful to investigate the possible practical issues that might arise during the implementation of experiments using students' personal mobile devices in the school lab. On the one hand, the practical issues might arise from students' potential difficulties in using their mobile devices in ways that might be unfamiliar to them, while on the other hand, the devices themselves could create a problem, i.e., the differences between (i) the technological capabilities of the different models, (ii) the device's operating system (iOS –Android), and (iii) the applications (Apps) which the devices utilize.

In the present study, we are investigating the possible differentiation between the results of experiments using the acceleration sensor of different models of mobile phones or mobile phones with different operating system (iOS / Android).

METHODS

Initially, the number and the models of students' mobile phones (MPs) to be used for recording measurements had to be determined. Our goal was to use a number of devices sufficient to permit simultaneous measurements from the same experiment. Towards this end, information about the MPs of 1,083 students from three Greek secondary schools was recorded and the most popular devices were identified, resulting in seven different smartphone models being selected for use in the experiment. Two, of these seven selected MPs, use the iOS while the rest the android operating system.

The experiment focused on the use of the accelerometer, a sensor with which all MPs are equipped and for which there are many suggestions in the literature for use in the classroom (e.g. Vogt & Kuhn, 2014). One of the proposed experiments was performed, namely the use of the accelerometer sensor to measure the acceleration (a) of a sliding body (Fig.1) in order to calculate the coefficient of friction (μ) between two surfaces (Equation 1).

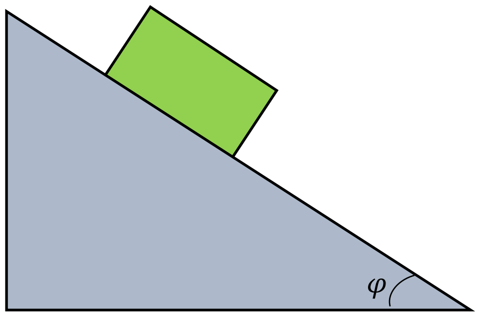

Figure 1. The sliding body on an inclined plan

$$\mu = \frac{g \cdot sin\varphi - \alpha}{g \cdot cos\varphi} \quad (1)$$

This specific experiment was chosen because it was possible for all seven MPs to be attached onto the same moving object (a wooden parallelepiped) and afterwards to study its motion (Fig.2), thus ensuring that possible variations in acceleration values will only be due to the type of device and not to other parameters.

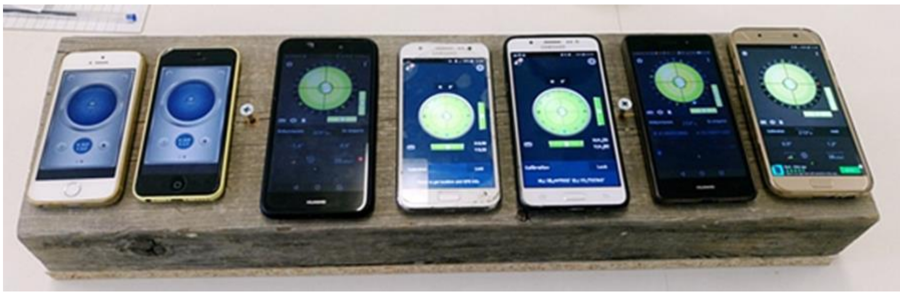

Figure 2. The smartphones on the wooden parallelepiped.

For measuring the value of acceleration, the application "SPARKvue" was used by all devices (https://www.pasco.com/sparkvue/). The selection of this App was made on the basis of the following criteria: (i) It is available free of charge for mobile devices, (ii) It has the same format and handling in both the iOS and Android platform, (iii) It automatically creates graphs and allows them to be handled on the device, (iv) It allows data to be extracted on spreadsheets, and finally (v) It allows a wide range of sampling frequency (0-1KHz).

In addition to the measurement of acceleration, the measurement of the slope angle of an inclined plane was also required during the experiment. Unfortunately, we could not find the same App for both the Android and iOS platforms, so we had to use the "compass level" application (https://play.google.com/store/apps/details?id=com.jee.level&hl=en) for the Android devices, while the "surface level" application was used for devices with the iOS platform.

Finally, it should be noted that the experiment was carried out by the researchers with the participation of the students who were the owners of the selected MPs. However, data on the ability of these students to use the devices during the experiment and on the learning processes were not recorded as these were not among the aims of the present study.

FINDINGS

In the first phase of the study, the models of the MPs owned by 1,083 students were recorded. The findings showed 303 different smartphone models from 32 manufacturers, with both iOS and Android operating platforms. The total number of the selected seven most commonly used MPs corresponds to 22% of the valid responses.

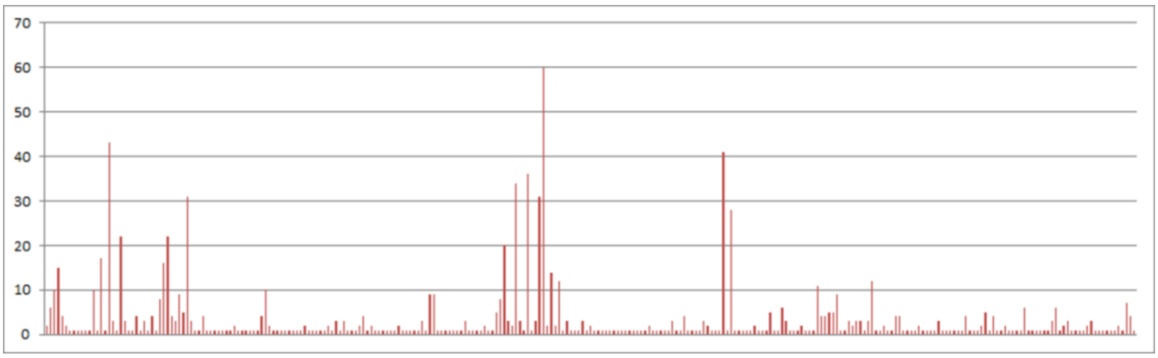

Figure 3. The number of each type of smartphone.

This highlights the wide range of MP models belonging to students (Fig.3) and, therefore, indicates the importance of undertaking a study concerning the reliability of the measurements of all these different devices.

In the experiment carried out, the following measurements were taken:

(i) The gravitational acceleration (g) was measured by the accelerometer of the MPs in order to gain knowledge not only about the reliability of the measurements, but also about their accuracy (Table 1).

Table 1. Measurements of the acceleration of gravity from the seven MPs.

Measurements of g in m/s^2						
MP 1	MP 2	MP 3	MP 4	MP 5	MP 6	MP 7
9.91	9.83	9.76	9.84	9.91	9.96	9.63
Mean: 9.83		SD: 0.10		C.V: 1.02%		

(ii) The angle (φ) of inclination of the inclined plane was simultaneously measured by all MPs (Table 2).

Table 2. Measurements of the slope angle of the inclined plane from the seven MPs.

MP 1	MP 2	MP 3	MP 4	MP 5	MP 6	MP 7
24°	24.5°	23.3°	24.4°	24.2°	23.8°	24.6°
Mean: 24.1°		SD: 0.4°		C.V: 1.67%		

(iii) The acceleration (α) of the moving body on the inclined plane was simultaneously measured by all MPs.

As it is shown in Figures 4 and 5, there is an area in the graph were the acceleration is approximately constant (plateau), corresponding to the duration of the sliding of the wooden parallelepiped along the inclined plane. From this area, a section (shaded section in Figure 4) was selected in which the minimum, the maximum and the mean value of the acceleration, as well as the standard deviation and the coefficient of variation, were calculated (Table 3). As it is mentioned above with the SPARKvue application, the extraction of these values is possible directly on the screen of the MPs (figure 5) or with the use of a computer and an appropriate software (figure 4).

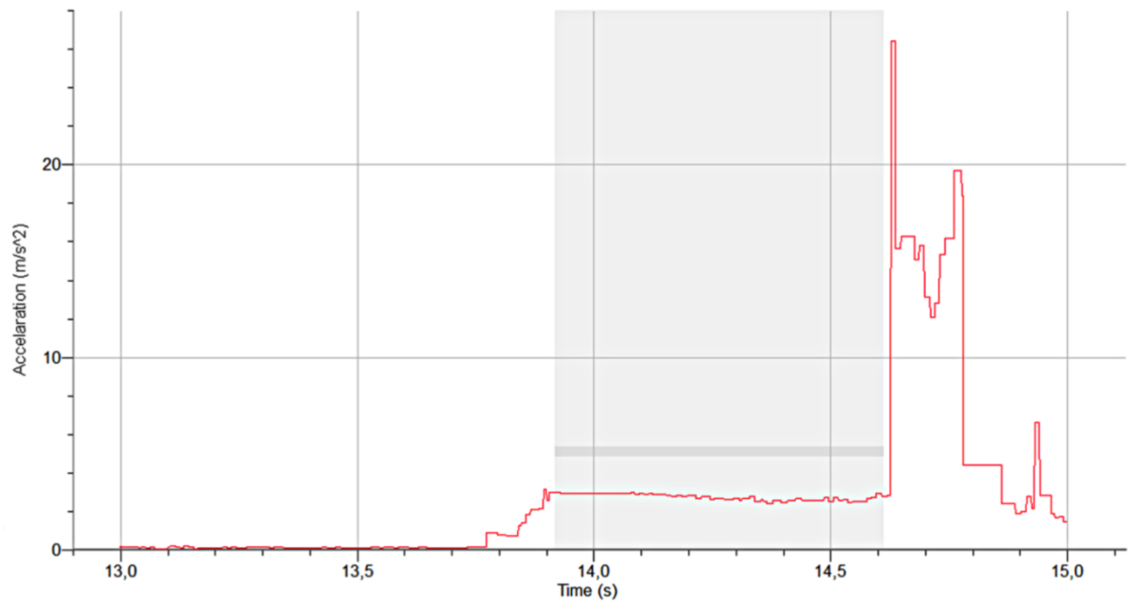

Figure 4. The graph of the acceleration in relation to time from the downloaded data of a MP in a PC using the Logger pro software.

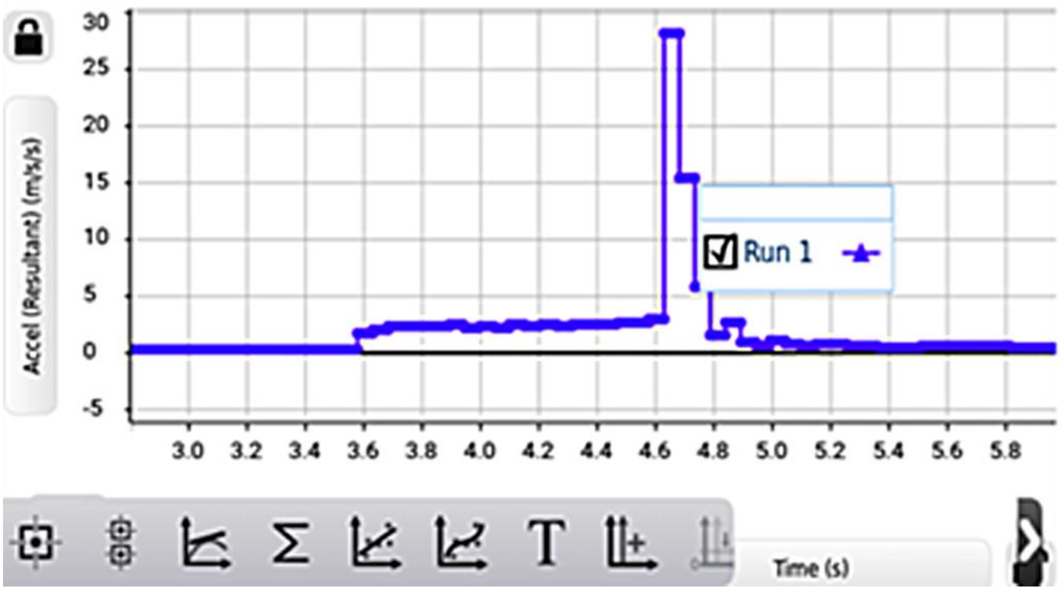

Figure 5. The graph of the acceleration in relation to time directly from the screen of a MP using the SPARKvue application.

Table 3. Characteristic values of the acceleration (in m/s^2) in the plateau area.

	MP 1	MP 2	MP 3	MP 4	MP 5	MP 6	MP 7
a_{min}	2.408	2.403	2.600	2.651	2.603	2.603	2.552
a_{max}	3.166	3.109	3.174	2.956	3.079	3.071	3.117
a_{mean}	2.776	2.736	2.792	2.774	2.820	2.826	2.815
SD	0.173	0.172	0.188	0.117	0.171	0.153	0.168
C.V.(%)	6.23	6.29	6.73	4.23	6.05	5.41	5.98

Finally, based on the measurements, the kinetic coefficient of friction (μ) between the body and the inclined plane was calculated by using the corresponding theoretical formula (Equation 1) (Table 4).

Table 4. The kinetic friction coefficient as it was calculated using the data from each MP.

MP 1	0.13
MP 2	0.15
MP 3	0.12
MP 4	0.14
MP 5	0.13
MP 6	0.13
MP 7	0.14

CONCLUSIONS AND IMPLICATIONS

As the present study confirms, students own a wide variety of mobile phone models. This means that the teacher who plans to implement the "Bring Your Own Devices" (BYOD) process (Stavert, 2013; Song, 2014) in the classroom or in the science lab will be faced with many different types of mobile devices and operating systems. Therefore, he/she should not only choose an App compatible with different operating systems, but he/she also should be aware of the range of measurement variation among the different devices. The results of the present study may contribute to this end.

With regard to App selection, there is a wide variety of suggestions, possibly ephemeral due to the rapid rate of technological development. In the present study, the "SPARKvue" App proved to be an appropriate choice for use in devices with different operating systems (iOS and Android). This specific application is free of charge, easy to use, allows the processing of data directly on the device and, finally, the data can be extracted for further processing with the appropriate software.

The main question addressed in the present study is whether measurement experiments in which the accelerometer of different mobile devices are used result in differences which render the use of these devices unsuitable for educational use. According to our findings, direct measurements with the MPs – such as the angle of the inclined plane, the acceleration of gravity, as well as the mean value of the acceleration during the sliding of a body – show differences which are not statistically significant. This makes the mobile devices useful educational tools for implementation in the school classroom or lab.

REFERENCES

Iliaki G., Velentzas A., Michailidi E. & Stavrou D. (2018) Exploring the music: a teaching-learning sequence about sound in authentic settings, *Research in Science & Technological Education*, 37:2, 218-238.

González, M. Á., & González M. Á. (2016). Smartphones as Experimental Tools to Measure Acoustical and Mechanical Properties of Vibrating Rods. European Journal of Physics, doi:10.1088/0143-0807/37/4/045701.

Kearney, M., Schuck S., K. Burden, & Aubusson P., (2012). Viewing Mobile Learning from a Pedagogical Perspective. *Research in Learning Technology,* 20 (1): 14406, doi:10.3402/rlt.v20i0.14406.

Klein, P., Hirth M., Gröber S., Kuhn J., & Müller A. (2014). Classical Experiments Revisited: Smartphones and Tablet PCs as Experimental Tools in Acoustics and Optics. *Physics Education* 49 (4): 412.

Kuhn, J., Vogt, P. (2013). Smartphones as Experimental Tools: Different Methods to Determine the Gravitational Acceleration in Classroom Physics by Using Everyday Devices. *European Journal of Physics Education,* 4(1), 47-58.

Monteiro, M., Cabeza, C. Marti, A. (2015). Acceleration measurements using smartphones sensors: Dealing with the equivalence principle. *Revista Brasileira de Ensiro de Fisica*, v. 37, n. 1, 1303.

Song, Y. (2014). "Bring Your Own Device (BYOD)" for seamless science inquiry in a primary school. *Computers & Education*, 74, 50–60.

Stavert B. (2013). BYOD in Schools Literature Review 2013, State of NSW Australia.

Vogt, P., Kuhn, J., (2014). Acceleration Sensors of Smartphones Possibilities and Examples of Experiments for Application in Physics Lessons. *Frontiers in Sensors (FS)* V.2, p.1-9.

Zacharia, Z. C., Lazaridou C. & Avraamidou L. (2016). The Use of Mobile Devices as Means of Data Collection in Supporting Elementary School Students' Conceptual Understanding about Plants. *International Journal of Science Education* 38 (4): 596–620.

GAME OF THRONES TO LEARN SCIENCE. AN EXPERIENCE WITH SPANISH PRE-SERVICE SCIENCE TEACHERS

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The most consumed media in Spain in 2018 was television, with fiction series being the favourite among young people. This paper shows how this medium can be used as an educational resource in science education by studying problematic situations of interest, presenting the results of an experience carried out with 52 pre-service science teachers (PST) who worked with the television show Game of Thrones in an educational innovation subject of the Master's Degree in Secondary Education Teaching at the University of Málaga (Málaga, Spain). The PSTs watched several sequences from the TV show, from which they had to select frames and propose driven questions on physics, chemistry, biology and geology for secondary school students, explaining how to approach them in the classroom. The researchers categorized the proposals in the scientific disciplines according to the contents used and the PSTs´ explanations. To assess the experience, the researchers used a questionnaire that included items about the learning achieved, the educational possibilities of the resource and the emotions felt. On their learning, they highlighted how a playful resource could be converted into an educational resource to motivate students. The resource was well received with a score of 8.53 out of 10.00, increasing the average knowledge of the PSTs of their educational possibilities from 1.96 to 4.54 (on a scale of 5.00 points) before and after the experience. The PSTs highlighted interest, satisfaction and concentration as the main emotions felt during the experience. This study is considered novel since it applies this strategy to teachers in training, analysing their capacity to teach and their perceptions. Finally, it should be noted that the educational use of television as a resource in the classroom allows us to connect scientific and school knowledge, can motivate disinterested students and provide a pedagogical tool that enhances instruction.

Keywords: teaching innovations, initial teacher education (pre-service), science education

INTRODUCTION

Teaching-learning science is often boring and difficult for high school students. To overcome this difficulty, some authors have formulated proposals with different educational resources to motivate and improve the learning of science and scientific attitudes of students. Among these is the media as a source of knowledge, and particularly television, a medium which, along with the Internet, is one of the most widespread in the current population due to its diffusion, power, influence and consumption (AIMC, 2018). TV consumption data show the influence of this type of media on students' conceptions, as well as the image presented of science on TV, which does not usually coincide with reality (Dudo et al., 2011).

Different studies have explored the use of fictional resources (films, television shows or novels) in formal and informal science education settings to teach science concepts or enhance critical-thinking skills (Li & Orthia, 2016). The educational use of TV shows, as the main preference of adolescents, is shown as an attractive alternative since it can make science learning more effective and motivating; namely, it can be a good way of getting students interested in science (Allday, 2003; Sánchez, 2010) and can contribute to the scientific and television literacies of teenagers by connecting the domains of scientific and school knowledge. Famous TV shows such as The Bing Bang Theory (Li & Orthia, 2016), CSI (Cass, Grazier, Thompson, & Marrinan, 2013), Prison Break (Franco-Mariscal, 2009), Bones (Milanick & Prewitt, 2013) or House (Millard, 2009), or cartoons such as The Simpson (Orthia et al., 2012) or Peppa Pig (Franco-Mariscal, 2016) have been used to learn science.

Despite its potential, the number of researches carried out to educate in the excellent use of television and the Internet, and more particularly, to teach and learn science or to create positive attitudes toward it are considered insufficient. Therefore, we face with two literacies (scientific and television) considered as important objectives of today's education.

The teacher’s role in implementing the resource into practice is also crucial, as he or she must be aware of its educational possibilities in order to get the most out of it, as well as know-how to guide the students discussing the science implied in the TV show sequences. In this sense, the works presented in this line with pre-service science teachers (PSTs) are very limited. For this reason, this paper presents the results of an experience with PSTs, which aims to study their ability to teach science through the TV show Game of Thrones and their perception of the resource to transfer it to the classroom as future secondary school teachers.

METHOD

A total of 52 Spanish PSTs of the Master’s Degree in Secondary Education Teaching of the University of Malaga (Malaga, Spain) participated in this study. The 59.60% were women and 40.40% men, aged between 22 and 44 years. The PSTs studied a subject of innovation and educational research in the specialities of Physics-Chemistry and Biology-Geology during the academic year 2018-2019. The experience presented here is framed within a teaching unit dedicated to educational innovation where different resources for the classroom were shown, including the use of TV shows to teach science.

The method used in the classroom is based on the use of fictional series in science teaching through the study of problematic situations of interest (King, 2012; Ültay y Çalik, 2012). Game of Thrones was the TV show chosen by a large number of followers in the ages of the participants in this research. According to *The Guardian,* Game of Thrones is the “most talked about show on television” (Hughes, 2014).

PSTs watched several sequences from the episode 7x06, totalling no more than 3 minutes of duration, including the ambush of the white walkers on Jon Snow in a frozen lake, the arrival of Daenerys with her dragon to help them, and the rescue of the dragon from the bottom of the lake by the white walkers. Working in groups, the PSTs should prepare a report explaining how they could use this resource in secondary science class. To do so, they should select different frames and propose scientific driven questions to pose to the students. They had to work three contents of physics, chemistry, biology and geology, clearly explaining how to approach them in the class. The researchers categorized the results according to the contents used in the different disciplines and their explanations.

In order to know their assessment of the activity, each PST completed a questionnaire after the experience where they had to explain what they had learned, the evolution of their knowledge of the resource before and after on an ordinal scale of 1 to 5 (1: I do not know anything, 2: I know a little, 3: I know it well, 4: I know it very well, 5: I can explain it to a friend), assess the best and the worst aspects of the task, give it a score over 10, and choose between several emotions how they had felt in their development justifying why. Evolution of their knowledge and emotions were taken from the *Knowledge and Prior Study Inventory* (KPSI) questionnaire (Jiménez-Liso, Martínez-Chico, Avraamidou, & López-Gay, 2019), with the PST being able to choose more than one of them.

RESULTS

PSTs' proposals

The PSTs made numerous proposals to bring this resource into a secondary classroom. Table 1 shows several examples of sequences, the associated scientific content and the driven questions.

Table 12. Examples of scientific contents and driven questions.

Discipline	Sequence	Scientific content	Driven question
Physics	Jon Snow´s group crosses the icy lake. In their chase, the horde of walkers fails and break the ice	Forces	Why Jon Snow and his friends manage to cross the frozen lake and when the white horde walkers pass the ice breaks?
Chemistry	Jon Snow seems to be having difficulty breathing during the chase	Oxygen concentration	Why Jon Snow has difficulty breathing in the mountains?
Biology	When rescuing the dragon from the ice, you can see that the colour of his eyes has changed to blue	Genetic	Why do some dragons have blue eyes and other blacks?
Geology	The horde of walkers appears from a narrow gorge	Formation of relief	How could a crack have formed in the middle of the mountain? Why isn't a mountain a perfect, smooth, seamless mass?

Two sequences (figures 1 and 2) related to the dragon are explained in detail below, which allowed to discuss different contents through driven questions in the field of biology.

Sequence 1: The eye of the dragon rescued from the ice has changed to blue.

Figure 1. The eye of the dragon

Content 1: Mendel's Laws.

Some PSTs proposed to work the laws of genetics to explain the colour of the eyes and how the transmission of characters takes place. Some driven questions were:

Driven question 1: Why do some dragons have blue eyes and another brown?

Educational approach: The aim is to address in the classroom that the colour of people' and animals' eyes is genetically determined, with DNA being responsible for defining this colour. Also, there are other objectives to address in class such as the belief that eye colour is a mixture of the colour of the parents is not valid; introducing the concepts of dominant character and recessive character by giving examples of the formation of eyes of different colour using the laws of genetics.

Driven question 2: Can two dragons with brown eyes have a dragon with blue eyes? If so, why?

Educational approach: To address this driven question, the student must first propose which is the dominant and recessive gene of eye colour in dragons. He/she can assume that the blue colour of the dragon's eyes, as in humans, is due to a recessive gene concerning his/her allele for the brown colour. Thus, if the dragon's parents have brown eyes and the offspring blue eyes, it is because the dragon son is homozygous recessive (aa), and his/her parents in order to pass on the gene “a” must be “Aa”.

Dragon parents genes: Aa x Aa

Dragon son genes: aa

Driven question 3: What colour do you think their parents and grandparents have?

Educational approach: It is about discussing through Mendel's laws the possible eye colours that the dragon's parents and grandparents could have so that theirs are blue.

Content 2: *Anatomy of the eye.*

The driven questions 4, 5 and 6 are oriented to know or identify the eye anatomy and the functions of its parts.

Driven question 4: What are the different parts of a dragon's eye?

Educational approach: The aim is to identify each of the parts in the dragon's eye: a lens called the crystalline lens, with adjustable focus according to distance; a "diaphragm" (the pupil), whose diameter is regulated by the iris (coloured area), and a light-sensitive tissue (the retina).

Driven question 5: How is the dragon's pupil initially located (dilated or contracted)?

Educational approach: This involves understanding that the pupil changes size depending on the amount of light the eye receives. Thus, through the phenomenon of myosis, the pupil decreases in size, while with mydriasis, it increases in size. The pupil is contracted in the sequence analysed (figure 1). Also, the pupil is vertically elongated and torn like a cat, allowing for a higher capacity for dilation and the ability to have a good depth of objects, which makes the dragon a good hunter.

Driven question 6: Why does the dragon have a second lateral eyelid? Is it fiction?

Educational approach: It will be indicated that this is not fiction since other reptiles have two eyelids, even some animals such as camels have three. As in humans, the eyelids have a protective function. A second function is related to the use they can give them in the air. This situation allows students to ask if they have ever ridden on a motorcycle or rolled down the window of a car, and what is wrong with their eyes, with the idea that they will identify that it is both to protect the eyes from anything getting in them and to keep them hydrated.

Sequence 2: The dragon.

Figure 2. The dragon.

Content 3: Taxonomic classification of the dragon.

The following driven questions allow us to know better the different kingdoms of life and their characteristics.

Driven question 7: To which kingdom of living beings would a dragon belong? Within the animals, what class?

Educational approach: This driven question allows us to approach the kingdoms of life, focusing on the animal kingdom and within it the vertebrates and the chords. It also explains the importance of classifying living beings in science.

Driven question 8: Does the dragon resemble any animal we know? What characteristics do they share and how do they differ?

Educational approach: This driven question aims to introduce the evolution of reptiles and their characteristics, a paraphyletic class of amniotic vertebrate animals with epidermal keratin scales.

PSTs' Assessments

On the learning achieved:

The PSTs highlighted how a playful resource could be converted into an educational resource to learn or explain science by making a good selection of scientific contents, attracting the students with means that they enjoy.

About the evolution before and after the knowledge of the PSTs about the resource:

The average knowledge of the PSTs of the educational possibilities that the resource can offer increased from 1.96 points (before its use) to 4.54 (after) (figure 3) on a scale of 5.00 points (1: I do not know anything, 2: I know a little, 3: I know it well, 4: I know it very well, 5: I can explain it to a friend).

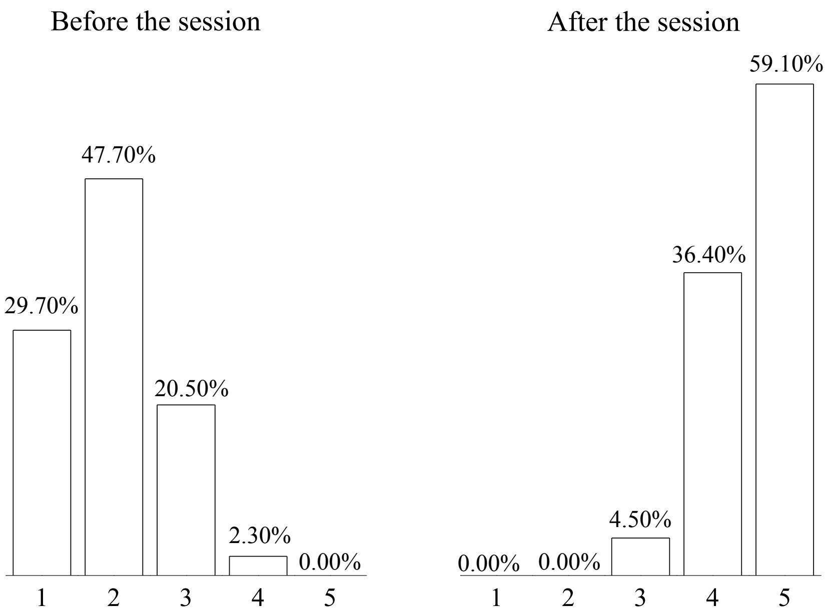

Figure 3. Evolution of the educational possibilities of the resource before (left) and after (right) its use.

About the score given to the resource and the best and worst rated aspects:

The average score of the resource was very good (8.53 out of 10.00 points). The most highly rated characteristics of the resource were its ability to motivate and innovate, its simplicity or its connection with everyday aspects. As negative aspects, they cited the previous knowledge required by the students to solve some driven questions o that the motivational capacity of the show will depend on whether it is known to the students.

Regarding the emotions felt:

81.80% of the PSTs showed interest as the main emotion felt during the activity (figure 4). Satisfaction (59.10%) and concentration (56.80%) were other major emotions. Only 2.30% felt bored, and 4.50% rejected the use of the resource.

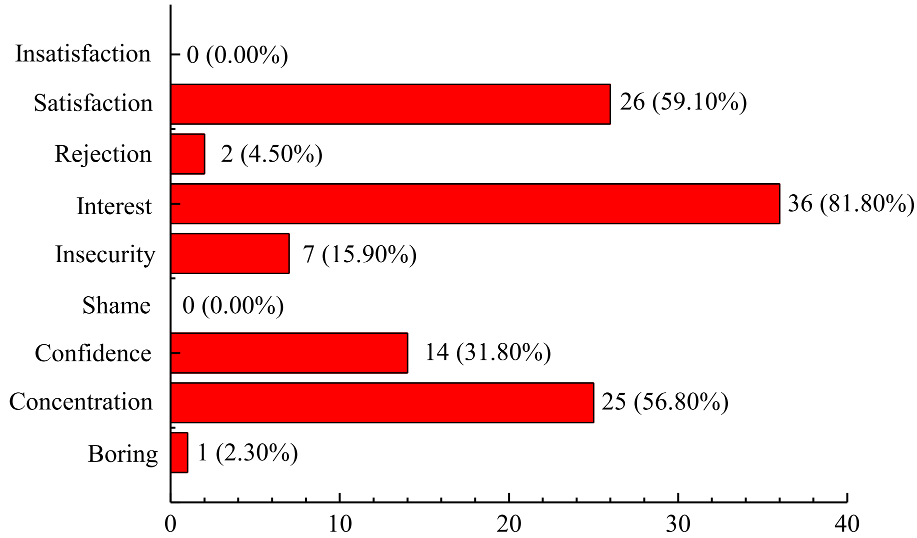

Figure 4. Emotions (%) felt by the PSTs during the activity.

CLOSING REMARKS

We agree with Raham (2004), Perales and Vílchez (2005) and García-Borrás (2008) that the results obtained from this kind of experience are encouraging and show the effectiveness of this resource, although they also highlight the obstacles encountered by secondary school students in explaining phenomena.

This experience has attempted to provide the PSTs with the necessary training to take the resource to the classroom, stressing the possible difficulties of the secondary students. Likewise, the method used does not intend to make an exhaustive follow-up of each chapter of the TV series, but only tries to analyse some situations from the perspective of science. Finally, the fact of having used an adult series does not imply that it will also be used with high school students and the PSTs are aware that they must use a TV series according to the preferences of their students.

ACKNOWLEDGEMENT

This work is part of the 'I+D Excelencia' Project EDU2017-82197-P funded by the Spanish Ministry of Economy and Finance through its 2017 research call and del PIE17-062 de la Universidad de Málaga.

REFERENCES

AIMC, Asociación para la investigación de medios de comunicación (2018). *Resumen general 2018*. Madrid: AIMC.

Allday, J. (2003). Science in science fiction. *Physics Education*, *38*(1), 27-30.

Cass, S., Grazier, K. R., Thompson, B., & Marrinan, C. (2013). Constructing Crimes: How the CSI effect is created. In D. J. Nelson, K. R. Grazier, J. Paglia, & S. Perkowitz (Eds.), *Hollywood*

Chemistry: *When science met entertainment* (pp. 145-151). Washington D.C.: American Chemical Society Publisher, ACS Symposium Series.

Dudo, A., Brossard, D., Shanahan, J., Scheufele, D. A., Morgan, M., & Signorielli, N. (2011). Science on Television in the 21st Century: Recent trends in portrayals and their contributions to public attitudes toward Science. *Communication Research*, *38*(6), 754–777.

Franco-Mariscal, A. J. (2009). Aprende física con Prison Break. [Learn physics with Prison Break]. *Alambique, Didáctica de las Ciencias Experimentales*, *60*, 82-94.

Franco-Mariscal, A. J. (2016). Óptica con Peppa Pig. [Optics with Peppa Pig.] *Alambique, Didáctica de las Ciencias Experimentales*, *83*, 57-63.

García-Borrás, F. J. (2008). House: Otra forma de acercar el trabajo científico a nuestros alumnos. [**House: another approch for dealing scientific work with our students].** *Revista Eureka sobre Enseñanza y Divulgación de las Ciencias*, *5*(2), 212-228.

Hughes, S. (2014). Sopranos Meets Middle-Earth: How Game of Thrones took over our World. T*he Guardian*, March 22. Retrieved from website: https://www.theguardian.com/tv-and-radio/2014/mar/22/game-of-thrones-whats-not-to-love (December 26, 2019).

Jiménez-Liso, M. R., Martínez-Chico, M., Avraamidou, L., & López-Gay, R. (2019). Scientific practices in teacher education: the interplay of sense, sensors, and emotions. *Research in Science & Technological Education*, DOI: 10.1080/02635143.2019.1647158

King, D. (2012). New perspectives on context-based chemistry education: using a dialectical socio-cultural approach to view teaching and learning. *Studies in Science Education*, *48*(1), 51-87.

Li, R. & Orthia, L.A. (2016). Communicating the Nature of Science through *The Big Bang Theory*: Evidence from a focus group study. *International Journal of Science Education, Part B*, *6*(2), 115-136.

Milanick, M. A. & Prewitt, R. L. (2013). Fact or Fiction? General Chemistry helps students determine the Legitimacy of Television Program Situations. *Journal of Chemical Education*, *90*(7), 904–906.

Millard, J. T. (2009). Television Medical Dramas as Case Studies in Biochemistry. *Journal of Chemical Education, 86*(10), 1216.

Orthia, L. A., Dobos, A. R., Guy, T., Kan, S. Z., Keys, S. E., Nekvapil, S., & Ngu, D. H. Y. (2012). How Do People Think About the Science They Encounter in Fiction? Undergraduates Investigate Responses to Science in The Simpsons. *International Journal of Science Education, Part B*, *2*(2), 149–174.

Perales, F. J. & Vílchez, J. M. (2005). The teaching of physics and cartoons: Can they be interrelated in secondary education? *International Journal Science Education*, *27*(14), 1647-1670.

Raham, G. (2004). *Teaching science fact with science fiction*. Portsmouth: Teacher Ideas Press.

Sánchez, C. H. (2010). *Todo lo que sé de ciencia lo aprendí mirando Los Simpson.* Buenos Aires: The author.

Ültay, N. & Çalik, M. (2012). A thematic review of studies into the effectiveness of context-based chemistry curricula. *Journal of Science Education and Technology*, *21*(6), 686-701.

SCIENCE PRE-SERVICE TEACHERS TPACK AND BELIEFS ABOUT LEARNING WITH DIGITAL MEDIA

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Even if the technical possibilities of ICT are given, the biggest obstacles for teachers in using digital media are a lack of expertise and competences. To prepare future science teachers for teaching science with digital media, a concept for a seminar for pre-service teachers of chemistry and primary science is developed, implemented, and evaluated. The main goal is to develop the pre-service teachers' skills and knowledge about the use of digital media in science classes and to change – if needed – students' beliefs about the usage of digital media in a positive way. Our seminar is based on a blended learning approach. It discusses new organisational possibilities and new learning media in science classes. The conceptual focus of the seminar is the development and production of educational videos on a certain topic. Besides the feedback for further development of the seminar, the evaluation focuses on pre-service teachers' beliefs and their TPACK regarding digital media in science education.

Keywords: ICT Enhanced Teaching and Learning, Higher Education, Computer Supported Learning Environments

INTRODUCTION

As the world in which we live and work becomes increasingly digital, the demands placed on school and higher education have changed. Parents, politicians, and learners see great potential in the digital society and demand learning with digital media. In various strategy papers, the Ministers of Education of Germany call for the digitisation of education in Germany, which could contribute to addressing several challenges (e.g. KMK 2017, 2019). It has been shown that the use of digital media or Information and Communication Technologies (ICT) has positive effects on teaching and learning (e.g. Hattie, 2008; Hillmayr, Reinhold, Ziernwald, & Reiss, 2017). Furthermore, researchers, especially in science education, see great potential, e.g. in process and model visualisation, in experimentation and knowledge acquisition as well as in inquiry-based learning (e.g. Meßinger-Koppelt, Schanze, & Groß, 2017; Maxton-Küchenmeister & Meßinger-Koppelt, 2014; Hogarth, Bennett, Lubben, Campbell, & Robinson, 2006).

In order to use digital media in a didactically meaningful way in school and, thus, to exploit their potential, a number of prerequisites must be met: in addition to a suitable and usable digital infrastructure, digital learning concepts and teachers trained in media didactics are required (Becker & Nerdel, 2017; Schmid, Goertz, Radomski, Thom, & Behrens, 2017).

Unfortunately, only a small number of teachers in general and science teachers in particular use digital media in their classrooms. Studies have shown that teachers in Germany use digital learning concepts rarely (e.g. Gerick & Eickelmann, 2017). The reasons for this, which have been identified in several studies, are that only 15 % of the teachers see themselves as qualified and only 25 % see the potential of digital media in class (Schmid et al., 2017). Thus, the lack of digitalisation of teaching and learning in schools is partly based on the lack of teachers' expertise, competence, and knowledge in designing learning settings with digital media (Initiative D21, 2016). To fulfil the demand for implementing digital technology, teachers need to professionalise in teaching with digital media.

THEORETICAL BACKGROUND

Concerning this need for professionalisation, it is important to identify the factors that influence teachers to use digital media in teaching. In general, the teachers' actions in class are influenced by two factors: (i) their knowledge and (ii) their beliefs about the subject, such as their beliefs about the use of digital media (Goodman, 1988). Knowledge and beliefs are seen as filters for all activities, and the processing of new information and are often difficult (Eilks & Markic, 2007). They can only be changed in a long-term learning process (Huberman, 1993).

With the TPACK framework, Koehler and Mishra (2008) have provided a model for the (i) knowledge the teachers need for using digital media in teaching in a didactically meaningful way. They refer to Schulman's concept of professional knowledge (1986) and expand it to include Technological Knowledge (see figure 1) which is the knowledge about technology, tools, and resources as well as the productive use of it at work and in everyday life. TPACK describes complex relationships between pedagogical knowledge (PK), content knowledge (CK), and technological knowledge (TK). The term TPACK stands for *Technological Pedagogical and Content Knowledge* and describes the knowledge about the selection and use of technologies for the promotion of learning processes in a subject matter. In this way, TPACK conceptualises the knowledge that teachers need to integrate digital media didactically meaningfully and effectively into their teaching (Schmidt et al., 2009). Guzey and Roehrig (2009) also conclude that the appropriate and effective use of digital media in science teaching depends largely on the TPACK of teachers.

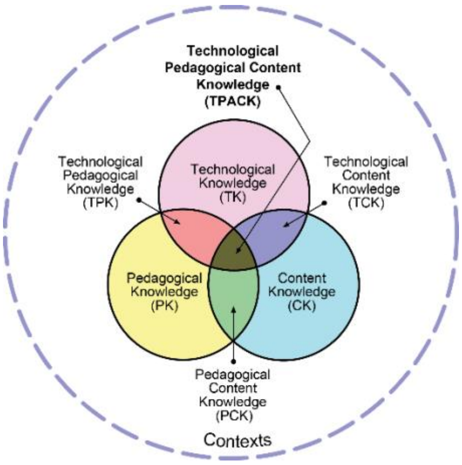

Figure 1. TPACK, Reproduced by permission of the publisher, © 2012 by http://tpack.org

Besides knowledge, teachers need positive (ii) beliefs to use digital media in their class. These beliefs depend on various internal variables of the teacher. The Social Cognitive Career Theory (SCCT) by Lent, Brown, and Hackett (2002) attempts to capture the complex interdependencies of these intrapersonal variables and to find out how these variables influence decision-making processes in the context of a profession. These variables, such as self-efficacy, outcome expectations, and interest are interdependent and influence the formation of personal goals as well as the selection, practice, and execution of behaviours, such as the use of digital media (Lent et al., 2002; Niederhauser & Perkman, 2008).

To sum up, to professionalise teachers in teaching with digital media, they need TPACK and positive beliefs about the integration of technology into their classroom. In order to develop this knowledge and beliefs, pre-service teachers need specific education at a very early stage of their university teacher education program. Thus, in our seminar, pre-service teachers of primary science and chemistry are supposed to obtain knowledge about usage of digital media, as well as expertise and competences in designing learning settings based on digital media for their future teaching. We developed, implemented, and evaluated a seminar for pre-service teachers of chemistry and primary science, that aims for the development of their TPACK, and beliefs and that teaches future science teachers the usage of digital media in class.

DESIGN OF THE SEMINAR

To reach the goal, a new concept for a seminar was developed at our university which follows a blended learning approach (Kerres & de Witt, 2003). The structure of the seminar is presented in figure 2.

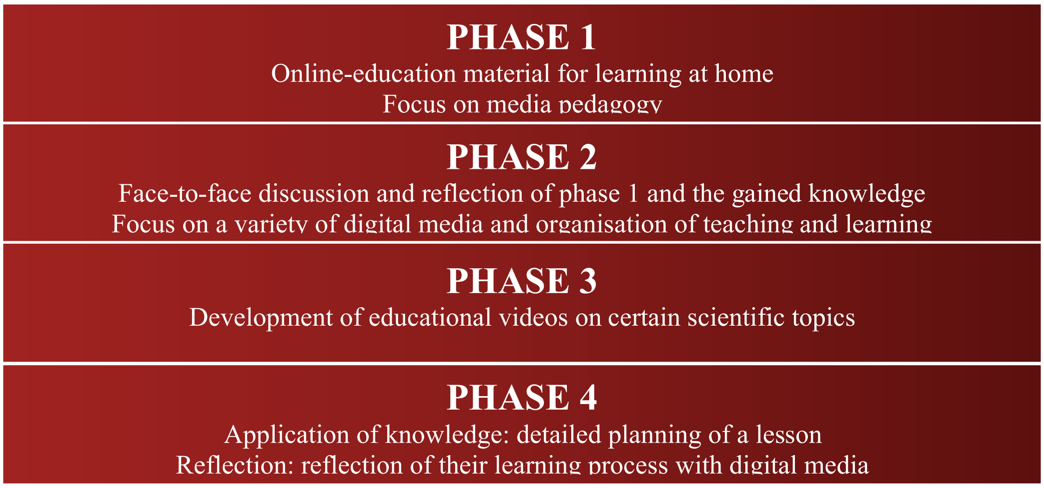

Figure 2. Design of the seminar

In phase 1 the pre-service teachers prepare individually and self-directed with learning materials, assignments, and further information at home. They learn with videos, texts, podcasts, and short online courses with assignments. The focus is on media pedagogy.

Phase 2 works strongly with cooperative and digital learning methods and is strongly learner-centred. The students meet two full days to discuss and reflect on the preparation and their gained knowledge. In this In-Class-Activity, the seminar focusses on the variety of digital media and the organisation of teaching and learning in science education. In these two days, the students work a lot with tablets, apps, and digital whiteboards, so the pre-service teachers can become familiar with these technologies and gain an impression of their productive use in class. They learn to plan lessons with digital media with a didactical concept. One of the topics is criticism of digital media in school and challenges that need to be faced if they want to implement digital media in school. Furthermore, the students will get to know general and scientific learning apps and, in particular, apps with gamification and serious game elements. They will discuss the chances of their use in class.

Finally, the central point of the seminar was in phase 3 the development of educational videos on a specific scientific topic. Educational videos are the most popular digital learning medium for students in their free time (Medienpaedagogischer Forschungsverbund Suedwest [MPFS], 2018). Explanatory videos can be of great use for the students. Especially videos with scientific experiments are considered because laboratory equipment and laboratories are sometimes not available in schools and, therefore, the experimental part of the subject is often insufficiently represented. Through the use of videos, chemical experiments can be integrated into everyday school life. The pre-service teachers need to design a lesson plan and think about how to integrate their video into the learning process. Following this, they develop a script and produce the video.

After the In-Class-Activity, in phase 4, the pre-service teachers in our study need to apply and reflect on their new gained knowledge. Each student creates a portfolio on the topics of the seminar and works on short lesson plans using different digital media in different settings. They reflect on their learning process and beliefs regarding digital media in their future teaching. With this knowledge and these experiences, students will hopefully be able to inform themselves about learning with digital media independently in the future.

RESEARCH QUESTION

Based on the insights from the literature, the goal of the seminar was to improve the pre-service teachers' TPACK and – if needed – to influence their beliefs in a positive way. Thus, three main research questions are raised for the evaluation:

(RQ1) How do pre-service teachers experience the developed seminar and what are their wishes and ideas for its improvement?

(RQ2) How does the concept of the developed seminar change the *technological pedagogical and content knowledge* of pre-service teachers of science and primary science regarding the usage of digital media in their future classes?

(RQ3) How does the concept of the developed seminar change the *beliefs* of pre-service teachers of science and primary science regarding the usage of digital media in their future classes?

METHOD AND SAMPLE

To answer these questions, a pre-post-follow-up-research-design was employed using qualitative and quantitative data. The post-test took place a few days after the seminar and the follow-up test took place four months after the seminar.

Regarding the first research question, the final evaluation of the seminar was based on open questions such as "What did you like about the seminar?", "What did you learn in the seminar?", and "What could be improved?". For answering the second research question, we used a questionnaire yielding quantitative data (Schmidt et al., 2009; translated by Mahler &

Arnold) which measures the pre-service teachers' perceived TPACK. For answering the third research question, a Likert-type questionnaire about pre-service teachers' beliefs about the usage of digital media was employed (Hulleman, Godes, Hendricks, & Harackiewicz, 2010; Hulleman & Harackiewicz, 2009; Davis, 1989; Lent et al., 2005; translated and slightly modified).

24 pre-service teachers of chemistry and primary science participated in the seminar. 20 of them were enrolled in a bachelor's program in primary science and in the first semesters of their degree. The remaining four students were enrolled in the master's program of chemistry for secondary school and in the final stage of their degree. Approximately 80 % of the pre-service teachers were female, which is typical for a University of Education in Germany. We analysed the data with a paired-samples t-test.

RESULTS

In the following, the results will be presented to answer the research questions.

RQ1

The pre-service teachers of chemistry and primary science in this seminar had fun producing the educational videos and liked that they could test a lot of devices and apps and learn that way. They stated that they discovered many possible applications and suggestions for their future classes and got a good overview. They said that the seminar had a good structure and that they liked the blended learning approach. They value the hands-on-activity and the active parts of the seminar. They had hardly any experience with digital media in learning scenarios before the seminar, except for educational videos, which they use to learn in school and higher education. We also asked for suggestions for improvement. After the first round of the new seminar, they only suggested a better timing of the working-phases and more practical examples in class. Based on the evaluation after the second round, we improved in both points.

RQ2

Regarding the second research question, the results are presented in figure 3.

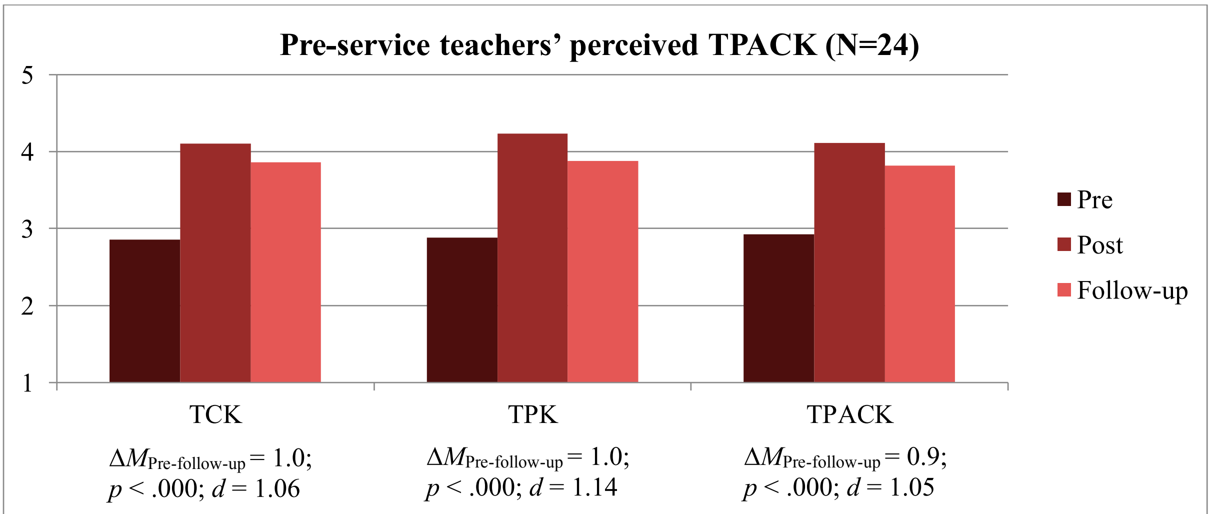

Figure 3. Pre-service teachers' perceived TPACK

The diagram shows the development of the pre-service teachers' perceived TCK, TPK, and TPACK in the pre, post, and follow-up tests. These are the intersections in which the technological knowledge is combined with the other domains and therefore this is interesting for the development of the pre-service teachers. The bars of the pre, post, and follow-up tests have almost the same height regarding the three TPACK intersections. The value in the pre-test is around 2.9 and it increases to a value of around 4.1 in the three cases in the post-test. In the follow-up-questionnaire the value decreased to approximately 3.8 in TCK, TPK, TPACK. The increase of the perceived TPACK is significant and has a large effect size with a Cohen's d > 0.8 (Cohen, 1988).

RQ3

The results regarding the third research question are presented in figure 4.

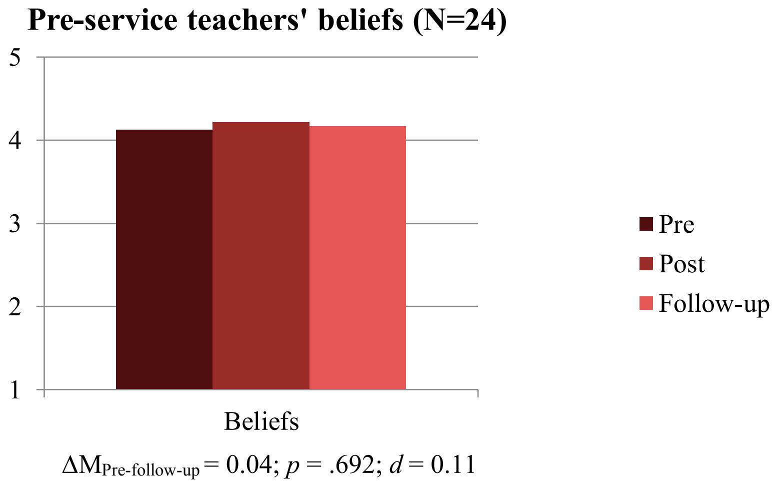

Figure 4. Pre-service teachers' beliefs

In the diagram, the development of the pre-service teachers' beliefs in the pre, post, and follow-up tests is displayed. The bars of the pre, post, and follow-up tests have almost the same height. The value in the pre-test is 4.1 and it increases to a value of 4.2 in the post-test. In the follow-up-questionnaire the value decreased to 4.15. Thus, there is a slight increase, but the differences are not significant. Overall, the beliefs remain on a high level with a value of around 4.1 on a Likert scale from 1 to 5.

DISCUSSION

The present study shows the impact of a specialised seminar on the development of pre-service teachers' perceived TPACK and beliefs about the usage of digital media in science lessons. To summarise our results, the pre-service teachers in this study have a positive impression of the seminar and the feedback became even more positive after the 2nd and 3rd round. A blended learning concept with digital media seems suitable for two full-day seminars in higher education. We recommend giving the pre-service teachers enough time to get to know the technology, such as tablets and apps. A great way to do that is to let them work on creative assignments in groups. They are engaged and will come up with thoughtful and appropriate ideas. Moreover, we suggest discussing criticism regarding digital media in school.

Regarding the perceived TPACK of the students, a significant increase could be observed, with the highest value in the post-study. Thus, we conclude that the seminar leads to an increased perceived TPACK. Here, the seminar reached the goal to develop the pre-service teachers' TPACK.

In contrast, the pre-service teachers' beliefs didn't change significantly but remained at a high level. We think that these results are due to the students' willingness to participate in the course. The course is optional in their study program and we believe that the majority of the students choose the course because they already have strong positive beliefs about the usage of digital media in learning. Furthermore, in Germany, the topic is trendy because there are important governmental campaigns for supporting the digitalisation of learning in schools. Thus, we assume that this could have increased the pre-service teachers' beliefs to this high value already before the seminar. The constantly high values of the beliefs can be interpreted as a positive result because we didn't discourage pre-service teachers with a realistic view of the implementation of digital media in class. Based on the evaluation, we believe that this type of seminar can help pre-service teachers to implement digital media in their future teaching in school. However, this question needs to be addressed in further studies.

REFERENCES

Becker, S., & Nerdel, C. (2017). Gelingensbedingungen für die Implementation digitaler Werkzeuge im Unterricht. In J. Meßinger-Koppelt, S. Schanze & J. Groß (Hrsg.). *Lernprozesse mit digitalen Werkzeugen unterstützen - Perspektiven aus der Didaktik naturwissenschaftlicher Fächer* (S. 36–55). Hamburg: Joachim Herz Stiftung Verlag

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences*. Hillsdale, N.J: L. Erlbaum Associates

Davis, F. D. (1989). Perceived usefulness, perceived ease of use, and user acceptance of information technology. *MIS Quarterly*, 13(3), 319–340

Eickelmann, B., & Gerick, J. (2017). Lehren und Lernen mit digitalen Medien - Zielsetzungen, Rahmenbedingungen und Implikationen für die Schulentwicklung. *Schulmanagement Handbuch*, 4, 54–81

Eilks, I., & Markic, S. (2007). Die Veränderung von Lehrerinnen und Lehrern in langzeitlichen Modellen partnerschaftlicher Unterrichtsentwicklung und -forschung durch Partizipative Aktionsforschung in der Chemiedidaktik. In: *Chimica etc. Didactica* 33(99), 30-48

Goodman, l. (1988). Constructing practical philosophy of teaching. study of pre-service teachers 'professional perspective. *Teaching and Teacher Education*, 4, 121-137.

Guzey, S. S., & Roehrig, G. H. (2009). Teaching science with technology: Case studies of science teachers' development of technology, pedagogy, and content knowledge. *Contemporary Issues in Technology and Teacher Education*, 9(1), 25-45.

Hattie, J. (2009). *Visible Learning: A Synthesis of Over 800 Meta-Analyses Relating to Achievement*. London: Routledge.

Hillmayr, D., Reinhold, F., Ziernwald, L., & Reiss, K. (2017). *Digitale Medien im mathematisch-naturwissenschaftlichen Unterricht der Sekundarstufe. Einsatzmöglichkeiten, Umsetzung und Wirksamkeit*. Münster: Waxmann.

Hogarth, S., Bennett, J., Lubben, F., Campbell, B., & Robinson, A. (2006). ICT in Science Teaching. Technical Report. In: *Research Evidence in Education Library*. London: EPPI-Centre, Social Science Research Unit, Institute of Education, University of London

Huberman, M. (1993) Linking the Practitioner and Researcher Communities for School Improvement, *School Effectiveness and School Improvement*, 4:1, 1-16, DOI: 10.1080/0924345930040101

Hulleman, C. S., Godes, O., Hendricks, B. L., & Harackiewicz, J. M. (2010). Enhancing interest and performance with a utility value intervention. *Journal of Educational Psychology*. 102, 880-895
Hulleman, C. S., & Harackiewicz, J. M. (2009). Promoting interest and performance in high school science classes. *Science*, 326, 1410-1412
Initiative D21 e.V. (Hrsg.). (2016). *Sonderstudie „Schule Digital". Lehrwelt, Lernwelt, Lebenswelt: Digitale Bildung im Dreieck SchülerInnen-Eltern-Lehrkräfte*. Retrieved from https://initiatived21.de/app/uploads/2017/01/d21_schule_digital2016.pdf
Kerres, M., & C. de Witt (2003). A didactical framework for the design of blended learning arrangements. *Journal of Educational Media*. 28, 101-114
Koehler, M.J., & Mishra, P. (2008). Introducing TPCK. In AACTE Committee on Innovation and Technology (Ed.). *The handbook of technological pedagogical content knowledge (TPCK) for educators*. (pp. 3-29). New York. NY: Routledge
Kultusministerkonferenz (KMK). (2017). *Bildung in der digitalen Welt. Strategie der Kultusministerkonferenz Bildung in der digitalen Welt*. Berlin. Retrieved from https://www.kmk.org/fileadmin/Dateien/pdf/PresseUndAktuelles/2017/Strategie_neu_2017_datum_1.pdf.
Kultusministerkonferenz (KMK). (2019). *Empfehlungen zur Digitalisierung in der Hochschullehre*. Berlin. Retrieved from https://www.kmk.org/fileadmin/Dateien/pdf/PresseUndAktuelles/2019/BS_190314_Empfehlungen_Digitalisierung_Hochschullehre.pdf.
Lent, R.W., Brown, S.D., & Hackett, G. (2002). Social cognitive career theory. In D. Brown (Ed.), *Career choice and development* (pp. 255–311). San Francisco: Jossey-Bass.
Lent, R.W., Brown, S.D., Sheu, H., Schmidt, J.A., Brenner, B., Gloster, C., Wilkins, G., Schmidt, L., Lyons, H., & Treistman, D. (2005). Social cognitive predictors of academic interests and goals in engineering: Utility for women and students at historically Black universities. *Journal of Counseling Psychology, 52*(1), 84–92
Mahler, D. & Arnold, J. (2018), unpublished manuscript.
Maxton-Küchenmeister, J., & Meßinger-Koppelt, J. (Hrsg.) (2014). *Digitale Medien im naturwissenschaftlichen Unterricht*. Hamburg: Joachim Herz Stiftung Verlag.
Medienpaedagogischer Forschungsverbund Suedwest (MPFS). (Hrsg.) (2018). *JIM-Studie 2017. Jugend, Information, Medien. Basisuntersuchung zum Medienumgang 12- bis 19-Jähriger in Deutschland*. Retrieved from https://www.mpfs.de/fileadmin/files/Studien/JIM/2018/Studie/JIM_2018_Gesamt.pdf
Meßinger-Koppelt, J., & Maxton-Küchenmeister, J. (Hrsg.) (2018). *Naturwissenschaften digital - Toolbox für den Unterricht*, Joachim Herz Stiftung Verlag: Hamburg.
Meßinger-Koppelt, J., Schanze, S., & Groß, J. (Hrsg.) (2017). *Lernprozesse mit digitalen Werkzeugen unterstützen – Perspektiven aus der Didaktik naturwissenschaftlicher Fächer*. Hamburg: Joachim Herz Stiftung Verlag.
Schmidt, D. A., Baran, E., Thompson A. D., Koehler, M.J., Mishra, P., & Shin, T. (2009). Technological pedagogical content knowledge (TPACK). The development and validation of an assessment instrument for preservice teachers. *Journal of Research on Technology in Education*, 42(2), 123–149
Schmid, U., Goertz, L., Radomski, S., Thom, S., & Behrens, J. (2017). *Monitor Digitale Bildung. Die Hochschulen im digitalen Zeitalter*. Gütersloh: Bertelsmann Stiftung. Retrieved from https://www.bertelsmannstiftung.de/fileadmin/files/BSt/Publikationen/GrauePublikationen/BSt_MDB3_Schulen_web.pdf

USE OF A COMPUTER TOOL IN SCIENCE TEACHING TO SUPPORT THE DESIGN OF EXPERIMENTS

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The computer supported environment LabNbook has been proposed to high school and university teachers to support the production of experimental reports or lab notebooks by students. Our focus is on activities where students have to design experiments including a formalisation part through the writing of the experimental protocol. LabNbook provides a protocol editor, Copex, to support students in this formalisation of their experiment. We investigate the pedagogical strategies developed by teachers to make students write protocols using the Copex tool. Forty-nine activities from twenty-one teaching units are analysed. While some teaching units do not spend much on the writing of the protocol, various creative strategies are proposed by the teachers with Copex. An insight on the use of Copex by students shows that the spontaneous use of Copex by the students for writing a protocol is encouraged by the value teachers give to the writing of the protocol and to the use of Copex, in previous activities. Two teachers' interviews show that the structuring power of the writing of the protocol supported by Copex, is used in particular to make students structure their work and thus better understand and connect, the strategy and the details of the experiment.

Keywords: Computer Supported Learning Environments, Laboratory Work in Science, Learning by Design

INTRODUCTION

Literature shows added values and benefits brought by active learning based education (e.g. inquiry learning, problem- or project-based learning (PBL), in terms of conceptual learning (Freeman et al., 2014). Among the possible activities associated to active learning, we are specifically interested in the design of experiments by students that helps them acquire new scientific skills (Etkina, Karelina & Ruibal-Villasenor, 2010).

LabNbook (labnbook.fr) is an online learning environment, which has been initially designed for researchers, to study the design of experiments by the students. LabNbook supports students (and teachers) who are committed to active learning based education and need to write either a lab notebook or a scientific report (e.g. inquiry learning, problem- or project-based learning (PBL), experimental process). For the means of designing experiments, LabNbook includes a protocol editor, named Copex, an original tool to support the writing of structured experimental protocols. This tool is based on one main hypothesis, valid for both high school and university learning: the design of an experiment is at the centre of the experimental process and can be related to each step of this process. This design task is complex and demanding and requires guidance in order to make it feasible by the students. This is supported by several researches in science education (Etkina et al., 2010; Girault, d'Ham, Ney, Sanchez & Wajeman, 2012; Girault & d'Ham, 2014; Arnold, Kremer & Mayer, 2014; van Riesen, Gijlers, Anjewierden & de Jong, 2018; Xenofontos, Zacharias & Hovardas, 2018). Most of these studies do not pay a particular attention to the experimental protocol which describes the experiment and belongs to the experimental process.

The experimental protocol

In our research, we put emphasis on the experimental protocol, in the belief it can play an important role for scientific learning through the design of an experiment. The protocol is a true scientific object that fulfils several functions in the experimental process. Despite an experimental protocol is compulsory in an experimental process, scientific publications seldom deal with it on epistemological issues. Discussions are mostly limited to repeatability and reproducibility questions, and to communicability for assessment by experts (see for instance Dean & Voss, 1999; Selwyn, 1996). This corresponds to an underlying practice: a protocol is a memory of what has been done during the experiment and it describes how the collected data were produced. A protocol carries thus essential information for data analysis and interpretation and for subsequent discussions. In books about the design of scientific experiments (Dean & Voss, 1999; Selwyn, 1996), the protocol is mentioned as a writing part that describes the procedure of an experiment (actions to carry out the experiment) and have to include objectives, information about material and apparatus and the data processing can have to be described as well. Selwyn underlines the necessity of writing a protocol before carrying out the experiment because "experiments that are designed on the fly are rarely successful". Thus the writing of a clear and structured protocol obliges to think, formalize and make clear what one is willing to do; it has to be assessed and improved. The protocol contains theoretical terms and is directed by concepts. The designer has thus to build links between the world of ideas and the world of facts (Tiberghien, Psillos & Koumaras, 1995).

What is the place and role of the experimental protocol in scientific education? For instance, the French upper secondary school curricula (ending 2020) often mention "run a protocol, sometimes "design and run a protocol" and once “propose a critical analysis of a protocol”. Following Chevallard’s framework (1985) to describe knowledge in an ecological context, the protocol can be considered as a para-scientific object: it is a scientific tool that a student must be able to use, but it is not a subject to be taught in itself and it is never defined nor described. In a previous study (Girault et al., 2012), laboratory manuals were analysed at high school level and at the first years of university. It showed that the protocols given to students in cookbook labs have various forms and do not resemble protocols as scientists would write them. The students may thus have difficulties to build a clear image of a protocol.

The protocol editor Copex

After performing several experiments where students design an experiment and write the protocol, we have built a model of a protocol (Bonnat, Marzin-Janvier, Girault & d’Ham, 2019). The model is simple and flexible in order to make it usable for a variety of protocols and suitable at upper secondary school level and for university students. This model was implemented in a protocol editor Copex. A high gain of Copex is to foster the writing of short sentences that are easy to understand, to include drawings, comments and tables and organise the procedure in a hierarchical way. The Copex model is composed of four introductory rubrics followed by the procedure. These rubrics are: Experiment objectives or research question, Experiment hypotheses or expected results, Experiment principle, List of material. The procedure is the description of the experimental actions to be carried out when running the experiment. The procedure is organised in steps, sub-steps and actions. Thus, Copex model supports a structured vision of the experiment that can be built by articulating a global view through the rubrics and the procedure main steps, with the details through sub-steps, actions (there is a possibility to add actions comments). Furthermore, looking ahead for what the experiment should produce (expected results) and connecting it with the hypotheses, requires reflecting on the relevance of the experiment and should foster problem solving.

Copex is available on the LabNbook platform (d'Ham, Wajeman, Girault & Marzin-Janvier, 2019), where students produce scientific reports collaboratively. Since LabNbook does not include content and do not address any pedagogy, the teachers have freedom to design the activity they wish for their students with the pedagogy they want. The teacher configures a template of the students' working space, named “mission”. The students work in collaboration in their own shared working space, named “report”: they write down their report by using four LabNbook editors, including the original protocol editor Copex. Copex can be fine-tuned by the teacher to structure the activity of experimental design at different levels. The teacher can include in the students' workspace a predefined Copex document, i.e. a protocol template which can be totally or partially filled, or empty. She/he can add instructions in the mission to assign a task to the students and to guide them. However, using a protocol editor is not a usual scientific or a teaching practice. Therefore teachers and students may use the LabNbook text editor for writing protocols instead of Copex editor.

Research questions

From 2017, LabNbook has been used by about 140 teachers. In this paper, we address the question of how the protocol editor Copex is used by teachers and students during experimental design activities to make students work on the experimental protocol. There could be a variety of uses of Copex by the teachers since they can structure the activity of experimental design at different levels. We specify two research questions (RQ) through the analysis of teachers' productions and of students' activity:

- RQ1: Which activities regarding the protocol do teachers propose to their students using the Copex protocol editor? What guidance do they implement within LabNbook to help their students in these tasks? Which pedagogical roles/values do teachers assign to these tasks?
- RQ2: When students have to design an experiment, do they spontaneously use Copex to write their experimental protocol? In which teaching circumstances?

DATA AND METHOD

Around 250 pedagogical activities have been created with LabNbook and used for teaching from September 2017 to January 2019, both at high school level (students aged 15 to 18) and at University level (age 19 to 23). The pedagogical activities are diverse, some teachers use LabNbook for one activity that lasts between two and four hours, while others use it through one semester for a project-based learning or for a collection of laboratory works during the two consecutive years of our study. Two kinds of data are used in this study: first we collect the template of working spaces, called missions, that have been built by the teachers for their students. Then, for collecting more information about the teaching process and the teacher's intentions, we conducted an interview with two teachers who designed a mission.

Missions

To answer RQ1 we analyse the 25 missions (10 at high school level and 15 at university level), that include predefined Copex documents (*i.e.* protocols given by the teachers in the template), spread over 12 teaching units (set 1). We collect 24 extra missions (set 2, organised in 9 teaching units) that have no predefined Copex document, while a Copex document was added by students in their LabNbook report. This reveals that students are expected to write a protocol. Among these 24 missions, 15 are connected to missions with predefined Copex documents, so they can be part of a guidance strategy.

For the selected missions, we use an analysis grid to analyse the predefined Copex documents (set 1 only) and the instructions within a mission, in order to identify the tasks that are demanded to the students regarding the experimental protocol. We thus seek for

1. the written instructions within the missions that are related to Copex or/and to a protocol.
2. information that is given or that is to be completed by the students within a predefined Copex document (set1), regarding the rubrics (objective, hypotheses, principle, material), and the procedure (steps, actions).

Students

To answer RQ2, we analyse the second set of selected missions (set 2). For each mission, we calculate the ratio of students who use Copex to write a protocol on all the students who work on the same mission.

Teachers' interviews

We choose two teachers who give an important and original place to the protocol within the missions they designed. These teachers do not use the protocol in the same way and they teach in different contexts.

Teacher 1 is an upper secondary school teacher in chemistry and physics for K12 level students (30 per year). He designed three missions for his own use, following his own will to improve his teaching.

Teacher 2 is teaching laboratories in electronics in an engineering school (L3 level, 360 students per year), and is part of a team of teachers. There is an institutional will to renew and improve all the laboratories. The interviewed teacher designed two missions belonging to two different teaching units, each one taking place at a different semester of L3. In fact, his students follow each semester other teaching units (labs in physics) using LabNbook.

The two teachers are interviewed in a semi-open mode (Planche et al., 2019), to make them express their motivation and objectives, tell what they did to make their students work with the protocol, what was successful and what has to be modified. We want to figure out the epistemological and pedagogical role they give to the protocol in the laboratory work they designed.

ANALYSIS OF MISSIONS

Guidance through Copex

We analyse the protocols in the predefined Copex documents of the 25 missions of set 1, to identify what kind of information is given by the teachers or is to be completed by the students: objective, hypotheses or expected results, principle, material, procedure (steps and tasks). We also look for instructions related to the production of the experimental protocol(s).

	Number of missions (a total of 25 missions)
Presence of predefined Copex documents with only a title	11
Teachers fill at least one rubric among research questions, hypotheses or expected results, principle	19
Steps and actions are given	7
Only steps are given	9
Only actions are given	0

Table 1. Types of information given by the teachers in predefined Copex documents. There can be more than one predefined Copex document in a mission.

The teachers use several guidance strategies to guide the students in the design of a protocol.

- The minimum of guidance is to give students an empty Copex document in the mission. This way, teachers push the students to use Copex to write a protocol. When creating a new document, giving a title is mandatory, this explains why there is at least a title. This is the case in 11/25 missions.
- Another type of guidance is to give students the context of the procedure that will be written by them. This corresponds to one, two or three rubrics filled with research questions or objectives, hypotheses or expected results and the principle of the experiment. This is the case in the majority of protocols (19/25).
- Regarding the procedure itself, some teachers give steps and actions (7/25) or only the steps (9/25). Our analysis shows that there are no missions (0/25) where the teachers would give the actions and the students would have to organise them by adding the steps.

We seek for instructions (in the mission and/or in the teachers' interviews) to associate the type of guidance with intended pedagogical activities. For this we also take into account the the 15 missions within set 2 (no predefined Copex documents) that have a connection with missions that do include predefined Copex documents.

We highlight several pedagogical activities. Some of them correspond to an activity inside a Copex document, while other activities imply an evolution throughout several Copex documents inside a single mission or through several missions. We are able to relate some activities to a pedagogical scenario that we describe in relation to the activities.

- A procedure (steps and actions) is given and the students have to infer the problem to be solved and the expected results (1/25 mission). The teacher expects students to have an overview of their protocol.
- The teacher gives the principle in the dedicated area and through the steps, and the students have to give the details by writing actions (1/25 mission). This gives the students an opportunity to detail the experiment that will be done, to force them to face the complexity of an experiment.
- A Copex document is given with steps and/or actions in an alphabetic order and students have to organise them (3/25 missions, 3 teaching units).
- Students are expected to write the entire protocols with no visible guidance (3/25 missions, 2 teaching units). These missions only propose an empty Copex document. For two of them, the students are working in a project at master level and probably have a degree of autonomy to write their protocol and get feedback from the teacher.
- Students are expected to write the entire protocols with guidance available in a resource area of the mission (1/25 mission). This is a sheet telling how to write a protocol.
- A Copex document is filled by the teacher and given as an example in a mission. Then, students have to write new protocols based on the given example. Combining the two sets of missions, we can describe different cases:
    - students have to learn from one example in a first mission, there is no predefined Copex document in the next missions of the same teaching unit (1/25 mission);
    - there is a fading throughout one mission with several Copex documents having less and less information (2/25 missions, 2 teaching units); or the fading happens throughout several missions (8/25 missions, 3 teaching units). The guidance is strong at the beginning and gradually fades to end with no scaffolds at all. Details are given in the next part, since the two interviewed teachers practice such fading guidance.

Detailed description of the teaching of the two interviewed teachers

Teacher 1: he designed three missions in LabNbook, all related to a transverse theme, the calibration of measuring tools, with a fading effect in the guidance. In the first mission, the teacher offers students a procedure with only steps that can be converted to actions and then steps and actions need to be ordered. In the two other laboratories, students are given only steps to order and must add the actions and the knowledge has to be transferred to a new experimental situation. According to the teacher, the last situation, which is not guided anymore, is significantly more difficult than the previous ones.

Teacher 2: the students have to write protocols in 15 missions within five teaching units during three consecutive semesters: semester 1 (teaching units T1 and T2), semester 2 (T3 and T4) and semester 3 (T5). Teacher 2 designed two LabNbook missions in teaching units T1 and T3, always with predefined Copex documents.

In T1, Teacher 2 designed four laboratories, but only one with LabNbook. The guidance appears through a sheet to be filled for the three paper-and-pencil labs, and with several predefined Copex documents with a fading effect along the LabNbook mission.

He designed one mission in T3, where several protocols are demanded to the students. The students have to exchange one set of data with another group of students (they give one data set and get one); they have to provide the protocol they designed and used to collect the data, and on the other hand they have to analyse and interpret the data set they receive.

These students experience guided protocol writing in two other teaching units: the guidance in T2 is faded through three missions, with predefined Copex documents only in the two first missions. Students use Copex in the third mission without being told. In the 6 missions of teaching unit T4, no predefined Copex documents are given but the students are reminded of Copex with an instruction giving the exact names of its rubrics.

In the 4 missions of T5, taking place the next year, students have to write protocols too, but nothing is done to remind them of Copex. However, the students continue using Copex.

Spontaneous use of a Copex document

Engineering school students do use Copex when there is no predefined Copex document in a mission (RQ2): when there is guidance almost all students use Copex (112/118 reports (95%) for the last mission of T2; 80/90 (89%) for the 6 missions of T4). The next year, students go on using Copex with no guidance at all (15/31 reports (50%) for the 4 missions of T5).

It can be compared with 4 other teaching units (within set 2) for which students are asked to write a protocol but with nothing to encourage the use of Copex in the mission or in connected missions. Some students do use Copex however. The number of students' reports using Copex spontaneously is between 5 to 20% (2/41 to 33/159). This suggests that students seldom use spontaneously Copex to write a protocol when they have not been taught and encouraged to use it.

TEACHERS'INTERVIEWS: DISCUSSION

Acquiring structures for a better understanding

Despite the different contexts, there are similarities between the two cases. First the two teachers have a common major trigger: they are struck by the fact that students do not understand what they are doing and are always focused on a single task at a time without any idea of where it should lead them. Thus they both want to guide their students into a structuring process that will help them to overcome this difficulty and for this they implement guidance with a fading effect. The work with experimental protocols takes a large part in this structuring process. Both tell to have succeeded and that some students said that they better organise their work and thus better understand what they are doing. Teacher 2 says that most students keep on structuring without being told the next year (Master 1) as is observed from our analysis. As described previously, the students were guided for structuring their work through four teaching units and 11 missions, all along the first year (Licence 3). According to the teacher, it is necessary to keep these guidance effort and stringent requirement for a year.

Teacher 1 comments the exercise he proposes in the first mission: this exercise engages all the students, whatever their achievement level, into a rich and collaborative cognitive activity. Students are asked to organise the procedure: they decide the status of each items, step or action, and discuss their position in the procedure and the meaning of it. They deeply experience the hierarchical nature of the protocol and the teacher does observe it "I almost watch the wheels in their brains rotate". Students are autonomous in conducting the process for the third mission despite a strong increase in the difficulty. The students do build a solving path, they link the global view to the detailed actions, identify the global objective, and they do not lose it anymore. It must be underlined that the procedures designed by both teachers include data processing and sometimes elements for data analysis and interpretation (such as "compare to the theoretical model or value"), and thus covers a large part of the experimental process at stake.

Paper pencil versus numerical tool

However, both teachers express reservations. Teacher 1 says that he was not able to check, and thus that he was not convinced, that his students would be able to transfer this know-how to another type of contents. But he said too that the exercise with the protocol cannot be achieved without Copex, and furthermore, when asking his students to write protocols in paper pencil mode, he is unable to guide and check the writing of the protocol before the students carry out the experiment. Teacher 2 thinks that it is necessary to combine both pencil paper and numerical mode for the writing of the reports. He fears that the use of the numerical support only could drive the students to think that the demanded structure of the report could be related to the numerical tool. Then they may not understand this structure as a general resource for laboratories and could not reuse it.

Role of the protocol

The two teachers do not consider the main role of the protocol in the same way: at high school, students have to build a structured description of what has to be done in order to carry out the experiment. The role of the protocol is mainly the design of the experiment, thus thinking and structuring the experiment ahead. This role, even if teacher 2 does not put emphasis on it, exists for the engineering students who have to write the protocol before the laboratory. Teacher 2 says that he wants them to reflect and organise the experimental work prior to the laboratory. However, the main point for him is that the protocol tells how the data are collected. This is required to interpret the data and to find out what is wrong when there is a problem with the data. This requires a high quality and detailed procedure. He designs one specific mission (in T3) in order to make the students feel this point and deepen their analysis, making them experience how much data processing and interpretation depends on how data are collected. During the laboratory, he initiates a discussion with the students in a feedback loop between the protocol and the experimental curves obtained from the collected data: he makes the students analyse, check and complete their data and correct and complete the protocol. But he thinks that the protocol writing skills of the students remain fragile.

Copex rubrics (objectives, hypotheses …) do not have the same pedagogical and scientific status for the two teachers. Teacher 1 does not value the rubrics, focusing on the procedure part. However, he tells that some students do fill the rubrics very seriously without being asked, include pictures or use the comments fields to include explanations. On the contrary, the engineering students have to fill the rubrics, and teacher 2 puts a high value on the "hypothesis or expected results" rubric. This is consistent with the role of a protocol as a description of the data.

CONCLUSION

Twenty one teachers, or teams of teachers, have designed on LabNbook platform the 49 pedagogical activities analysed in this paper that propose students to work on the experimental protocol. These scientific activities belong to a variety of teaching units that are meant for very different populations of students, from K10 to M1, at technical and general high school, university, engineering school ... In twelve teaching units, the teachers make use of the protocol editor Copex which seems to provide an appropriate medium. For instance, engineering school teachers go on using Copex protocol model to guide their students. However, our results suggest that students seldom use spontaneously Copex to write their protocols when they have not been taught or encouraged to use it.

The teachers express a true creativity in the building of exercises about the experimental protocol with Copex. A number of teachers seem to want their students to learn how to write an experimental protocol. But the role of the protocol in these activities goes far beyond just telling what one has to do to run the experiment, as it is usual in cookbook laboratories. Students have to use the protocol as a tool for data analysis and interpretation and to discuss data quality. The protocol is used to think and organise the experiment ahead: the students have to write the protocol, to re-organise or analyse the procedure… Both interviewed teachers consider the protocol as an indispensable element of the report. They both highlight the structuring potential of the experimental protocol in fostering understanding. They find here a solution to an initial and common behaviour they both underline as highly problematic: students focusing on a single task they perform, hindering any understanding of the experiment and more generally of their doings.

The analysis of the pedagogical activities with the protocol also carries original pedagogical strategies. For instance some teachers scaffold the students' learning of a structured approach by using a fading effect in the guidance of the activity. Asking the students to structure and organise a protocol within Copex is used successfully to foster the students understanding of the experimental process at stake by building a global view of the process and connecting it to the detailed parts.

The new French secondary school curricula (starting 2018 to 2021) better highlight the scientific role and the pedagogical potential of the experimental protocol. A wide variety of exercises are recommended, such as "discuss the influence of the measurement device and of the protocol with reference to the data accuracy", "test the limit of usage of the protocol", "identify steps in a protocol", "understand the importance of reproducibility of sampling protocols", "do a critical analysis of protocols and justify the techniques used", "compare the pro and cons of protocols". The experimental protocol should thus take a more important place in teaching. This, together with the presented results, supports that the experimental protocol as a key element of experimental processes, is worth to be learnt and could be used as a powerful tool for learning experimental science.

ACKNOWLEDGEMENT

This study is supported by Idex formation (Grenoble-Alpes University), the French Ministry of Research and Education (AMI project) and Institut Carnot de l'Education. Many thanks to E. Martinet and R. Phlypo for their time, creativity and involvement.

REFERENCES

Arnold, J. C., Kremer, K.,and Mayer, J. (2014). Understanding students' Experiments. What kind of support do they need in inquiry tasks? *International Journal of Science Education*, *36(16)*, 2719-2749.

Bonnat C., Marzin-Janvier P., Girault I. & d'Ham C. (2018). Modélisation didactique pour la conception d'étayages dans un EIAH : exemple d'une activité de conception expérimentale en biologie. *STICEF*, *25(2)*, 31-61

Chevallard, Y. (1885). *La transposition didactique. Du savoir savant au savoir enseigné*. Grenoble, France: La Pensée Sauvage.

Dean, A.M. and Voss D.T. (1999). *Design and analysis of experiments*. New-York, NY: Springer.

Etkina, E., Karelina, A., & Ruibal-Villasenor, M. (2010). Design and reflection help students develop scientific abilities: learning in introductory physics laboratories. *The Journal of the Learning Sciences*, *19*, 54–98.

Freeman, S., Eddy, S.L., McDonough, M., Smith, M.K., Okoroafor, N., Jordt, H., & Wenderoth, M.P. (2014). Active learning increases student performance in science, engineering, and mathematics. PNAS, *111(23)*, 8410-8415.

Girault, d'Ham, C., Ney, M., Sanchez, E., & Wajeman, C. (2012). Characterizing the Experimental Procedure in Science Laboratories: A preliminary step towards students experimental design. *International Journal of Science Education, 34(6)*, 825–854.

Girault, I., & d'Ham, C. (2014). Scaffolding a Complex Task of Experimental Design in Chemistry with a Computer Environment. *Journal of Science Education and Technology*, 23(4), 514–526.

d'Ham, C., Wajeman, C., Girault, I., & Marzin-Janvier, P. (2019). LabNbook, plateforme numérique support des pédagogies actives et collaboratives en sciences expérimentales. *Actes de la 9ème Conférence sur les Environnements Informatiques pour l'Apprentissage Humain*, 49-60.

Planche, M., Girault, I., Mandran, N., Marzin-Janvier, P., d'Ham, C., & Wajeman, C. (2019). Contribution de différents outils de mesure à l'évaluation des usages d'une plateforme numérique par un processus longitudinal : Cas du travail à distance. *Actes de la 9ème Conférence sur les Environnements Informatiques pour l'Apprentissage Humain*, 139-144.

van Riesen, S., Gijlers, H., Anjewierden, A. & de Jong, T. (2018). Supporting learners' experiment design. *Education Technology Research and Development*, *66*, 475–491.

Selwyn, M.R. (1996). *Principles of Experimental Design for the Life Sciences*. USA: CRC Press.

Tiberghien, A., Psillos, D. & Koumaras, P. (1995). Physics Instruction from epistemological and didactical bases. *Instructional Science*, *22*, 423-444.

Xenofontos, N. & Zacharia, Z. & Hovardas, T. (2018). How Much Guidance Students Need When Designing Experiments. a Computer-Supported Inquiry Learning Environment. *International Journal of Learning and Teaching*, *4*, 20-24.

APPROACHING MODERN PHYSICS THROUGH A VIDEOGAME

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Gran Sasso Video Game owes its name to the national physics laboratory located under the mountain of Gran Sasso (LNGS), which is the largest operative underground laboratory in the world carrying out a research activity at the frontier of science. The main plot of the game takes place inside the lab, where it really was conceived and developed thanks to a collaborative teamwork made of researchers, science communicators and videogames experts. It is meant as a way to approach young students to modern physics with the curiosity and passion of a researcher. The game environment faithfully reproduces every single detail of the experiments, with the pixel art design, in the following areas: Dark Matter, Double Beta Decay, Solar Neutrino and Nuclear Astrophysics. In this framework, Zot the alien, the video game protagonist, has been catapulted in our Universe due to an unexpected time–space singularity. In order to come back home he needs to repair the four experiments with the help of scientists. The video game, developed in HTLM5, is usable on PC, Mac, Linux or iOS or Android mobile devices, as tablet or smartphone. Next step for authors, due to the collaboration between LNGS and Indire, is to investigate the impact of the game on young students and their learning.

Keywords: Educational Technology, STEM Education, Teaching Innovation.

INTRODUCTION

The purpose of this contribute is to describe a still ongoing project aimed at using the video games to bring 14-19 year old students to study physics and, furthermore, to approach a general public to the scientific culture.

A collaborative teamwork made of researchers, science communicators and videogame experts has developed a game named Gran Sasso Videogame (www.gransassovideogame.it) because it is set in the Gran Sasso National Laboratories (LNGS), the largest operative physics underground laboratory in the world.

The final goal of this project is to study and identify, through a collaboration between LNGS and Indire, a particular kind of learning obtained by exploiting videogames dynamics to approach young people closer to physics. This game was created in the framework of the PILA project (Physics In Ludic Adventure), winner of a call from the Italian Ministry of Education for "Initiatives for scientific culture dissemination". In the next paragraph, the theoretical background that suggested and encouraged this work will be outlined.

In the following paragraphs, after a description of the process of the game development and an explanation of the choices made by the team, authors will illustrate some very early evidences and indicate future work perspective.

THE THEORETICAL BACKGROUND.

In the last forty years, the video game industry has integrated the traditional play experience with a new kind of games that, in this period, have undoubtedly become part of our culture. (Esposito, 2005). However, it is only in the first years of the new millennium that this field of study began to be considered as an emerging academic field at an international level, so that 2001 is considered (Aarseth, 2001) the Year Zero of the study of videogames. Since then, several scholars have developed classifications of the new type of games (Garris, Ahlers and Driskell, 2002, Malone, 1981, Prensky, 2001) based on the characteristics they show in addition to those borrowed from their non-electronic precursors (Huizinga, 1938, Caillois, 2000, Sales & Zimmerman, 2003).

The game is described as an activity or a voluntary occupation performed within fixed limits of time and place, according to freely accepted but absolutely binding rules, having its purpose in itself and accompanied by a feeling of tension, joy and awareness that is "different" from ordinary life (Huizinga, 1938).

So the game is separated from the routine of life, occupies its time and space and its rules suspend ordinary laws and behavior. It involves imaginable realities that can be compared with "real life". (Caillois, 2000).

Sometimes the game enacts an artificial conflict that ends in a quantifiable result (Sales & Zimmerman, 2003), sometimes it has a narrative background.

The game is also the ideal condition for experiencing the flow that is being completely involved in an activity that is an end in itself. "The ego slips away. Time flies. Every action, movement and thought inevitably descends from the previous one, like when you play jazz. Our whole being is involved and we use our skills to the fullest ". (Csikszentmihalyi, 1990).

Scholars talk about serious game when the goal of the game is not to entertain the player, which could be an added value, but to use its funny feature for training, education, health, public policies and strategic communication (Zyda, 2005). The interactive aspect favors the active cognitive processing of educational material, and this is a prerequisite for effective and sustainable learning (see Wouters, Paas, & van Merriënboer, 2008).

However, the learning principles that good games incorporate are all strongly supported by contemporary research in cognitive sciences. The good games give information "on demand" and "just in time", not out of the context of actual use or outside the gamer's objectives and goals, as it happens too often in schools. People are rather poor in understanding and remembering the information they have received out of the context or far too long before they can use it (Barsalou, 1999; Glenberg and Robertson 1999).

Good games operate at the outer and growing edge of a player's competence, remaining challenging, but affordable, while schools often operate at the lowest common denominator (diSessa, 2000). Since games are challenging but affordable, they are often also pleasantly frustrating, which is a very motivating state for human beings.

Several theories underline the potential of serious games to positively influence intrinsic motivation (Garris et al., 2002; Malone, 1981). This means that players are willing to invest more time and energy in the game not because of extrinsic rewards, but because the game itself is rewarding. Several features of serious games have been identified for this motivating appeal. Malone (1981) has proposed that the most important factors that make playing an intrinsically motivating computer game are challenge, curiosity and fantasy.

Two other essential factors associated with computer games, autonomy (ie the opportunity to make choices) and competence (ie, a task is experienced as difficult but affordable), derive from the theory of personal determination and are known to positively influence expert motivation (Przybylski, Rigby, & Ryan, 2010; Ryan, Rigby, & Przybylski, 2006).

Lastly, a particular kind of serious games are the so-called "games for learning" considered by Mayer as all those games or those simulations that intentionally have the objective of favoring learning, which therefore produce a measurable change in the academic knowledge or in the cognitive abilities of the students.

METHODS

The underground structure of the Gran Sasso National Laboratory (LNGS) represents a unique setting for a physics game. The mission of the laboratory is to address the open questions in the astroparticle field, through its main research lines: properties of neutrino, dark matter and nuclear astrophysics.

In order to involve the players in the life of experiments a series of interviews with the researchers working in the various experiments were recorded. The interviews were aimed at understanding scientists' activities, motivations, passion and competition and so suggestions and ideas for the video game story emerged. In particular, the elements that could stimulate curiosity in the players were analyzed; the knowledge and technology challenges; the charm of the setting in the huge underground halls.

Thus, the idea of an adventure-type game was born, an exploration of the underground labs in which interacting with objects and characters to achieve the goals set. In the writing of the screenplay, the different points of view of the working group have converged to get enjoyable gaming experience for students, but also fully satisfactory for insiders and for researchers working in the laboratory.

The fictional component of the game is entrusted to the main plot. The alien Zot, who happened in our Universe due to a space-time singularity, has to restore four LNGS experiments in order to reactivate the damaged circuits of his spaceship and return home. At the end of each experiment, a minigame is unlocked, with a simple game dynamics (i.e. touching some objects and not others) in which quick reflexes come into play. This minigame was introduced to make the continuation of the game interesting.

In the early stages of game design, a series of sketches were made. All the game setting were realized based on available photographic references and on the visit of the working group team in the LNGS experimental halls, like the control room of the Xenon experiment, shown in fig. 1, reproduced in the video game using the pixel art design.

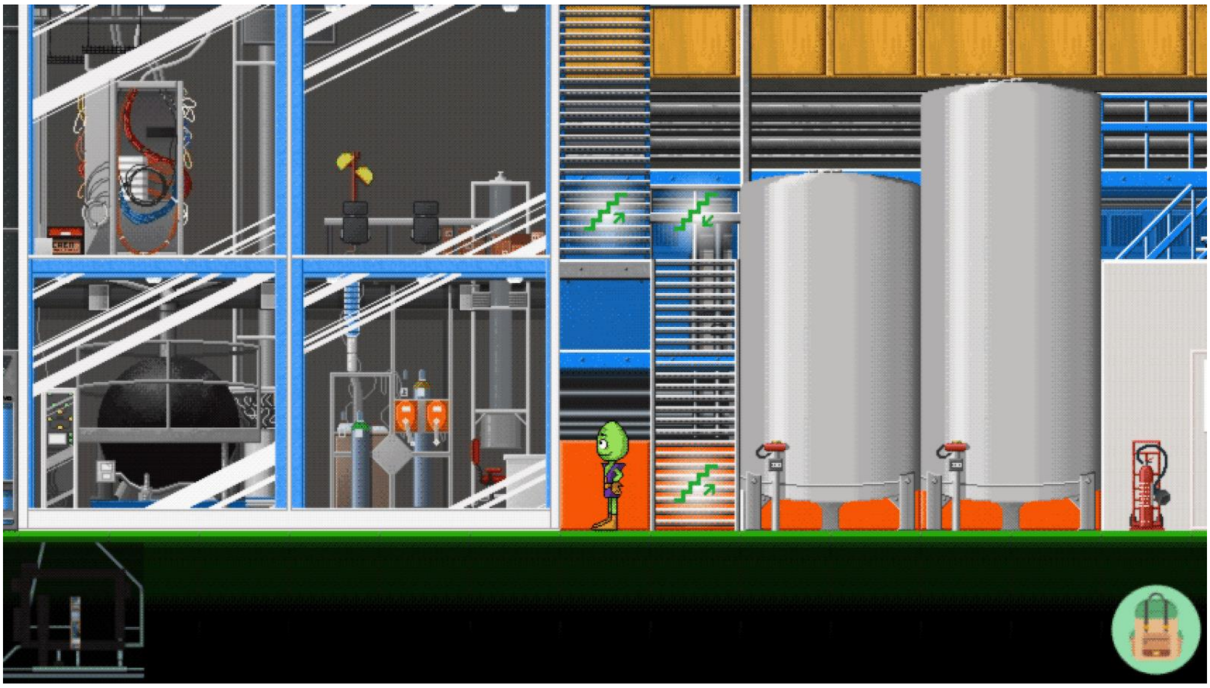

Figure 1. An experimental control room reproduced using the pixel art design.

In the development of the videogame, objects and actions have been chosen to underline important experimental concepts and approaches such as the pure target preparation, the 3D printer to realized detector frames without contaminant, ect.

Each experiment and the related objects are connected to a short card that the player is free to read or not. The card has a dual function: on one side contains a suggestion to be used in the game, on the other it is a way to stimulate curiosity on the particular topic and to eventually direct the user to a more in-depth information sheet, external to the game and hosted on Gran Sasso videogame website.

Gran Sasso videogame is also imagined to be used in schools, within a single class, in a scheduled time duration between half an hour and two hours, in one or more sections of the game.

In this regard the PILA project, mentioned above and proposed by LNGS-INFN together with the communication agency *formicablu srl*, takes advantage from the collaboration with INDIRE, the National Institute for Documentation, Innovation and Research in Education, especially in the phase of experimentation in schools, which only the pilot has been carried out until now. However, the deep knowledge and competence of LNGS researchers in physics is completed and enriched, for the purposes of this project, by Indire competence in the pedagogical field and for its knowledge of the schools located throughout the Italian territory, with which it has a consolidated relationship built over the years through well-known projects and national teacher training plans.

The innovativeness of the proposal, moreover, is not only inherent in the chosen medium, but also in the treated topics, which are not normally included in the school physics curriculum neither in the final years of the scientific high school. The topic are the neutrino physics, the existence of non-visible matter, the fascinating evolution of the stars reproduced in the laboratory with nuclear astrophysics. The videogame tries to put students in front of these themes, without trivializing them but instead honoring their complexity, trying to leverage them to fascinate girls and boys thus stimulate students' interest in further study of physics.

The PILA project has a duration of 24 months and includes, in addition to the creation of the videogame, the production of a website with downloadable materials to support teachers.

In the second year (2018-2019) of the project, a user experience evaluation has been conducted in order to fine-tune the final version of the videogame and the related teaching materials. The experience evaluation was foreseen in testing the game in a number of schools located in the Abruzzo region, the same where LNGS are set, involving their teachers as co-researchers. The project team referred to the literature in this field in order to identify and understand the possible benefits and outcomes deriving from the use of games in school. The team planned to extend the test in a wider territory in Italy in the third year of the project.

RESULTS

At the LNGS Open Day 2018 the beta version of the videogame was presented and an evaluation questionnaire was submitted to the participants in the event, where they were asked to express their appreciation for the gaming experience on a likert scale.

The users were not the ones defined in the project, even if mostly young people, but it was interesting to observe the reactions to the use of the game for the first time and a great interest for a deeper involvement in the physics topics was recorded.

Some good insights emerged from the analysis of the website accesses too. In addition, during Didacta educational faire 60 STEM teachers participated in a workshop based on the game and they filled in a survey, answering the questions if they would use this video game in their teaching activity and what possible advantages they expected to gain. The great majority of them replied that they would gladly use the game in their classroom, especially the ones who teach in the upper secondary, while the others were afraid that the topics were too difficult for younger pupils. Among the advantages of using the game in the classroom, teachers mainly indicated the following. The game can stimulate the interest in physics and the in-depth study of the theoretical lesson, due to a graphic language close to the world of teenagers. It stimulates the curiosity that leads to the continuation of the game. Teachers saw the possibility of using it as a first approach to complex topics to be studied and the possibility of stimulating collaboration between players, avoiding competition among those with more or less playing skills. They consider the game even useful to prepare a visit to the real LNGS. Finally, they consider the logical sequence of the steps to be taken in the game, a formative aspect for students.

In spring 2019, the beta version was played in 23 classrooms, involving 382 students of high schools in an average age of 17, but the analysis of the results of the evaluation questionnaire is still in progress. A preliminary analysis shows that the 45% of the students are interested in scientific matters, and they found this videogame helpful to getting closer to physics.

CONCLUSION AND FUTURE PERSPECTIVES

After the release of the beta version, the game has been improved. Additional elements have been introduced such as bonus elements that push players to complete the exploration of underground laboratories in every hidden door or corridor. The English version has been implemented to allow the game fruition even outside the Italian territory. The insertion of new sub-works and new scientific experiments have been evaluated. In 2019, due to the involvement of INDIRE further 8-10 classes of upper secondary schools located in the Abruzzo Region, participated in the evaluation of the videogame by testing its functionality and the real usability of the didactic materials for dealing with topic related to modern research in physics. The evaluation sections with the classes had a duration of 2 hours. The user experience evaluation, made in the second year of the project and the tests in schools, will allow adapting the didactic contents to the real needs of students and teachers.

In 2020 with the final version of the video game and material ready, further inquiry can take place, involving schools from all over Italy. After the first exploratory phase, the future research will go into more detail about the possible effects on students of the use of video games in physics classes. Measurable change in the academic knowledge or in the cognitive abilities of the students (engagement increase or intrinsic motivation, development of cognitive processes, or understanding and retention of content over the long term) will be the subject of future study.

REFERENCES

Aarseth, E. (2001) Computer Game Studies, Year One. *Game Studies*, 1(1).

Barsalou, L. W. (1999) Perceptual Symbol Systems, *Behavioral and Brain Sciences*, 22.4 577-660.

Brown, S. (2009). *Play: how it shapes the brain, opens the imagination and invigorates the so*ul. New York: Avery.

Caillois, R. (2000). *I giochi e gli uomini: la maschera e la vertigine*. Milano: Tascabili Bompiani.

Csikszentmihalyi, M. (1990). *Flow: the psychology of optimal experie*nce. New York: Harper & Row

Detering S., Dixon D., Khaled R., & Nacke L. (2011) From game design elements to gamefulness: defining "gamification", *Proceedings of the 2011 MindTrek conference*.

diSessa, A. A.(2000) *Changing Minds: Computers, Learning, and Literacy*. Cambridge, Mass.: MIT Press.

Esposito N. (2005) A Short and Simple Definition of What a Videogame Is- *Proceedings of DiGRA 2005 Conference: Changing Views – Worlds in Play*. Authors & Digital Games Research Association DiGRA.

Garris, R., Ahlers, R. & Driskell, J.. (2002). Games, Motivation, and Learning: A Research and Practice Model. *Simulation & Gaming*. 33. 441-467. 10.1177/1046878102238607.

Gee, J. P. (2003) *What Video Games Have to Teach Us About Learning and Literac*y Publisher: Palgrave Macmillan; 1 edition (May 1, 2003)

Giampaoli, A., Lazzarato, L., Conti, F., Formicola, A., & Venturi, I. (2020) Gran Sasso videogame: La fisica e il gioco nei laboratori sotterranei del Gran Sasso [Gran Sasso videogame: physics and gaming in the Gran Sasso underground laboratory] *IJET*. Forthcoming DOI (10.17471/2499-4324/1077)

Glenberg, A. M., & Robertson, D. A. (1999). Indexical understanding of instructions. *Discourse Processes,2*8, 1–26.

Huizinga, J. (2002). *Homo ludens*. Torino: Einaudi.
Malone, T. (1981). *What Makes Things Fun to Learn? A Study of Intrinsically Motivating Computer Games.* Pipeline. 6.
Mayo, M. J. (2007) Games for science and engineering education. July 2007 *Communications of the ACM 50*(7):30-35 DOI: 10.1145/1272516.1272536
Przybylski, A.K., Rigby, C. S., & Ryan, R. M. (2010) A Motivational Model of Video Game Engagement. *Review of General Psychology* © 2010 American Psychological Association 2010, Vol. 14, No. 2, 154 –166
Prensky, M. (2001) *Digital game based lea*rning McGraw-Hill
Salen, K., & Zimmerman, E. (2003). *Rules of play: game design fundamentals*. Cambridge, Mass: MIT Press.
Sitzmann, T. (2011). A meta-analytic examination of the instructional effectiveness of computer-based simulation games. *Personnel Psychology*, 64, 489–528. doi:10.1111/ j.1744-6570.2011.01190.x
Vygotsky, L. S. (1976). Play and its role in the mental development of the child. (as cited in Bruner, J.S., Jolly, A. & Sylva, K. (Eds.), *Play: Its role in development and evolution* New York: Basic Books. pp. 537-554).)
Wouters, P.J.M., Paas, F. & Van Merrienboer, J.J.G. (2008). How to Optimize Learning From Animated Models: A Review of Guidelines Based on Cognitive Load. *Review of Educational Research*. 78. 10.3102/0034654308320320.
Zyda, M. (2005) *From visual simulation to virtual reality to games*. IEE Computer Society

EVALUATION OF A FEEDBACK-SUPPORTED EDUCATIONAL APP TO PROMOTE STUDENTS' UNDERSTANDING OF PCR AND GEL ELECTROPHORESIS DURING HANDS-ON EXPERIMENTATION

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An educational app was developed including feedback on learning tasks to support students' conceptual understanding of PCR and gel electrophoresis during hands-on experimentation in an out-of-school laboratory. N = 134 secondary students learned and carried out experiments based on the information and instructions in the app. Moreover, the students conducted a knowledge test on PCR and gel electrophoresis before and after using the educational app. The Biology grade and information on the Cognitive Load were asked. The reliability of the knowledge test was satisfactory. Scores of the pretest and the posttest were compared in order to derive evidence that indicates validity of the app. The results showed a significant increase of knowledge on PCR and gel electrophoresis after using the educational app. Furthermore, correlations between Biology grades and pretest scores as well as correlations between Cognitive Load and posttest scores were conducted. The results support the idea of validity of the measures of the knowledge test. To investigate the appropriateness of the learning tasks failure frequencies were analysed. The results show that the number of students who need additional support as they were not able to respond to the learning tasks correctly, was in an acceptable range. Beyond that, students who failed to give the correct response to the learning task often had Biology grades that indicates a low level of expertise. All in all the results of the analysis consistently indicate acceptable validity of the learning environment. The next step is to vary different types of feedback in a pre-post-intervention study.

Keywords: Feedback, ICT Enhanced Teaching and Learning, Secondary School

THEORETICAL BACKGROUND

Learning PCR and gel electrophoresis in out-of-school laboratories

PCR and gel electrophoresis (GEL) are essential methods in Science and therefore an obligatory learning content in schools in various countries (OECD, 2007). Out-of-school laboratories offer opportunities to conduct experiments including PCR and gel electrophoresis. The understanding of the underlying concepts requires prior content knowledge, instruction and is highly cognitive demanding (e.g. Duncan & Reiser, 2007). Therefore, a multimedia learning environment representing abstract molecular concepts in multiple external representations could support students' conceptional understanding of PCR and gel electrophoresis (Mayer, 2014; Sweller, 1994). Moreover, as students differ concerning their prior content knowledge (Ceci & Chi, 1987) learning environments that provide individual support are held to be even more effective. Against this background a well-designed tablet-supported educational app with integrated automated feedback offers the potential to reduce cognitive load and enhance the learning outcomes for students during experimentation including PCR and gel electrophoresis in an out-of-school laboratory.

Feedback

Feedback is reported to be one of the most enhancing factors concerning individual learning (Hattie, 2009). In the context of computer supported and automated feedback we define feedback as “any kind of information provided to students about their actual state of learning or performance in order to modify the learners thinking or behavior” (Goldin, Narciss, Foltz & Baauer, 2017, pp. 384-386).

The interactive tutoring feedback model (Narciss, 2013) describes different types of feedback. Two of them are Knowledge of Response (KR) and Knowledge of Correct Response (KCR). KR gives information about the correctness of a respond to a learning task while KCR provides the correct respond. Modern information technologies, such as tablets, allow utilizing the advantages of immediate feedback in multimedia learning environments (van der Kleij, Feskens, & Eggen, 2015). More complex types of feedback are described as elaborated feedback. Elaborated feedback combines all types of feedback that provide additional information besides KR and KCR.

The effect of feedback on the learning outcome is affected by the the cognitive processes that are needed to solve a task. A meta-analysis shows that KR and KCR has a positive effect on lower order learning outcomes. Elaborated Feedback, however, has a positive effect on lower order learning outcomes and higher order learning outcomes (van der Kleij, Feskens & Eggen, 2015).

AIM AND RESEARCH QUESTION

In this preliminary study we evaluate a self-designed and programmed educational app, which includes multiple information, instruction and learning tasks as well as KR and KCR feedback for students who visit an out-of-school-laboratory to learn the concepts of PCR and gel electrophoresis and conduct experiments including these methods. Hence the aim of this preliminary study is to derive evidence about the reliability and validity of a feedback-supported educational app to promote the understanding of PCR and gel electrophoresis during hands-on experimentation in Biology. The following research question is addressed:

RQ: To which extend do measures of reliability and validity indicate the quality of the educational app including the integrated learning tasks?

RESEARCH DESIGN AND METHODS

Development of the educational app

First a laboratory course in an out-of-school-laboratory was developed, where students of secondary schools conduct hands-on experiments including PCR and gel electrophoresis. Then, to support the conceptual understanding of PCR and gel electrophoresis and to guide the students through the steps of experimentation, an educational app for iPads was developed. Students’ knowledge about the concepts of PCR and gel electrophoresis was derived within a single-choice test before and after using the educational app and conducting the experiments. At the same time the structure of the app and the test (Figure 1) organises the laboratory course.

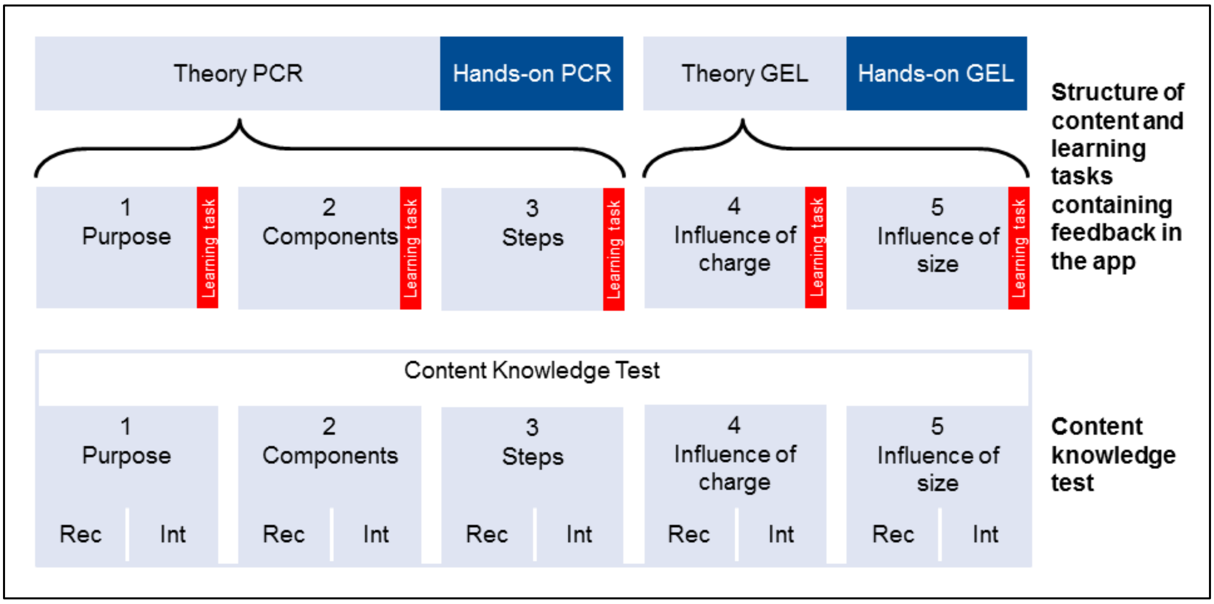

Figure 1. Structure of the app and the content knowledge test.

Note. Rec = Recognition of facts. Int = Integration of facts. GEL = Gel electrophoresis.

In the developing process we oriented to the national curricula and interviewed Biology teachers. They were asked for crucial aspects in understanding PCR and gel electrophoresis as well as for aspects students often trouble to understand. Based on a qualitative analysis five sub concepts were derived, which are key for understanding PCR and gel electrophoresis in the given context (PCR: *purpose*, *components*, *steps*; GEL: *influence of charge*, *separation by size*). Each of the concepts represents one chapter of the app.

At the end of each chapter we integrated a learning task in a single-choice format with four answer options that covers the concept of the chapter. Students had to respond to the tasks and received immediate feedback. In this study the types of feedback were KR for correct responses, KR and KCR for incorrect responses.

The structure of the app is also the basis for the content knowledge test that consists of 27 items. On a first level the test is structured by the five derived sub concepts of PCR and gel electrophoresis (s. a.). On the second level it includes two cognitive processes (compare Anderson, 2014): *recognition of facts* and *integration of facts*. Recognition of facts means that only a single fact is needed to complete a task, whereas integration of facts means that a minimum of two facts has to be integrated to complete a task.

During the app development we applied principles of the Cognitive Theory of Multimedia Learning on instruction in e-Learning (Mayer, 2014; Mayer & Clark, 2016). We, for instance, based on the Multimedia Principle, used text and graphics instead of words alone. Based on the Segmenting Principle we divided the app into chapters with each chapter being subdivided into coherent sequences. The order of the chapters is structured and students can unlock new chapters by completing the previous one. Students can navigate between the sequences at their own pace and in a free order. This level of guidance offers sufficient structure in an open learning environment. Since engagement can support learning we added a few prompts for students to interact with and engage in the prompted contents (Figure 2).

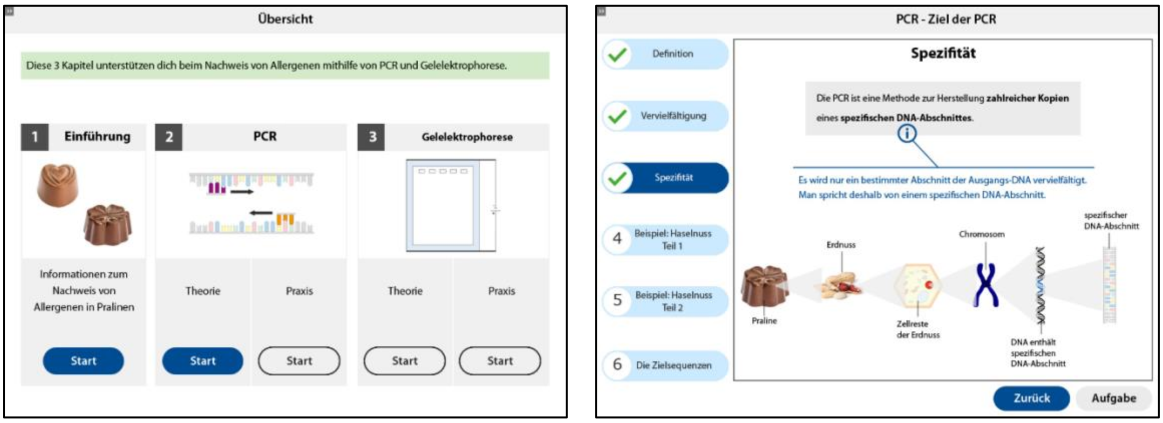

Figure 2. Examples pages of the app. On the left side there is the main menu. On the right side there is a typical content page.

In the following we will describe the appearance of a typical page representing a chapter in the app (Figure 2). At the top there is a headline that describes the chapter. A content box takes up the majority of the page. Buttons on the left allow for navigation and provide control over the content box. Each of the numbered buttons represents one sequence of the chapter and is activated by touch. Once a student touched one of the buttons the content box displays the related information. After touching the buttons a checkmark replaces the number, which indicates that the sequence has already been viewed. We placed a button to navigate to the following chapter in the bottom right, but they remain inactive until the student selected all sequences of a chapter. In the top left there is a button to expand and collapse a table of contents, but chapters are not accessible before they have been unlocked by completing the previous one.

Design and Sample

In this preliminary study 134 students (69% female) with an average age of $M = 16.8$ years ($SD = .90$) took part. Content knowledge on PCR and gel electrophoreses was assessed in a pre-post design using a 27-item self-developed content knowledge test. The sub concepts of PCR and gel electrophoresis as well as the two cognitive processes of recognition of facts and integration of facts structure the test.

In Addition to the content knowledge test the students' Biology grades were asked in the pretest and their Cognitive Load (CL), measured as mental effort on a 11-point rating scale (Leppink, Paas, van der Vleuten, van Gog & van Merriënboer, 2013), was asked in the posttest. The Biology grade was on average in the middle range (*Mdn* = 3/C).

RESULTS

Content knowledge test

Table 1 presents the Cronbachs α values for all scales and subscales of the content knowledge test. The reliability of the overall test was good ($n = 27$ items; $\alpha = .80$). Moreover, the reliabilities of its subscales were calculated. All measures were satisfactory ($.50 < \alpha < .73$) with the exception of the scale GEL x recognition of facts (6 items; $\alpha = .36$). Furthermore we checked reliability of the Cognitive Load Scale, which shows good internal consistency ($n = 8$ items, $\alpha = .80$).

Table 1. Item number and Cronbachs α of subscales of the content knowledge test.

Scale	Items (n)	Cronbachs α (post)
Overall	27	.80
Recognition of facts	16	.69
Integration of facts	11	.68
PCR	15	.73
GEL	12	.60
PCR x Recognition of facts	10	.66
PCR x Integration of facts	5	.54
GEL x Recognition of facts	6	.36
GEL x Integration of facts	6	.50

The mean knowledge increase for the whole test is M = 10.20% (SD = 13.09%), for the items of recognition of facts M = 12.41% (SD = 15.74%), and for items of integration of facts M = 6.99% (SD = 18.82) (Figure 3).

Since integration of facts is meant to be a higher cognitive process than recognition of facts, items on integration of facts should be answered correctly less frequently. Posttest-scores of items of integration of facts were significantly lower than the posttest-scores of items of recognition of facts ($t(133) = 9.02$, $p < .001$, $d = .58$) (Figure 3). This indicates construct validity of the test.

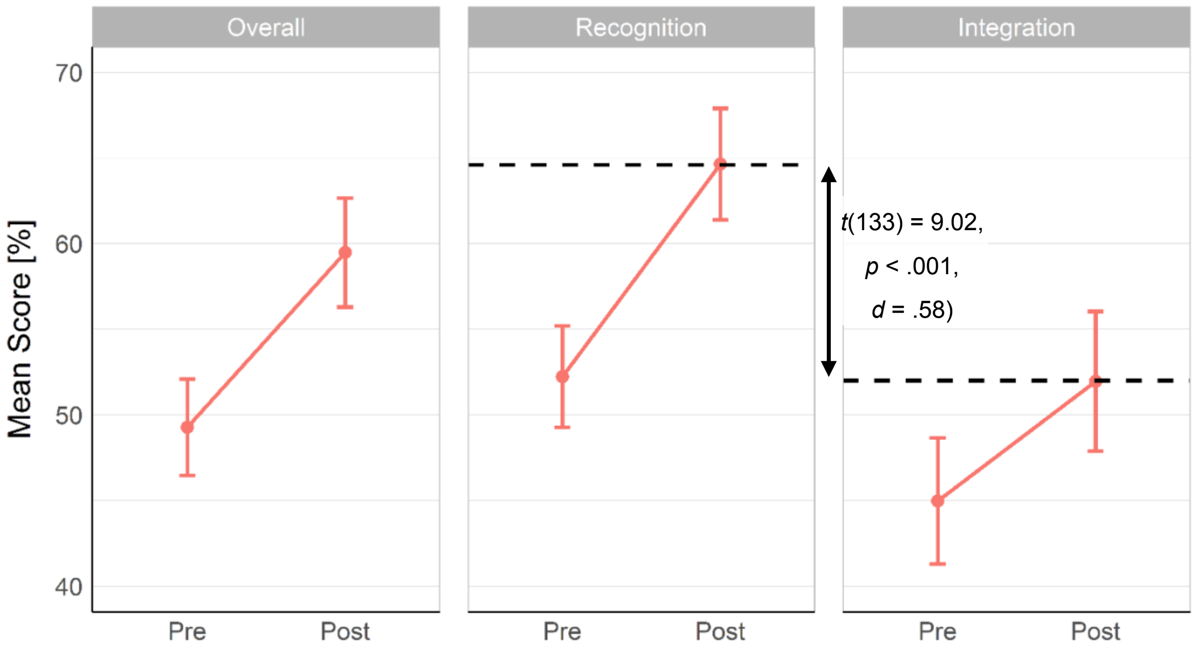

Figure 3. Increase in content knowledge overall and for the cognitive processes separately.

We further investigated correlations between the test scores and other criteria. Spearman correlations between the Biology grade and scores of the pretest were conducted. The better the Biology grade of the students the higher they scored in the pretest ($r_s(132) = -.49$, $p < .001$). Since the Biology grade points to the level of students' expertise in Biology and in Germany lower grades represent better performances, we see this as indicator for criterion validity.

Additionally negative correlations between CL (M = 2.04, SD = 1.48) and scores of the posttest indicated the higher students reported on their CL the lower they scored in the posttest ($r_s(132) = -.30$, $p < .001$). This again indicates criterion validity of the test.

Learning tasks

According to the analysis of the learning tasks the failure frequencies were within a range of $.13 < M < .47$ (Figure 4). Three learning tasks had intermediate failure frequencies and two had a lower one. The low failure frequency on learning tasks 3 and 5 indicate that only few students needed support on these tasks. As a result these tasks are not suited to measure the effect of feedback on learning outcome and therefore need revision.

The distribution of failure frequency over all tasks is fairly normally distributed (Figure 4). The analysis shows that 9.7% of the students answered no learning task wrong. Therefore, it is not possible to investigate the effect of feedback on these students. In addition to that, 11.9% of the students answered four or five of the learning tasks wrong. It is at least questionable if those students are even able to profit from feedback considering their low conceptual understanding.

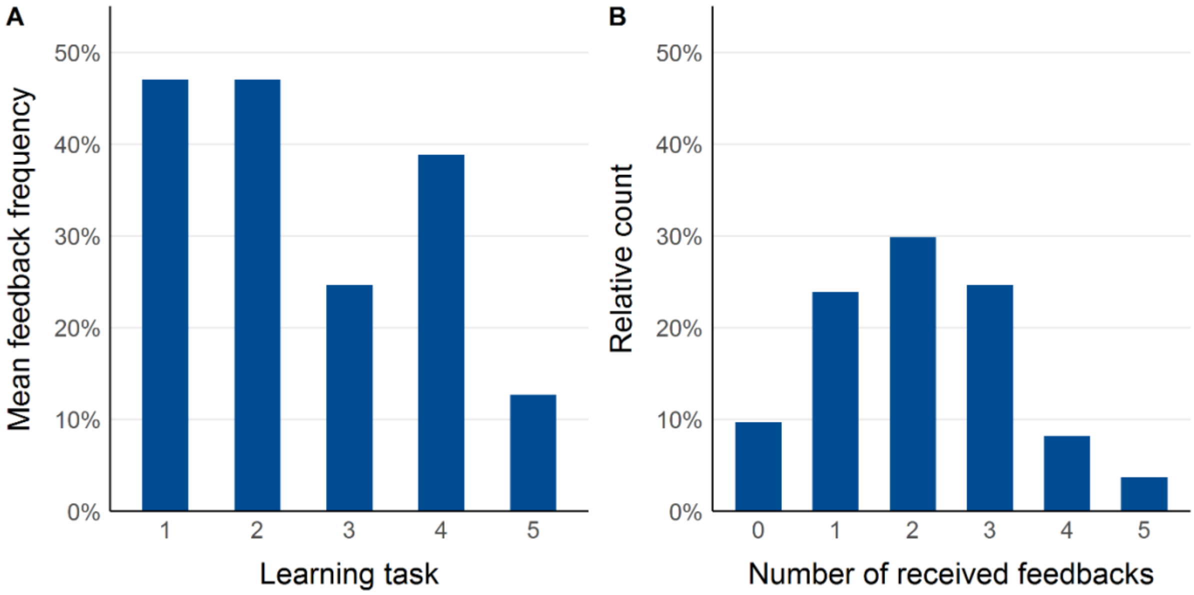

Figure 4. A: Feedback frequency per learning task. B: Distribution of feedback frequency over all learning tasks.

Finally correlations show: the worse the Biology grade the higher was the failure frequency in the learning tasks ($r_s(132) = -.28$, $p < .01$). This connects the learning tasks with the content knowledge test and indicates criterion validity.

DISCUSSION

In this preliminary study the aim was to derive evidence about the reliability and validity of a feedback-supported educational app. To do so we developed a knowledge test on PCR and gel electrophoresis. The reliability of the content knowledge test is acceptable and only one subscale needs revision. Items should represent the cognitive process of either recognition of facts or integration of facts. The higher difficulty of items that were constructed for integration of facts in comparison to items that belong to recognition of facts indicates construct validity of the test. Studies show that in tests that are designed for large-scale assessment it can be difficult to post-hoc operationalize items towards the cognitive processes that are needed to solve them (Kauertz & Fischer). However, interventional studies often aim for considerably smaller and more homogeneous samples. That is why we think, despite using simple but common methods, the content knowledge test meets the requirements satisfactorily. Based on correlations between outcome related criteria, such as Biology grade and CL, and learning outcomes we found several indicators for criterion validity.

Some limitations should be noted. Firstly, we used a short content knowledge test with only 27 items. Therefore, the test might not represent the concepts of PCR and gel electrophoresis in every detail. However, by doing so we could ensure a time-effective data collection during the laboratory course. Short tests are widely used for assessing students' abilities in interventional studies, because their concentration and attention is limited. Secondly, we assessed the Biology grade and CL as self-reports. Although self-reported CL seems questionable many studies demonstrated that students are capable of reporting on their mental effort (Paas, Ayres & Pachmann, 2008). This is why measuring CL as self-reported mental effort is a common practice in educational research. Because the results are consistent with our theoretical framework we conclude that there are sufficient and reliable arguments to use the instruments in combination with the app in further studies with focus on the effect of different types of feedback on the learning outcome.

Feedback is only useful when it is needed. All students needing feedback on every learning task, however, would indicate a mismatch between the learning prerequisites of the students and the learning environment, because content knowledge as well as abilities that are necessary to use the app for learning, e. g. reading, should be normally distributed in the population. Therefore, most learning tasks showed an appropriate failure frequency while two of them need revision. The failure frequencies of the learning tasks indicate that the number of students who need further support concerning crucial concepts of PCR and gel electrophoresis is appropriate. The correlation between the Biology grade and the failure frequencies of the learning tasks indicates that especially students on a lower level of expertise may profit from feedback.

At this point we do not know which types of feedback foster students understanding of PCR and gel electrophoresis on a lower order and on a higher order level during experimentation in an out-of-school laboratory. For this reason, we plan to investigate the effect of different types of feedback in a pre-post-intervention study based on the evaluated learning environment and test in this preliminary study. So far, the used feedback covers only KR and KCR. Elaborated feedback is supposed to be more effective on tasks that require higher order learning skills. The next step is to integrate elaborated types of feedback into the educational app. We consider that by doing so especially a deeper understanding of PCR and gel electrophoresis is promoted. Students who receive elaborated feedback might then score higher on scales that cover the cognitive process of integration of facts.

REFERENCES

Anderson, L. W. (2014). *A taxonomy for learning, teaching, and assessing: A revision of Bloom's* (Pearson new international edition). Pearson Education.

Ceci, S. J., & Chi, M. T. H. (1987). Content knowledge: Its role, representation, and restructuring in memory development. In H. W. Reese (Ed.), *Advances in child development and behavior* (pp. 91–142). Academic Press Inc.

Clark, R. C., & Mayer, R. E. (2016). *E-learning and the science of instruction: Proven guidelines for consumers and designers of multimedia learning* (Fourth edition). Wiley.

Duncan, R. G., & Reiser, B. J. (2007). Reasoning across ontologically distinct levels: Students' understandings of molecular genetics. *Journal of Research in Science Teaching*, *44* (7), 938–959. doi: 10.1002/tea.20186

Goldin, I., Narciss, S., Foltz, P., & Bauer, M. (2017). New Directions in Formative Feedback in Interactive Learning Environments. *International Journal of Artificial Intelligence in Education*, *27* (3), 385–392. doi: 10.1007/s40593-016-0135-7

Hattie, J. A. C. (2009). *Visible learning: A synthesis of over 800 meta-analyses relating to achievement*. Routledge.

Kauertz, A., & Fischer, H. E. (2006). Assessing Students´ Level of Knowledge and Analysing the Reasons for Learning difficulties in Physics by Rasch Analysis. In X. Liu & W. J. Boone (Eds.), *Applications of Rasch measurement in science education* (pp. 212–246). JAM Press.

Leppink, J., Paas, F., van der Vleuten, C. P. M., van Gog, T., & van Merriënboer, J. J. G. (2013). Development of an instrument for measuring different types of cognitive load. *Behavior Research Methods*, *45* (4), 1058–1072. doi: 10.3758/s13428-013-0334-1

Mayer, R. E. (2014). Cognitive Theory of Multimedia Learning. In R. E. Mayer (Ed.), *Cambridge handbooks in psychology. The Cambridge handbook of multimedia learning* (pp. 43–71). Cambridge University Press.

Narciss, S. (2013). Designing and Evaluating Tutoring Feedback Strategies for digital learning environments on the basis of the Interactive Tutoring Feedback Model. *Digital Education Review*, *23*, 7–26.

OECD. (2007). *PISA 2006 Science Competencies for Tomorrow's World*. Paris.

Paas, F., Ayres, P., & Pachmann, M. (2008). Assessment of cognitive load in multimedia learning: Theory, Methods and Applications. In D. H. Robinson & G. J. Schraw (Eds.), *Current perspectives on cognition, learning, and instruction. Recent innovations in educational technology that facilitate student learning* (pp. 11–35). Information Age Publishing.

Sweller, J. (1994). Cognitive load theory, learning difficulty, and instructional design. *Learning and Instruction*, *4* (4), 295–312. doi: 10.1016/0959-4752(94)90003-5

Van der Kleij, F. M., Feskens, R. C. W., & Eggen, T. J. H. M. (2015). Effects of Feedback in a Computer-Based Learning Environment on Students' Learning Outcomes: A Meta-Analysis. *Review of Educational Research*, *85* (4), 475–511. doi: 10.3102/0034654314564881

MEANINGFUL LEARNING AFTER USING MULTIPLE MEDIATIONS TO TEACH BOHR ATOM IN SECONDARY SCHOOL IN BRAZIL

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The present research sought to investigate the main ways to approach the teaching of the Bohr atom model to secondary school students of a high socially vulnerable neighbourhood in Brazil. The theoretical framework used is the CNMT (Cognitive Networks Mediation Theory) to find out which mediations may contribute to a better learning of the Bohr atom model four mediations used within a PMTU (potentially meaningful teaching unit) teaching sequence. Our results indicate that the hypercultural mediation stood out among the students interviewed; However, all mediations have contributed to the understanding of the Bohr atom in some specific facet, and many combine different mediations to better understand Bohr Atom.

Keywords: Computer Based Learning, Physics, Video Analysis.

INTRODUCTION

Many obstacles can be manifested in physics teaching in 9th grade, which represents the end of the Elementary School (ES) in the Brazilian educational system (1st to 9th school year). Many teachers are not trained in this area of knowledge, that is, they are not graduates in Physics or Chemistry, which technically does not qualify them to work with these disciplines and generates problems in teaching. The lack of laboratories is also a factor mentioned by the authors, since it can negatively affect the motivation of teachers and students to teach-learn science.

Given the panorama of the teaching of physics in PE in Brazil and due to so many questions, this research aimed to investigate and analyze the mental images acquired or modified by PE students after using extracerebral tools for the study. learning concepts relevant to the study of the Bohr atom model. This research has chosen as its theme the Bohr atom model, because this content can be approached jointly in the disciplines of Chemistry and Physics. Since the guidance is for these last year of the ES to work together, Bohr's Atom enables this initiative. The concepts expressed in this atomic model can be developed in both disciplines, as evidenced by some 9th grade science textbooks.

Bohr's atom can contribute to the explanation of many phenomena observed in people's daily lives, such as lights and lamps, flame testing or fireworks. In his master's research, Silva (2013, p. 158) describes that many students believe that fireworks had different colors due only to the use of dyes, that this "is not related to the electronic jumps that occur in the metals that make up this firework. artifact, but because of the presence of dyes ".

Fluorescence and phosphorescence are other phenomena that can be discussed in the classroom with students approaching everyday examples when working on the Bohr atom (Silva et al., 2014). Accordingly, Parente, Santos and Tort (2014) state that when developed on the Bohr atom in the classroom, it contributes to its being a gateway to the world of the internal structure of the subject for students, a subject that often brings the curiosity of the students.

The theme was explained using a didactic sequence elaborated by the researchers-teachers of this research. The didactic sequence, entitled Didactic Sequence from the perspective of the UEPS-based TMC, was proposed after the use of seven Potentially Significant Teaching Units (UEPS), a concept proposed by Moreira (2011), prior to the PIBID Physics subproject. The didactic sequences elaborated in this research were based on extracerebral tools applied during the proposed activities, such as a computer simulation or the making of the Bohr atom model, for example.

Therefore, we elaborated this research considering the reality of physics teaching in PE and the context of the school community. The research was conducted in partnership with the Physics subproject of the Institutional Teaching Initiation Scholarship Program (Pibid) of the Lutheran University of Brazil, in Canoas, RS. The college in which the project was conducted is the João Paulo I State Elementary School, located in a neighborhood near the University. The students participating in the project were from the 8th and 9th grades of EF. The two classes were chosen based on the fact that they are in the final stretch of the ES, in preparation for the beginning of high school (MS).

To analyse the results, we used the Cognitive Networks Mediation Theory (CNMT). In his CNMT, Campello de Souza, Silva, Silva, Roazzi, & Carrilho (2012) indicates that cognitive development involves the interaction of an individual with objects and systems that have the ability to perform computations, being a process that involves the simultaneous emergence of internal and external mechanisms of mediation. The individual not only allocates the same computational resources, but also gains new concepts, where the new internal mechanisms present in the cognitive structure of the individual are named *drivers* (as employed in computation) that make possible the use of external mechanisms.

For Campello de Souza, Silva, Silva, Roazzi, & Carrilho (2012), also detailed in Serrano et al. (2018), there are four levels of mediation: Psychophysical Mediation, related to the physiological characteristics of the subject with the composition of the object; Social Mediation, when interaction occurs with different people in the same environment; Cultural Mediation, implying the language and the capacity of society to report events involving categorizations of ideas and concepts; And Hypercultural Mediation, which uses access to technology, to the computer, to simulations, that is, there is use of technological tools. Therefore, our research question is which mediations best help the FE student to understand the concept of the Bohr Atom?

METHODOLOGY

For the sake of clarity, the methodology has been divided into two parts: research methodology and didactic methodology. The research methodology brought results through interviews conducted following the Report Aloud protocol and the Pibidian logbook. After the descriptive gestural analysis the students were separated into three categories based on the four TMC mediations. Significant learning was verified through observations from the Pibidians and interviews with students in 2017 and 11 months later, with the project ending in 2018.

The didactic methodology was based on the work together with Pibid with the elaboration and application of a didactic sequence from the perspective of TMC based on Potentially Significant Teaching Units (UEPS).

The classes were explained using a didactic sequence elaborated by the teachers-researchers of this research. The didactic sequence was proposed after the use of seven Potentially Meaningful Teaching Units (PMTU), a concept proposed by Moreira (2011), in the previous moment of the PIBID subproject of Physics. The didactic sequences elaborated in this research were based on extra cerebral tools applied during the proposed activities, such as a computer simulation or the construction of a Bohr atom model (using Styrofoam, colored pencils, led bulbs, for example). This research was applied during the whole year of 2017, the first semester dedicated to create and test the PMTUs and the second semester was dedicated to gather the data presented in this article (31 meetings with the students). A total of 31 students started in the classes (themselves scheduled to the counter-shift of their regular classes) but only 11 students remained till the end of the research; this study is based on those 11 students.

Therefore, we elaborate this research considering the reality of the teaching of Physics in the FE and the context of the school community. The research was conducted in partnership with the Physics subproject of the Institutional Scholarship Initiative Program (Pibid) of the Lutheran University of Brazil, in Canoas, RS. The school in which the project was conducted is the State School of Primary Education João Paulo I, located in a high social vulnerability neighbourhood near the University. The students participating in the project were 8th and 9th year FE students. The two classes were chosen based on the fact that they were in the final stretch of FE, in preparation for the beginning of High School.

The students had contact with the four mediations (social, cultural, psychophysical and hypercultural), which had different durations. Social mediation took place during all monitored classes by interaction with the teachers. Psychophysical mediation took place during four classes mostly by building a Bohr Atom model with led lights of different colours representing the different wavelengths of the absorbed/emitted radiation; cultural and hypercultural mediations took place in one class each, the first by using books (including didactic books) and the second by using a computer simulation of the Bohr Atom model. After the study, the students were interviewed where they were asked to explain the Bohr Atom (what it is? How does it works? What happens when a photon is absorbed and how a photon is emitted and the relationship between wavelength and the distance between orbit radii?). For the interviews we applied the Report Aloud technique, where the student first solve the questions by themselves and then explains in the interview how he solved them (Trevisan, Serrano, Wolff and Ramos, 2019). For Depictive Gesture Analysis, we employed the method used by Monaghan & Clement (1999) and Clement & Stephens (2010).

RESULTS AND CONCLUSION

Given the results that were obtained in the research it was possible to highlight what Erickson (1986) portrays in his research on abstract universals and concrete universals. “Universal” suggests that it was possible to identify certain concepts in more than one student, not just one. In this research it was observed that the use of the four mediations was useful for teaching certain concepts.

According to Erickson (1986), the researcher has the chance to perceive the universality that occurs with all students, as well as the possible particularities in each one.

In this research we obtained four abstract universals:

I. The atom image comes in many forms, and may come from psychophysical mediation or cultural mediation (as in books or television series);

II. The idea of photon is related to hypercultural mediation and the image of the electronic layers related to psychophysical mediation;

III. The color associated with the specific emission of light within the Bohr atom model (different colors related to different hops) is the result of interaction with psychophysical mediation;

IV. Hypercultural mediation was also responsible for providing drivers that allowed students to understand the mechanics of the Bohr atom model (more precisely to understand that bouncing causes photon emission or absorption);

The concrete universals that, according to Erickson (1986, p.130), form a “specific case in great detail and then comparing it with other cases studied in equally great detail”, reveal that, in this research, it was possible to perceive the particularities of each student. We divided the students into categories, which evidenced a different mediation, or combined mediations, in their learning process. Following are four concrete universals resulting from this research.

I. When asked what he knew about the Bohr atom, student A4 mentioned the Bohr atom model of LED (psychophysical mediation).

> E: When you talk about Bohr atom, what are you imagining?
> A4: Oh, I can't tell you, but in her mind she thinks a lot.
> E: What are you imagining?
> A4: You can remember that thing [00:46, GLA] that we did, in this case in the last Styrofoam class.

Student A3 quoted a television series (cultural mediation) as answering how he imagined Bohr's atom

> A3: The atom I imagine ... (Student draws)
> E: You saw it somewhere right? Remember where you saw it?
> A3: In The Big Bang Theory Series

II. Regarding the notion of the photon, student A1, for example, portrayed the image he retained from computer simulation (hypercultural mediation).

> E: And this photon, what does his face look like, what do you imagine?
> A1: Lightning.
> E: A lightning bolt, a lightning bolt that appears there or elsewhere?
> A1: Which appears on the computer image.

Already student A2 mentioned the electron jumps he thinks occur in the Bohr atom model of LED (psychophysical mediation).

> A2: When we took the ball [10:52, #E] and put it, let's say from the smaller orbit and jump let's say to the third layer and take the drums and put it in the light, that caught my attention, which I thought that would have been, like I thought ah, that I thought so, since since the color is changing then each one, each color must be something different then I started to remember the other materials as well.

III. Regarding the association of different colors for different jumps, student A3 explained his ideas when asked what he remembered about electron jumps from one orbit to another.

> E: Ah, so why do you remember more? That's right, and did you remember any different colors when he jumped from different orbits?
> A3: Yes.
> E: But do you know why or when?
> A3: It's because one color has more energy than the other.
> E: Ah, so yeah, the color that has the most energy happens when the jump is bigger or smaller?
> A3: Larger.
> E: Bigger, that's right then. And you remember, when you remember that you remember the computer or you remember others?
> A3: Of the colors?
> A3: From there? (LED)
> E: From that one, talking about different heels and different colors do you remember that one from there?
> A3: Of colors from there, jumping with colors.

IV. During the interview students A3 and A2 stated the importance that the computer had for their understanding regarding the emission and absorption of photons. Student A3 says that:

> E: Everyone, everyone or is there a preference?
> A3: I think more about the computer, in case I had it ... I used the computer a lot and I was playing with it a lot, so he jumped up and down.

E: Ah, so why do you remember more? That's right, and did you remember any different colors when he jumped from different orbits?
A3: Yes.
E: Okay, the jump itself do you see the computer?
A3: Yes.

Thus, given these results, answering the research question, after the data collection indicate that the hypercultural mediation stood out from the other mediations and that mediations are complemented in the teaching of the Bohr atom model (Figure 1). The results also indicated that each of the mediations was used to explain some specific facet of the Bohr atom.

According to the logbook of the teachers and the observations made by the teacher-researcher of this work, the students felt more at ease after the proposed didactic sequence, as it enabled them to carry out activities that helped them to remember previous contents, arousing curiosity about the subject that would be taught in class. The activities involving experiments enabled ES students to feel they were learning physics, when they themselves carried out the experiments and debated the process, learning, at each class, based on experiences that they realized with their own hands.

Figure 1. The same sequence of depictive gesture was made by one student in Nov/2017 (a) and Oct/2018 (b) the experiment.

Considering the data collected during these two years of research, the students' contact time with each mediation did not influence the comprehension of the content addressed. Although the computational (hypercultural) simulation activity was shorter and performed shortly before the interview, it was the most frequently mentioned by all students. The same can be said of the activity involving the LED model (psychophysics), which was used on average in four classes, not being mentioned very often. Each student used a "different combination" of mental images that came from different mediations to explain the Bohr atom model; some students used two mediations together, others used a single mediation for a particular concept.

Student A1 being questioned during the interview about what Bohr's atom was to him, the student uses the image of the atom of computer simulation in the psycho-physical model made of LED. That is, in his mind explaining about the model of the atom and Bohr era imagines the hypercultural mediation atom in psychophysical mediation, bringing this combination to his learning (Figure 2).

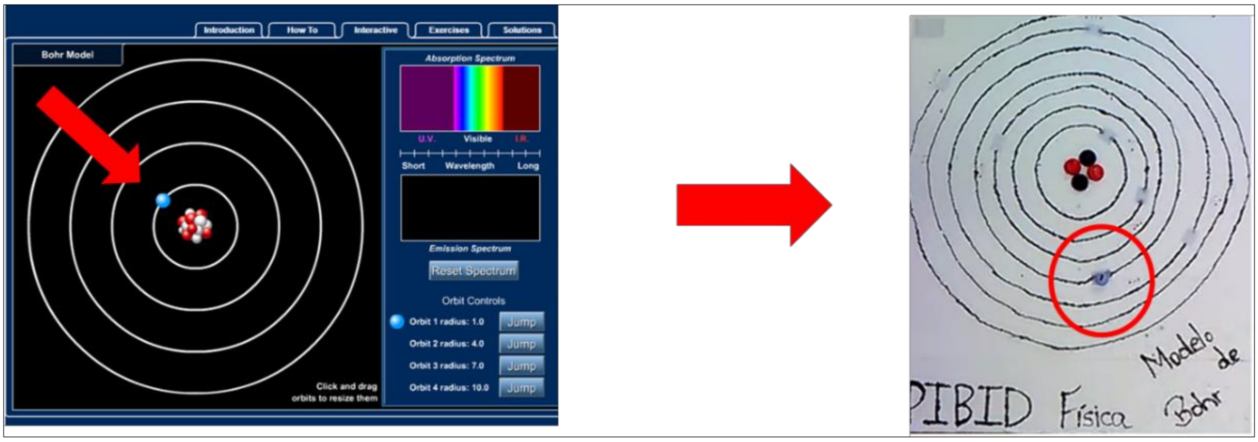

Figure 2. The student imagined the Bohr atom of computational simulation (hypercultural) in the LED model (Psychophysics).

The image of the atom has been associated with cultural mediation, sometimes students reported mental imagery that were from television series or some book; the image of the photon emerged only after the use of hypercultural mediation; finally, the electronic layers gained a representation soon after the students had used psychophysical mediation (Figure 3).

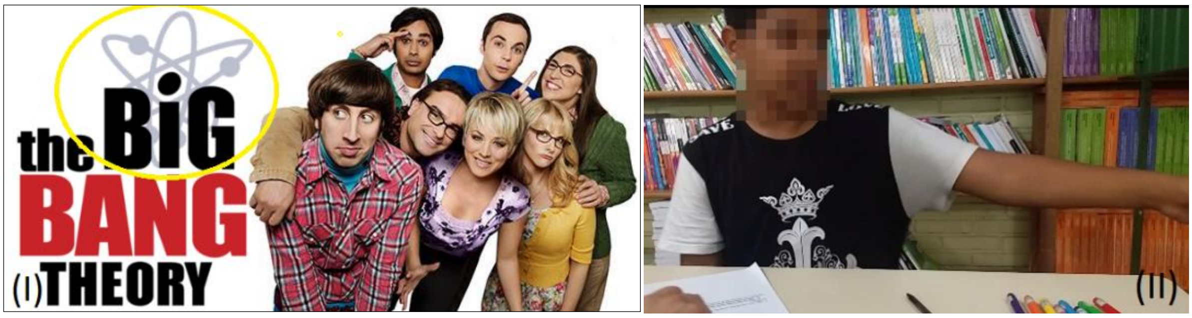

Figure 3. The student (II) recalled a television series (I) when asked about Bohr's atom

All mediations helped to understand the Bohr atom model, but hypercultural mediation was evidenced by most students, even those without daily access to computers and the internet (Figure 1). These students come from low-income families, but the format of the classes led them to become more involved in the study of science. Considering the process of this research in its totality, from its conception to the data collection, we believe in the relevance of the findings observed in the teaching of Physics in the FE in socially vulnerable areas. In addition, after 6 months of finishing the activities, the students were interviewed one more time and we were quite surprised to learn that they could recall the previously discussed, being able to correctly explain the Borh Atom, and even instigating them to learn from their questions through the experiences proposed (see figure 1).

Social mediation was mentioned by student A2 when the interview was conducted. Student A2 began by gesturing what would be Bohr's atom to him (Figure 4). When asked about the origin of this image, he pointed to the picture placed beside him, as well as the other mediations. That is, at first he claimed to remember the picture on the board to explain what he understood about the Bohr atom model. A2 stated that he had forgotten the leap from one layer to another. But at the 33rd meeting, he recalled the content and mentions that in his mind he saw the teacher explaining.

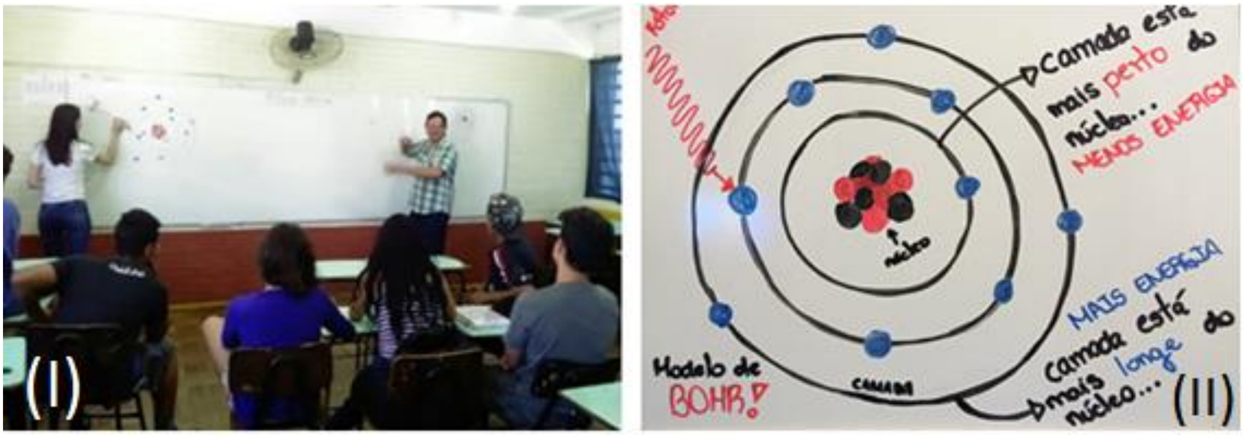

Figure 4. Image of teachers explaining on board (I) and interacting with students and the image of Bohr's atom on board (II).

_Hypercultural mediation was essential for students to understand the mechanics of the Bohr atom model: interviews showed that hypercultural mediation was essential for students to complement what they imagined about the Bohr atom.

This research also highlighted three important points: how teaching Modern Physics in fundamental school contributes to motivation and learning, the importance of using the four mediations combined to enhance learning even in fundamental school and, especially, the relevance of the use of the didactic sequence from the perspective of PMTU. The four mediations aided learning of the proposed theme, but the computational simulation was the most important and, in a way, was able to fill the students' comprehension gaps based only on the teacher's explanation, essentially allowing them to build mental images to model the Bohr Atom.

ACKNOWLEDGEMENT

This work was partially supported by FULBRA, FAPERGS and CAPES.

REFERENCES

Campello de Souza, B., Silva, A. S., Silva, A. M., Roazzi, A., & Carrilho, S. L. S. (2012). Putting the Cognitive Mediation Networks Theory to the test: Evaluation of a framework for understanding the digital age. *Computers in Human Behavior*, 28(6), 2320-2330.

Clement, J. J. & Stephens, A. L. (2010). Documenting the use of expert scientific reasoning process by high school physics students. *Physics Education Research*, 6(2), 20122-1-20122-15.

Erickson, F. (1986). Qualitative Methods in Research on Teaching. In: Wittrock, M. C. (Ed.) *Handbook of Research on Teaching* (p. 119-161). New York: MacMillan.

Monaghan, J. M., & Clement, J.J. (1999) Use of a computer simulation to develop mental simuations for understanding relative motion concepts. *International Journal of Science Education*. 21(9), 921-944.

Moreira, M. A. (2011). *Aprendizagem Significativa: a teoria e textos complementares.* São Paulo: Editora Livraria da Física.

Parente, F. A. G., Santos, A. C. F., Tort, A. C. (2014). O átomo de Bohr no Ensino Médio. *Revista Brasileira de Ensino de Física*, v. 36(1), p. 1502-1-1502-4.

Serrano, A., Trevisan, R., Meggiolaro, G., Anjos, J., Freitas, S., & Moreira, L. P. (2018). Where do representations and drivers for solving physics problems come from? an analysis of four experiments. In Finlayson, O. E., McLoughlin, E., Erduran, S., & Childs, P. (Eds.), Electronic Proceedings of the ESERA 2017 Conference. *Research, Practice and Collaboration in Science Education*, Part 4 (co-ed. Juuti, K., Kyza, E. A.), (pp. 622-629). Dublin, Ireland: Dublin City University. ISBN 978-1-873769-84-3.

Silva, G. G. (2013). *A abordagem do modelo atômico de Bohr através de atividades experimentais e de modelagem.* (Master Degree Dissertation, Universidade Federal de Santa Maria, Brazil).

Silva, J. A., Souza, C. M. S. G., O modelo ondulatório como estratégia de promoção da evolução conceitual em tópicos sobre a luz em nível Médio. *Ciência & Educação*, v. 20(1), p. 23-41.

Trevisan, R., Serrano, A., Wolff, J., Ramos, A. (2019) Peeking into students' mental imagery: the Report Aloud technique in Science Education research. *Ciência & Educação*, v. 25(3), p. 647-664.

USING FLIPPED CLASSROOM WITH DIGITAL MEDIA FOR PRE-SERVICE PRIMARY SCIENCE TEACHER EDUCATION

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Based on various reasons, it is demanded to use digital media in higher education. For the present study, a flipped classroom module for pre-service primary science teachers at the Ludwigsburg University of Education (Germany) was developed. Following the approach of a flipped classroom, information about the content on the specific topic are provided by online education resource before the lecture. After this preparation, the students work learner-centred during an in-class meeting, discuss and reflect on their gained knowledge and actively used it in, e.g. problem-solving tasks. Finally, after the in-class meeting, students deepen their knowledge on the topic. Most of the methods – especially the first phase – are based on digital media, which are used in the learning management software. The evaluation focuses on the students' feedback on the used flipped classroom concept and the development of pre-service teachers' TPACK and beliefs regarding the use of digital media in education. The results of the evaluation will be used for the improvement of the concept and the development of open educational resource.

Keywords: ICT Enhanced Teaching and Learning, Higher Education, Computer Supported Learning Environments

INTRODUCTION

With the digitalization of the every-day life, demands are placed on education and especially in higher education. Students and politicians expect that lecturers in higher education exploit the great predicted potential of digital media in teaching. The Ministers of Education of Germany call in various strategy papers for the digitisation of education in Germany, which could contribute to addressing several challenges in higher education (e.g. KMK 2017; 2019). Furthermore, several studies have shown positive effects on teaching and learning with digital media (e.g. Hattie, 2008; Hillmayr, Reinhold, Ziernwald, & Reiss, 2017).

Teaching with digital media can make higher education more attractive, more individual, more practical and more flexible, enabling it to partly respond to qualitative and quantitative changes in the student population. (Dittler & Kreidl, 2018). However, Dittler and Kreidl (2018) and Schmid, Goertz, Radomski, Thom, and Behrens (2017) show that the possibilities of digitization in higher education have so far been insufficiently and only selectively realized. Germany-wide student surveys show that only 50% of courses at universities use audiovisual media (Bargel, Müßig-Trapp, & Willige, 2008). Students would like to see more digital media in teaching (Bargel, Multrus, Ramm, & Bargel, 2009; Kreidl & Dittler, 2018) and expect digital media to enrich university courses and offer new and meaningful opportunities (Kreidl & Dittler, 2018). University lecturers also wish to use digital media and concepts in their seminars and lectures (Alvarez, 2012; Bergmann & Sams, 2012), but mostly only use presentation software (e.g. Microsoft Powerpoint) and learning management platforms (e.g. Moodle) to provide digital text documents. Lecturers state, that they face multiple challenges, e.g. legal issues, high technological innovation dynamics, higher teaching load, high costs and lack of IT- and didactical-support. Related to students, they see the risk of student' distraction, disruption and fraud (Schmid et al., 2017).

THEORETICAL BACKGROUND

Flipped-classroom-concept

One of the most used concepts to reach the goal of digital learning in higher education is the blended learning approach with the focus on flipped classroom. The flipped classroom is an instructional model, which uses the advantages of learning at home and in-class. Students learn basic contents self-controlled at home asynchronously and independent of location. The selected learning materials can have different formats, such as online videos, texts, podcasts, interviews and illustrations (Bergmann & Sams, 2012; Strayer, 2012). In the lecture, the learning activities are student-centred, collaborative and interactive (Strayer, 2012). These two phases of the lecture are - in contrast to the traditional and teacher-centred lecture concept - flipped or inverted (Bergmann & Sams, 2012). The implementation of a flipped classroom in higher education is used to promote students' engagement, perceptions and attitude, different forms of metacognition, performance, understanding, achievement, and self-efficacy (Al-Samarraie, Shamsuddin, & Alzahrani, 2019). The development of students' deep understanding of the materials by providing them with more control over what and how they learn, is one offered opportunity. Another goal is to facilitate students' acquisition of information, ideas, and reflection on their self-learning experiences (Al-Samarraie et al., 2019).

Several studies validate the potential of a flipped classroom in different learning contexts. Overall, the studies show the potential of the flipped classroom concept in support specific learning outcomes, e.g., engagement, attitude, understanding, metacognition, performance (Strayer, 2012), and self-efficacy (Al-Samarraie et al., 2019). Students take responsibility for their learning and are better prepared for in-class meetings (Alvarez, 2012). Flipped classroom encourages the synthesis of material, critical thinking and higher-order thinking skills (Bergmann & Sams, 2012). The potential of a flipped classroom in higher education has gradually increased across disciplines (Al-Samarraie et al., 2019).

In education courses, most of the previous studies found that the flipped classroom concept is used to enable students to process higher level of reflection and inquiry (Vaughan, 2014). In this area, the flipped classroom can also promote students' creativity through fluency, flexibility and novelty (Al-Zahrani, 2015) and foster the development of learners' self-efficacy and knowledge (Hao & Lee, 2016). The concept promotes students' positive perceptions towards the course (Zainuddin & Attaran, 2016). It enables students to develop positive attitudes (Xiu, Moore, Thompson, & French, 2018) and increase satisfaction (Ritzhaupt & Sommer, 2018) toward the learning process. When students are exposed to learning problems using supportive materials that are consistent with their learning styles, they are likely to develop positive attitudes towards the way of instruction they have experienced (Al-Samarraie et al., 2019).

Although the concept offers several positive opportunities, there are also challenges in the implementation. The main obstacles that need to be faced when using the flipped classroom concept are the time spent and technical difficulties. Furthermore, design efforts, limited practical sessions, lack of immediate feedback and course structure have a negative influence on the perception of the teaching (Al-Samarraie et al., 2019; Hotle & Garrow, 2015). In education courses, difficulties related to the requirement for discipline-specific skills and pre-preparation to implement the flipped learning model were stated in the literature (e.g. Al-Zahrani, 2015).

DEVELOPMENT AND DESIGN

To implement a flipped classroom in our university, we developed a new concept for the lecture "Introduction to science teaching". To sum up, the contents of the lecture are principles of science teaching, constructivism, diagnostic in science teaching and inquiry-based learning as well as dealing with students' misconceptions and language-sensitive teaching. One lecture addresses learning with digital media in science teaching as well. The structure of the single meetings is presented in figure 1. Phase 1 is the preparation at home based on online educational materials. Here the students work on educational videos, texts, interactive presentations (e.g. Prezi, www.prezi.com), tests and collaborative tools. The learning media are accompanied by assignments to work on. In phase 2, the students meet for the in-class actions at the university. Here they discuss, repeat and reflect on their preparation and get short theoretical input from the lecturer. They need to implement the gained knowledge in a practical task, such as the development of diagnostic-instruments and language-sensitive working sheets, jigsaw classroom activities, experiments in the lecture and other practical tools for their future teaching. In phase 3, the pre-service teachers reflect and/or deepen on the topic at home with the help of the mentioned digital education materials.

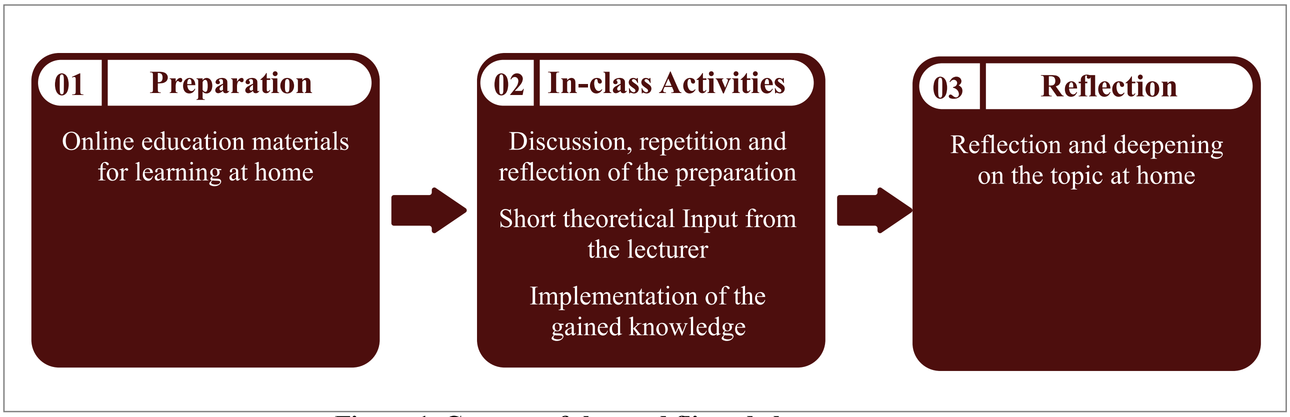

Figure 1. Concept of the used flipped classroom

Impact on pre-service teachers' media knowledge and beliefs

Pre-service teachers observe how lecturers in higher education behave when using media, how they use it, and how they evaluate social change and the changes it brings to their future schools. Because of that, we tried to design a lecture with didactically appropriate use of digital media in all learning phases and that way to introduce various forms of digital learning to the pre-service students. The lecturer and the lecture itself can be seen as a model, as defined by the social learning theory by Bandura (1977), which influence the student's knowledge, behaviour and beliefs. Thus, they could gain active experience as a learner and see how digital media can be successfully deployed in education. This way, they can learn about application scenarios, characteristics, advantages and disadvantages of digital learning concepts. This knowledge can be used in their future teaching with digital media. In conclusion, we suppose that the successful use of digital media in higher education for pre-service teachers could lead to the learning of media knowledge (e.g. TPACK) and the change of beliefs regarding digital media in teaching.

The term TPACK stands for *Technological Pedagogical and Content Knowledge* and describes the knowledge about the selection and use of technologies to support learning processes in a subject area (Schmidt, Baran, Thompson, Koehler, Mishra, & Shin, 2009). Koehler and Mishra (2008) have provided this framework for the knowledge that a teacher needs in order to use digital media successfully in class. They refer to Schulman's concept of professional knowledge (1986) and expand it to include technological knowledge, that is the knowledge about technology, tools and resources as well as productive use in work and everyday life. *TPACK* describes complex relationships between pedagogical knowledge (PK), content knowledge (CK) and technological knowledge (TK).

Teachers beliefs regarding the use of digital media in learning scenarios are essential if they ought to use them. These beliefs depend on various internal variables of the teacher. The Social Cognitive Career Theory (SCCT) by Lent, Brown and Hackett (2002) attempts to capture the complex interdependencies of these intrapersonal variables and to find out how these variables influence decision-making processes in the context of a profession. These variables, such as self-efficacy, outcome expectations, and interest are interdependent and influence the formation of personal goals as well as the selection, practice, and execution of behaviours, such as the use of digital media (Lent et al., 2002; Niederhauser & Perkman, 2008).

RESEARCH QUESTIONS

Starting from the theory, we raised three main research questions for the evaluation:

(i) How do pre-service primary science teachers experience the developed lecture, and what are the wishes and ideas for the improvement of it?

(ii) How does the concept of the newly developed lecture change TPACK of pre-service primary science teachers regarding the usage of digital media in their future classes?

(iii) How does the concept of the newly developed seminar change the beliefs of pre-service primary science teachers regarding the usage of digital media in their future classes?

METHODS AND SAMPLES

Regarding the first research question, students evaluate the concept following open and closed questions in an online survey after the lecture. In the closed-ended questions, the students respond to the statements, if they liked the interaction and the structure of the lecture as well as the variety of used methods. Furthermore, they rate their effort and learning outcome. In the open-ended questions, we asked for comments on the methodical concept of the lecture and opinion on the used digital media. The pre-service teachers are requested to give ideas for improvement of the lecture and name, which topic they liked the most.

For answering the second research question, the evaluation of pre-service teachers` perceived *TPACK* bases on a quantitative questionnaire (Schmidt et al., 2009; translated by Mahler & Arnold). For answering the third research question, a Likert-type questionnaire about pre-service teachers' beliefs about the usage of digital media was employed (Hulleman, Godes, Hendricks, & Harackiewicz, 2010; Hulleman & Harackiewicz, 2009; Davis, 1989; Lent, Brown, Sheu, Schmidt, Brenner, & Gloster 2005; translated and slightly modified).

131 pre-service primary science teachers participated in the study. They were aged 19 - 38 (*M* = 23). The pre-service teachers were at the beginning of their teacher training, visiting the second or third semester in a bachelor's program. Approximately 80 % of the pre-service teachers were female, which is typical for universities of education in Germany.

RESULTS

In the following, the results will be presented to answer the research questions.

RQ1

The quantitative results (figure 2) show that the participants like the used variety of methods (M = 4,08 on a 1-5 Likert-scale) and that the lecture was designed with interaction (M = 3,79). They pointed out the better structure of the lecturer (M = 3,88) and that they took a lot of the lecture (M = 3,66). They had an average effort (M = 3,23) in this lecture.

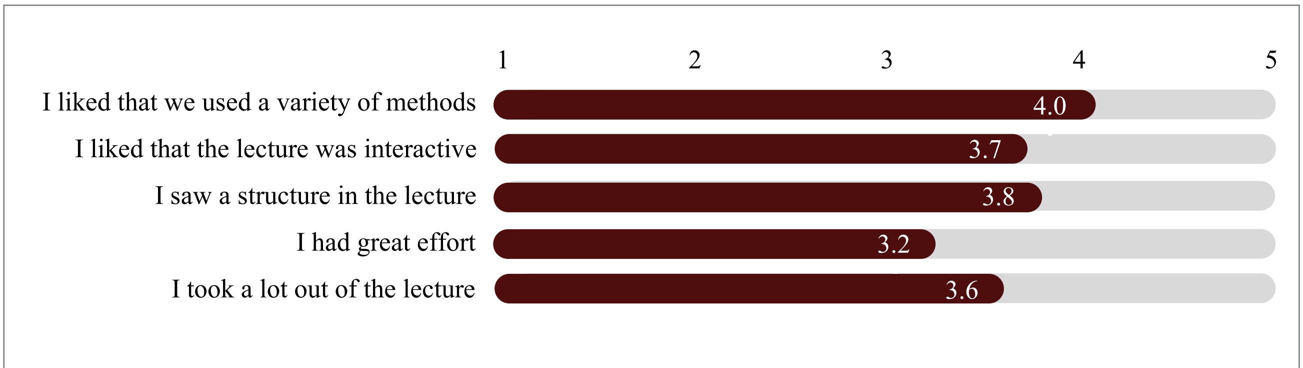

Figure 2. Closed-ended questions (N=131)

The qualitative data supported these results and put them into context. For most of the pre-service primary science teachers in this study, this was the first touch with a flipped classroom. About 20 % stated that they worked more comparing to a traditional lecture. However, the vast majority pointed out that they learn more compared to the traditional lecturer by the combination of theory in preparation at home and practical application in the lecture. Only some of the pre-service teachers in this study felt overstrained and wished for a traditional lecture with theoretical input from the university educator and only a few digital learning settings. The great majority of the pre-service teachers highlighted the work with a variety of digital media in this lecture was new and attractive, and they stated that this primarily facilitated their learning. They mentioned that they got a good overview as well as inspiration and knowledge for their future digital teaching.

Furthermore, for a majority, the cooperative group activities facilitated their learning. These active learning opportunities with the development of practical tools were labelled as useful for their future profession. Overall, they evaluate the flipped classroom concept positive and got a good overview as well as inspiration and knowledge for their future teaching.

RQ2 and RQ3

The results regarding the third research question are presented in figure 3.

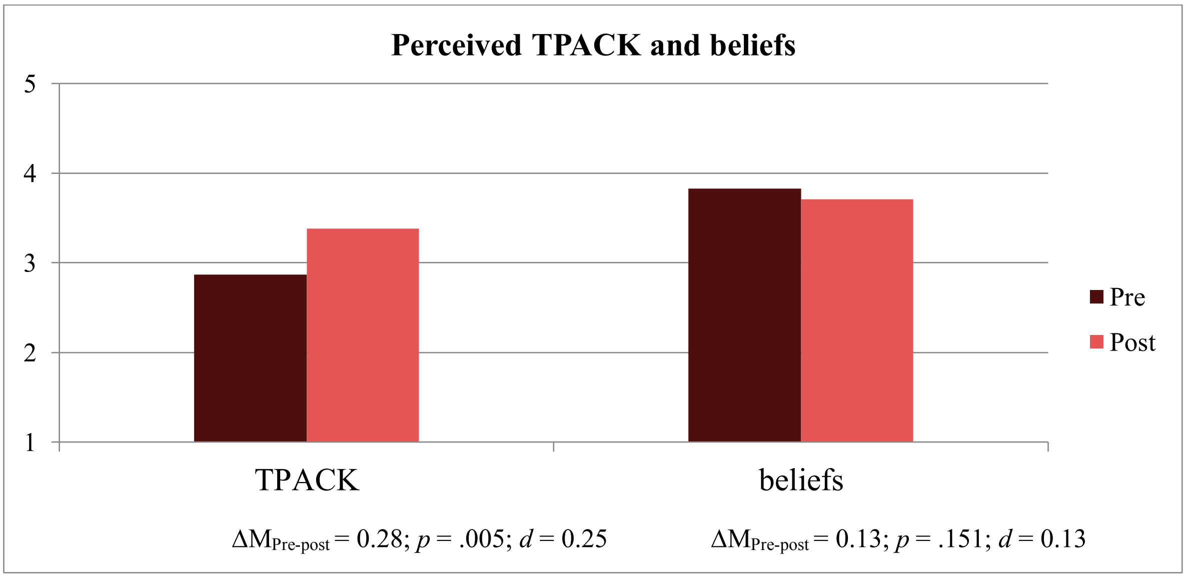

Figure 3. Pre-service teachers' perceived TPACK & beliefs (N=131)

The diagram in figure 3 shows the development of the pre-service teachers' perceived TPACK in the pre- and post-test. The value in the pre-test is 3.1, and it increases to a value of around 3.4 in the post-test. The pre-service teachers` perceived TPACK increased significantly ($\Delta M_{Pre\text{-}post} = 0.28$; $p = .005$; $d = 0.25$). The increase of the perceived TPACK is significant and has a small effect size with a Cohen's $d > 0.2$ (Cohen, 1988). The development of the pre-service teachers' beliefs in the pre- and post-tests is also demonstrated in figure 3. In comparison to the TPACK, the pre-service teachers` beliefs regarding the learning with digital media decreased, but not significantly (ΔMPre-post = 0.13; p = .151; d = 0.13). Overall, the beliefs remain on a high level with a value of 3.8 on a Likert scale from 1 to 5.

DISCUSSION

The present study shows the evaluation of a flipped classroom based on digital media in higher education from the perspective of pre-service primary science teachers. For our group of pre-service primary science teachers, a flipped classroom seems to be a fitting opportunity to combine theoretical and practical elements in a lecture and lead the students to work effectively. The pre-service students liked the concept and learning activities in the lecture. Though it was the first experience for them, it was easy to work this way. The participants see the value and the advantages of the flipped classroom for their professional development.

Regarding the perceived TPACK of the students, a significant increase could be observed, with the highest value in the post-study. Thus, we conclude that the lecture leads to an increased perceived TPACK. On the opposite, the pre-service teachers' beliefs slightly decreased insignificantly but remained at a high level. In Germany, the topic of digitalization in trendy because of the overall digitalization of society and a massive governmental campaign for supporting the digitalization in schools is set up. Thus, we assume, that this could explain the high level of beliefs before the lecture, especially because they stated, that they did not come in contact with digital media in an educational scenario before this lecture. The remaining of the beliefs at a high level can be interpreted as a positive result since the lecture did not discourage pre-service teachers with a realistic view on the implementation of digital media and the learning with and in this digital concept.

Interestingly, pre-service teachers can develop perceived TPACK and get a more realistic view, eventually mainly through the frequent use of digital media together with one specific session. In the debate about the responsibility for the education of pre-service students in media knowledge in higher education, frequent usage of digital media could be one practical and influential way for every participating domain. However, this requires further studies.

REFERENCES

Al-Samarraie, H., Shamsuddin, A., & Alzahrani, A.I. (2019). A flipped classroom model in higher education: a review of the evidence across disciplines. *Education Tech Research Dev*, doi:10.1007/s11423-019-09718-8

Al-Zahrani, A. M. (2015). From passive to active: The impact of the flipped classroom through social learning platforms on higher education students' creative thinking. *British Journal of Educational Technology, 46*(6), 1133–1148.

Alvarez, B. (2012). Flipping the classroom: Homework in class, lessons at home. *Education Digest*, 77(8), 18–21

Bandura, A. (1977). *Social learning theory*. Englewood Cliffs, NJ: Prentice Hall.

Bargel, T., Multrus, F., Ramm, M., & Bargel, H. (2009). *Bachelor-Studierende: Erfahrungen in Studium und Lehre; eine Zwischenbilanz*. Bonn: Bundesministerium für Bildung und Forschung

Bargel, T., Müßig-Trapp, P., & Willige, J. (2008). *Studienqualitätsmonitor 2007. Studienqualität und Studiengebühren (*HIS:Forum Hochschule 1/2008). Hannover: HIS.

Bergmann, J., & Sams, A. (2012*). Flip Your Classroom: Reach Every Student in Every Class Every Day*. Washington DC: International Society for Technology in Education

Davis, F. D. (1989). Perceived usefulness, perceived ease of use, and user acceptance of information technology. *MIS Quarterly*, 13(3), 319–340

Dittler, U., & Kreidl, C. (Hrsg.) (2018). *Hochschule der Zukunft. Beiträge zur zukunftsorientierten Gestaltung von Hochschulen*. Wiesbaden, Springer Fachmedien

Hao, Y., & Lee, K. S. (2016). Teaching in flipped classrooms: Exploring pre-service teachers' concerns. *Computers in Human Behavior, 57,* 250–260.

Hattie, J. (2009). *Visible Learning: A Synthesis of Over 800 Meta-Analyses Relating to Achievement*. London: Routledge.

Hillmayr, D., Reinhold, F., Ziernwald, L., & Reiss, K. (2017). *Digitale Medien im mathematisch-naturwissenschaftlichen Unterricht der Sekundarstufe. Einsatzmöglichkeiten, Umsetzung und Wirksamkeit*. Münster: Waxmann.

Hotle, S. L., & Garrow, L. A. (2015). Effects of the traditional and flipped classrooms on undergraduate student opinions and success. *Journal of Professional Issues in Engineering Education and Practice, 142*(1), 05015005.

Hulleman, C. S., Godes, O., Hendricks, B. L., & Harackiewicz, J. M. (2010). Enhancing interest and performance with a utility value intervention. *Journal of Educational Psychology*. 102, 880-895

Hulleman, C. S., & Harackiewicz, J. M. (2009). Promoting interest and performance in high school science classes. *Science*, 326, 1410-1412

Koehler, M.J., & Mishra, P. (2008). Introducing TPCK. In AACTE Committee on Innovation and Technology (Ed.). *The handbook of technological pedagogical content knowledge (TPCK) for educators*. (pp. 3-29). New York. NY: Routledge

Kultusministerkonferenz (KMK). (2017). *Bildung in der digitalen Welt. Strategie der Kultusministerkonferenz Bildung in der digitalen Welt*. Berlin. Retrieved from https://www.kmk.org/fileadmin/Dateien/pdf/PresseUndAktuelles/2017/Strategie_neu_2017_datum_1.pdf.

Kultusministerkonferenz (KMK). (2019). *Empfehlungen zur Digitalisierung in der Hochschullehre*. Berlin. Retrieved from https://www.kmk.org/fileadmin/Dateien/pdf/PresseUndAktuelles/2019/BS_190314_Empfehlungen_Digitalisierung_Hochschullehre.pdf.

Lent, R.W., Brown, S.D., & Hackett, G. (2002). Social cognitive career theory. In D. Brown (Ed.), *Career choice and development* (pp. 255–311). San Francisco: Jossey-Bass.

Lent, R.W., Brown, S. D., Sheu, H., Schmidt, J., Brenner, B. R., Gloster, C. S. (2005). Social cognitive predictors of academic interests and goals in engineering: Utility for women and students at historically Black universities. *Journal of Counseling Psychology, 52*(1), 84–92

Mahler, D. & Arnold, J. (2018), unpublished manuscript.

Niederhauser, D., & Perkmen, S. (2008). Validation of the Intrapersonal Technology Integration Scale: Assessing the Influence of Intrapersonal Factors that Influence Technology Integration. *Computers in The Schools*. 25. 98-111. 10.1080/07380560802157956.

Ritzhaupt, A., & Sommer, M. (2018). Impact of the flipped classroom on learner achievement and satisfaction in an undergraduate technology literacy course. *Journal of Information Technology Education: Research, 17*(1), 159–182.

Schmid, U., Goertz, L., Radomski, S., Thom, S., & Behrens, J. (2017). *Monitor Digitale Bildung. Die Hochschulen im digitalen Zeitalter*. Gütersloh: Bertelsmann Stiftung. Retrieved from https://www.bertelsmannstiftung.de/fileadmin/files/BSt/Publikationen/GrauePublikationen/BSt_MDB3_Schulen_web.pdf

Schmidt, D. A., Baran, E., Thompson A. D., Koehler, M.J., Mishra, P., & Shin, T. (2009). Technological pedagogical content knowledge (TPACK). The development and validation of an assessment instrument for preservice teachers. *Journal of Research on Technology in Education*, 42(2), 123–149

Shulman, L. (1986). Those who understand: Knowledge growth in teaching. *Educational Researcher*, 15, S. 4-14

Strayer, J. F. (2012). How Learning in an Inverted Classroom Influences Cooperation, Innovation and Task Orientation. *Learning Environments Research*, 15, 171-193. http://dx.doi.org/10.1007/s10984-012-9108-4

Vaughan, M. (2014). Flipping the learning: An investigation into the use of the flipped classroom model in an introductory teaching course. *Education Research and Perspectives (Online), 41,* 25.

Xiu, Y., Moore, M. E., Thompson, P., & French, D. P. (2018). Student perceptions of lecture-capture video to facilitate learning in a flipped classroom. *TechTrends*. https://doi.org/10.1007/s1152 8-018-0293-6.

Zainuddin, Z., & Attaran, M. (2016). Malaysian students' perceptions of flipped classroom: A case study. *Innovations in Education and Teaching International, 53*(6), 660–670.

PART 5: STRAND 5

Teaching-Learning Sequences as Innovations for Science Teaching and Learning

Co-editors: *Nikos Papadouris & Italo Testa*

CONTENTS

STRAND 5: INTRODUCTION

TEACHING-LEARNING SEQUENCES AS INNOVATIONS FOR SCIENCE TEACHING AND LEARNING

This chapter gathers the contributions to the ESERA 2019 e-proceedings for STRAND 05. The strand focuses on Teaching Learning Sequences (TLS), namely structured sequences of instructional activities, with well-documented suggestions for teachers and expected student reactions. In other words, studies in this strand are prominently empirical, including small-group interventions, with emphasis on the evaluation of students' learning and affective outcomes.

At the ESERA 2019 conference, 26 oral contributions and 36 posters were presented in this strand. 10 of the oral contributions and 4 posters have been included in the e-proceedings.

Amongst the studies that were presented as oral contributions, three concern physics topics, three address modelling approaches, two report on biology topics whereas the last two were presented in a symposium about the MultiCO Project.

Amongst the three studies that addressed physics topics, Kardaras and Kallery present a TLS about the continuous spectrum of the stars and specifically blackbody radiation. Results show a significant impact on the students' learning about this specific topic. Meli and Koliopoulos describe a TLS that focuses on the first law of thermodynamics. Results suggest that the proposed activity sequence lead to a sufficient level of student's understanding of the addressed topic. In the third paper about physics, Rico et al., present the design and development of a TLS about sound for prospective primary teachers. The third study focuses on learning objectives and the key ideas about sound emerging from an epistemological analysis.

The three contributions about modelling present different methods and contents. Bermudez et al. present a TLS about biological diversity. Results show that after the TLS the students' representations of biodiversity increased in abstraction and complexity. Koukioglou & Psillos describe how a TLS on optical properties of materials increased students' epistemological beliefs regarding models in science. Sadidi & Pospiech, discuss about how a particle physics scenario helped to increase students' skills in likelihood and uncertainty analysis as well as their critical thinking.

The two contributions about biology topics address animal physiology and evolution theory. Manzoni-de-Almeida et al. discuss how an open inquiry TLS in a non-formal teaching environment provided students with the possibility to collect and analyze data in biology. Papadopoulou & Ntinolazou use the Ideas, Cosmos and Evidence framework to develop a TLS on evolution theory. Results show positive results on students' understanding of evolution concepts.

Finally, two papers are taken from the symposium on the MultiCO project. This EU funded H2020 project aimed to raise students' awareness about knowledge and skills in STEM careers using specific career-based scenarios. The study by Connolly & Simon investigates the use of a scenario of a female Nuclear Medicine Technologist. Results show that the activities promoted interest in the proposed physics topic. Drymiotou & Constantinou discuss how a scenario focused on Polar Bears helped to generate and sustain students' situational interest and raise their awareness about science-related careers.

The four remaining papers concern the poster sessions of the conference. In the De Ambrosis et al. paper, the Feynman's sum over paths approach is presented. Data analysis shows that the TLS was effective in uncovering students' difficulties about introductory quantum mechanics. Malgieri et al. discuss a TLS on the micro-macro relationships in thermodynamics. A qualitative analysis shows an overall effectiveness of the TLS on students' participation in the activities. The study by Sakamoto et al. aims to examine the potential of a TLS on genetically modified organisms to enhance students' socio-scientific decision-making. Results suggest that the activities promoted students' reasoning about trade-offs taking multiple perspectives. The last paper by Ueno-Guimaraes et al. discusses a laboratory-based TLS on the inclined plane. Results are encouraging as students improved their experimental skills after being engaged in the TLS.

Overall, this chapter of the e-proceedings brings together studies that confirm that the TLS research field is active in several international contexts and continues to provide insights about how to innovate teaching practice in a variety of context.

Co-editors: Nikos Papadouris & Italo Testa

TEACHING THE CONTINUOUS SPECTRUM OF THE STARS WITHIN PHYSICS COURSES: A MODULE AND THE STUDENTS' LEARNING OUTCOMES

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Continuous spectrum generated by a blackbody, such as incandescent bulbs and stars, is interpreted with fundamental quantum laws and concepts that are also important for the understanding of contemporary physics. Teaching them within the frame of astrophysics can motivate students for learning and help them obtain a more profound and qualitative understanding of the blackbody's properties and their application in the laboratory in astrophysical settings. In the present study we present a module for the teaching of continuous spectrum of the stars within physics courses and specifically blackbody. The design of the module was based on the model of educational reconstruction. Students' previous ideas were investigated, and textbook analysis was carried out. Students of the upper secondary education engaged in a combination of computer simulations and hands-on activities. The approach was structured inquiry. In order to evaluate students' learning outcomes interviews, questionnaires and worksheets were administered. The data were qualitatively and quantitatively analyzed. The results showed that the intervention had a significant impact on the students' learning outcomes.

Keywords: blackbody, spectrum, stars

INTRODUCTION

In upper secondary education the teaching of concepts related to the starlight properties and the fundamental quantum concepts is insufficient and fragmented as indicated by the literature research. School textbooks offer few relevant information and the connection between these subject areas is neither clear nor explicit as these are studied in different units and chapters of textbooks. Teaching these concepts with coherence and cohesion may increase the understanding of individual concepts and all-around knowledge of the phenomena. In literature, relevant studies in the cognitive region of the celestial bodies usually refer to the motion of these bodies and few of them concern the physics of the stars (e.g. Colantonio, Galano, Leccia, Puddu, & Testa, 2017). In view of all the above, we designed a module and implemented it in the 2nd grade of Lyceum (students aged 17), where we combine the concept of the blackbody and the laws that describe it (Planck, Wien, Stefan-Boltzmann) with the concept of the continuous spectrum through the use of experimental activities, aiming at the deeper understanding of both concepts. In the experimental activities we consider the incandescent bulb (Bonnet & Gabelli, 2010) and the Sun as blackbodies. In this work we present a short description of our module as well as the students' learning outcomes after the implementation of the module.

METHODOLOGY

Design and implementation of the module

The study was carried out in Greece. The design of our intervention considered the country's curriculum and the physics concepts it includes. Accordingly, the duration of the intervention was 4 hours. The approach adopted in the intervention was that of structured inquiry.

The intervention was carried out on 41 students aged 17 years during the school year 2018-2019. This was the 1st main implementation of the intervention since the pilot of the year before. The design of the module was based on the model of educational reconstruction (Duit, Gropengießer, Kattmann, Komorek, & Parchmann, 2012, Viiri, J. & Savinainen, A., 2008): it is iterative, with three intertwining components (i) analysis of the content structure, (ii) empirical investigation (textbook analysis and students ideas) and (iii) construction of instruction.

The design of the module was guided by the following research questions:

(1) How can we design a teaching module based on a sequence of activities that helps students understand blackbody radiation within the frame of continuous spectra?

(2) What is the impact of the designed teaching module on students' learning outcomes and on their understanding of physics concepts and laws related to continuous stellar spectra?

The first steps towards an educational reconstruction of blackbody radiation and its continuous spectrum consisted of identifying key concepts and laws and reviewing students' conceptions of this topic**.**

Key concepts of blackbody radiation and continuous spectra

In order to identify key concepts and laws for the description of the continuous spectrum and blackbody radiation and also to acquire knowledge about how these are presented, we analyzed school textbooks and introductory university physics books (Young et al. 2014, Hewitt 2014). According to our analysis the key features of teaching blackbody radiation within continuous spectra are:

- Phenomena: analysis of the light, thermal radiation
- Concepts: photon, continuous spectrum, temperature, energy, wavelength, blackbody radiation, intensity, index or refraction, heat
- Laws: Wien, Stefan-Boltzmann, Planck.

Students' conceptions

As stated by the National Research Council (2005) students' ideas play important role for their future knowledge acquisition. Moreover, the framework of Educational reconstruction places great emphasis on the investigation of students' misconceptions, previous knowledge and understanding of their basic ideas in order to make the complex and abstract scientific knowledge meaningful to them. This way it influences the construction of instruction (Duit et al., 2012).

Drawing from literature review, students face difficulty in understanding fundamental concepts such as heat and temperature (Harrison et al.1999). They also give incomplete or erroneous responses regarding the black body (Sadoglu, 2015) and demonstrate misconceptions about photons, stellar temperature, stellar spectra and stellar energy (Bardar, 2006).

To find out our students' previous knowledge of blackbody radiation and its spectrum we had them complete a questionnaire with multiple choice and open-ended questions. We observed that some students were not aware of the relationship between radiation – energy and they mix up the types of radiation. Many of them also hold the view that red color of radiation is related with greater energy, express the conception that colors of visible light are attributed to the intensity of light and do not have sufficient knowledge about stars.

Module content and activities

The module consists of two units, in which fundamental laws and concepts for describing continuous spectra are gradually introduced. In unit 1, the driving questions that lead students to encounter fundamental concepts and laws, are 'What is a continuous spectrum?', 'Which physical quantities are necessary for describing and interpreting a continuous spectrum?', 'What is the emitted power distribution for a given temperature in different wavelengths?' In Unit 2 'Which are the mathematical equations that relate the quantities of temperature with wavelength of maximum power output and total power output?', 'How can we apply these equations in describing stars' temperature, color and luminosity?'. The structure and content of the module is presented in Table 1.

Table 1. Description of the module's content and activities.

Duration	Units	Content	Activities
2h	Continuous spectrum,	Properties of continuous spectrum	Observation of Sun and incandescent light bulb's spectra
	Plot of the ligh intensity versus wavelength	Planck's law	Process and plot of the Sun's spectrum with software
2h	Concepts describing	Wien's law	Variation of Bulb's voltage-variation of the spectrum
	blackbody, wavelength	Stefan-Boltzmann's law	Experiment study of Stefan-Boltzmann's law
	of maximum power		with measurement of light bulb's resistance and its light intensity

output, temperature	Calculation of the Sun's photosphere temperature through temperature measurement of a liquid in a can

A fundamental feature of the module is that it is based mainly on experimental activities and students engage in a combination of computer simulations and hands-on activities. Students carried out activities, two of which we describe below, wrote down their observations and the results, processed them and finally discussed them in the class.

An important experiment that students performed in order to study the Solar spectrum and confirm its similarity to the corresponding spectrum of blackbody radiation as described in theory, was the analysis of the sun's spectrum spectral chart obtained by a spectroscope, with NASA's HEASARC software (Figure 1).

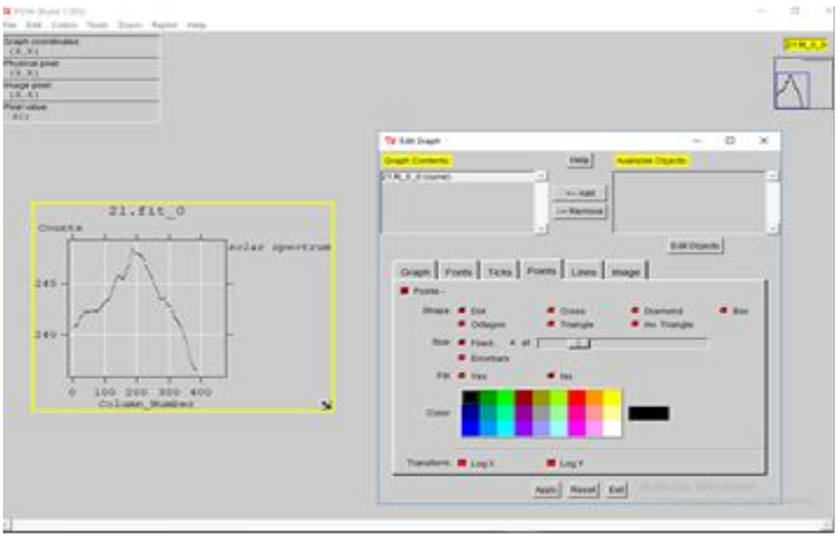

Figure 1. Screenshot, showing on the left the graph of the solar light's intensity in different wavelengths of the visible spectrum obtained by students with NASA's HEASARC software, available (http://heasarc.nasa.gov/lheasoft/ftools/fv/fv_download.html).

This way students became familiar with the Sun's spectrum and ascertained that its spectral emittance has many similarities with those predicted from the Planck's law. They also realized that the maximum power output occurs at about 510 nm, which corresponds, applying Wiens' law, to 5800 K, that is the temperature of the photosphere of the Sun. Moreover, they understood why Sun appears white-yellow since its maximum emitted energy is in the yellow part of the visible spectrum.

Another experimental activity, in order to probe Stefan-Boltzmann's law, was the measurement of the dissipative power, at different temperatures, of a tungsten filament light bulb which was used as the emitting source of the blackbody radiation (Bonnet, I., & Gabelli, J. 2010, Wellons, M., 2007) (Figure 2). Students measured the voltage and the current and subsequently calculated the temperature and the emitted power of the filament knowing that the resistivity ρ is a nonlinear function of the temperature. Then, by plotting a graph of lnP versus lnT, students tested whether the relationship between P and T is a power law and the exponent of that power law is the slope of the curve.

Figure 2. Experimental setup to measure the emitted power of an incandescent lamp, by calculating filaments' temperature of the lamp.

Assessment of students' learning

To evaluate students' learning progress we administered, among other assessment tools (observations, worksheets and interviews), two questionnaires. One of them consisted of ten multiple choice items, three of which are presented in Table 2.

Table 2. Sample questions for the evaluation of students' learning outcomes

Questions
1. Antares is a red star, Sun is a yellow-white star and Vegas is a blue star. Which one has the higher surface temperature
a) the Antares b) the Sun *c) the Vegas*
2. Warmest stars emit most of their energy in the region of a) infrared b) ultraviolet c) visible *d) X-rays*
3. A continuous spectrum is emitted by
a) a hot solid *b) a hot gas* c) a cool gas

Students were also asked to complete a questionnaire with open-ended questions, (Young et al. 2014, Hewitt 2014), in order to test if they acquired deep understanding of the topic and developed critical and scientific thinking of this subject area. They should justify their responses in writing by explaining their reasoning in words and by mathematical calculation. The level of understanding of each response was evaluated as correct, partially correct, or incorrect. Two of the questions are presented in table 3.

Table 3. Sample of open ended, explanation type questions in order to evaluate the quality of students' argumentative discourse.

Open ended questions
Q1. Could you explain why do we perceive a "green-hot" star not as green but as white?
Q2. Could you explain why a lamp filament that is made of tungsten emits a continuous spectrum rather than a tungsten line spectrum when light from an incandescent lamp is viewed with a spectroscope?

Implicit in the question Q1 is the idea that the objects don't emit a single wavelength of light but they emit photons in a range of wavelengths and in the question Q2 the idea that the otherwise well-defined energy levels of outer electron shells are smeared by mutual interactions among neighboring atoms.

RESULTS

Questionnaire with open ended questions

The qualitative assessment of the data showed that before the intervention none of the students gave correct answers and only a small percentage of them were able to give partially correct answers. This was due to their lack of knowledge. After the intervention, students were able to answer correctly and partially correctly, achieving average scores of 26% and 32% respectively to question Q1 and average scores of 32% and 36% respectively to question Q2, as presented in Figures 3 and Figures 4. Therefore, we observe that teaching blackbody radiation within the frame of continuous spectra and with a variety of experimental activities helps students develop a more sophisticated view of the complexity of the blackbody radiation.

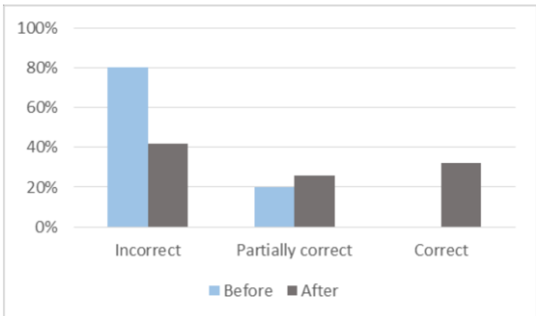

Figure 3. Quantitative assessment based on students' answers to the question Q1 before and after the implementation of the teaching module.

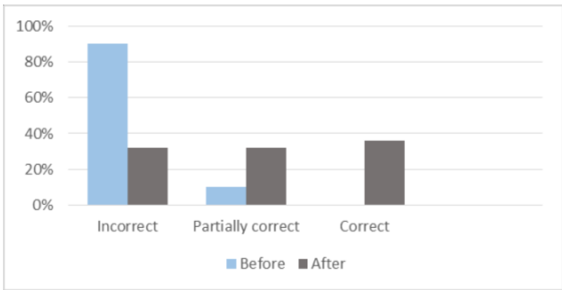

Figure 4. Quantitative assessment based on students' answers to the question Q2 before and after the implementation of the teaching module.

Multiple choice questions

The results of students' responses to three questions of the multiple choice questionnaire are presented in figure 5.

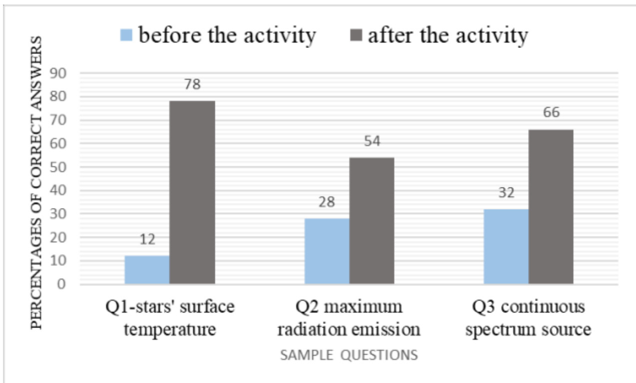

Figure 5. Percentages of students' correct answers to three questions before and after the teaching intervention.

The results obtained from these three questions, before and after the intervention, are shown in Figure 5. High scores were attained after the intervention and a noticeable improvement can be seen. After gathering data from all the questions, we proceeded to the statistical analysis using SPSS 23 statistical package. Initially, we conducted the normality test which indicated that the data were normally distributed and then we performed a dependent t-test that compares the mean difference between our samples (Field, 2009). The test consisted of ten multiple choice questions, where each correct answer was assigned 1 point and thus, for a student who had answered correctly all the questions, the total maximum score was 10.

Figure 6. Distribution of students' score for the overall test before and after the intervention..

The statistical analysis of the responses showed that the impact of the intervention on students' understanding was noteworthy since the mean value and the standard deviation before the main implementation were M=2.82, SD=0.93, while after M=5.80, SD=2.21 respectively. The difference in performances between pre-test and after-test (Figure 6), as evaluated using the statistical package SPSS 23, is statistically significant (t=10.78, df=40, $p<10^{-4}$). For the item analysis, for each question after the implementation, we calculated the indices of difficulty (proportion of correct answers) and discrimination (how well an item distinguishes students with high scores from those with low scores) (Ding & Beichner, 2009). The acceptable item-difficulty values range from 0.3 to 0.9 and for the item-discrimination index are greater than or equal to 0.3. The average value of the difficulty index and the average value of the discrimination index for all items was 0.58 and 0.68 respectively, therefore within the accepted criteria values.

DISCUSSION

The structure and content of the implemented module that bridges blackbody's laws and concepts with the continuous spectrum of star light as well as the approach used, seem to have had a positive impact on students' learning outcomes and also on their understanding of physics concepts and laws related to continuous stellar spectra. The findings of the study create perspectives that the combination of the specific content with hands-on activities, simulations and software and their application in the laboratory in astrophysical settings can be effective for the teaching of such complex and difficult concepts and laws in secondary education. Nevertheless, our study continues with further applications for the improvement of the intervention as well as with investigations of the students' attitudes towards the experimental procedures used.

REFERENCES

Bardar, E. M. (2006). *Development and Analysis of Spectroscopic Learning Tools* (Doctoral dissertation, Boston University).

Bonnet, I., & Gabelli, J. (2010). Probing Planck's law at home. *European Journal of Physics*, *31*(6), 1463–1471. https://doi.org/10.1088/0143-0807/31/6/012.

Colantonio, A., Galano, S., Leccia, S., Puddu, E., & Testa, I. (2017). A teaching module about stellar structure and evolution. *Physics Education*, *52*(1). https://doi.org/10.1088/1361-6552/52/1/015012.

Ding, L., & Beichner, R. (2009). Approaches to data analysis of multiple-choice questions. *Physical Review Special Topics - Physics Education Research*, *5*(2), 1–17. https://doi.org/10.1103/PhysRevSTPER.5.020103.

Duit, R., Gropengießer, H., Kattmann, K., Komorek, M., & Parchmann, I. (2012). The Model of Educational Reconstruction – A Framework for Improving Teaching and Learning Science. *Science Education Research and Practice in Europe: Restropertive and Prospective*, (December), 13–38. https://doi.org/10.1007/978-94-6091-900-8_2.

Field, A. (2009). Discovering statistics using SPSS (3rd edition). London: Sage Publications

Harrison, A. G., Grayson, D. J., & Treagust, D. F. (1999). Investigating a grade 11 student's evolving conceptions of heat and temperature. *Journal of Research in Science Teaching: The Official Journal of the National Association for Research in Science Teaching*, *36*(1), 55-87.

Hewitt, P. G. (2014). *Conceptual physics*. Pearson Higher Ed.

National Research Council, Donovan, S., & Bransford, J. (2005). *How students learn*. National Academies Press.

Sadoglu, G. P., & Akdeniz, A. R. (2015). Turkish Student's Perception about the Black Body Radiation, Photoelectric Effect and Compton Scattering Phenomena.

Viiri, J., & Savinainen, A. (2008). Teaching-learning sequences: A comparison of learning demand analysis and educational reconstruction. *Latin-American Journal of Physics Education*, *2*(2), 1.

Wellons, M. (2007). The Stefan-Boltzmann Law. *Physics Department, The College of Wooster, Wooster, Ohio*, *44691*.

Young, H. D., Freedman, R. A., Ford, A. L., & Zemansky, M. W. (2014). *Sears and Zemansky's University Physics*. Pearson

RESEARCH-BASED DESIGN OF A TEACHING AND LEARNING SEQUENCE FOR THE FIRST LAW OF THERMODYNAMICS

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In this study, we present the design principles and the respective development of a Teaching and Learning Sequence (TLS) in the field of introductory thermodynamics, with particular focus on the First Law of Thermodynamics (FLT), for upper secondary school students. The TLS design takes into account the poles of knowledge, learning and teaching that correspond to three theoretical domains; (a) epistemological aspects related to the FLT, (b) students' cognitive capacity for dealing with the various features of the FLT and (c) pedagogical approach of this topic. Regarding the epistemology of the field, we analyze the historical framework in which the FLT emerged and the textbook approaches for the introduction of this law. The cognitive analysis includes the categorization of the multi-dimensional alternative frameworks and the reasoning patterns that the students put forward in explaining phenomena related to the FLT. About the pedagogical aspects of the TLS, we analyze the constructivist approach as a learning alternative for the traditional approach, which prevails among science curricula. The conclusions drawn by the three-level analysis formulated the design principles for a medium-level TLS (12 sub-sections) that covers the FLT along with several introductory thermodynamic topics. The results from the implementation of the TLS are presented briefly.

Keywords: Science Education, Teaching Learning Sequences, Physics

INTRODUCTION

In science education contexts, the development of a Teaching and Learning Sequence (TLS) aims to students' facilitation in their pursuit of understanding the established scientific knowledge. The design of a research-based TLS relies particularly on the results of preceding studies for a chosen topic (Ruthven, Laborde, Leach, & Tiberghien, 2009). In this study, we present the design principles and the respective development of a research-based TLS that addresses the First Law of Thermodynamics (FLT) as an introductory physics thermodynamics topic.

The FLT suggests an expression of energy conservation throughout a thermodynamic system and its surroundings. It also describes the distribution of energy through the conversions of the implicated energy entities (heat, work, and change in internal energy). Therefore, it is considered a fundamental principle of thermodynamics and its understanding is crucial for all experimental scientists, technicians and modern citizens.

In this case, we design a TLS for the FLT addressing the second year of secondary school. For this educational level, the research regarding the teaching and learning of thermodynamics, beyond the understanding of basic concepts such as temperature and heat, is rather limited (Meli, Koliopoulos, Lavidas, & Papalexiou, 2016). Our main goal is the improvement of students' representations regarding energy conservation. This design takes into account three basic pivots; knowledge, learning and teaching. Each of these pivots corresponds to a theoretical domain; these are respectively epistemology, cognition, and pedagogy (Buty, Tiberghien, & Le Maréchal, 2004). In the following sections, we elaborate on these domains and we present a sample of the TLS as the product of this analysis.

DESIGN PRINCIPLES OF THE TEACHING AND LEARNING SEQUENCE

Epistemological analysis: historiographical and textbook analysis regarding the FLT

By the end of the 17th century, scientists had fully realized that materials at a gaseous state behave like any other fluid and conducted experiments for the investigation of the thermal properties of gases. At first, their main focus was on the interpretation of the nature of heat, which involved microscopic issues that could not touch just yet; the fundamental work of John Dalton (1766-1844) was about a century away from being established and representations of the micro-level world were unattainable (Cardwell, 1971). Although a few scientists, like Daniel Bernoulli (1700-1782) worked toward a Newtonian-like explanation for thermal properties, the absence of material points inevitably gave rise to a new branch of physics that developed aside from the dominating Newtonian system (Harman, 1982). In that sense, “physics of heat” was the first scientific revolution that emerged after Isaak Newton’s (1643-1727) era.

One additional particularity of this new physics was that its applications preceded its theoretical establishment for about a century. In 1712, Thomas Newcomen (1663-1729) constructs the first functional steam engine, which plays a substantial role in the Industrial Revolution. The urgent need for the improvement of its efficiency shifted scientists’ focus from the nature of heat to the conservation of heat. Many prestigious scientists, like Sadi Carnot (1796-1832) made a clear distinction between microscopic hypothesis and developments at the macroscopic level (Meli & Koliopoulos, 2019). Through their work, the initial statement of heat conservation evolved to the notion of heat-work equilibrium and finally to energy conservation, which was expressed with the complete form of the FLT by Rudolf Clausius (1822-1888) in 1854 (Clausius, 1854, p. 484).

The principle of energy conservation in a qualitative and quantitative form through the explicit formulation of FLT affected all scientific fields. Each discipline introduces the FLT under its particular scope and therefore diverse textbook approaches are describing the same thermodynamic law (Christiansen & Rump, 2008). Physics and engineering textbooks offer many interesting perspectives that are often in agreement and complement each other. These refer to multiple statements of the FLT in terms of wording, mathematical expressions, and alternative representations.

One major strategic choice for a textbook suggests the “macroscopic vs. microscopic” approach of the FLT (Tarsitani & Vicentini, 1996). While macroscopic approaches reflect the classical theory as developed during the 19th century (e.g. Baehr, 1973), the microscopic approaches introduce the statistical mechanical theory that was developed during the 20th century in a vastly mathematical way (e.g. Landau & Lifshitz, 1976). However, in some cases, elements of both approaches can co-exist in the same textbook (e.g. Young & Freedman, 2012). Another strategic choice for the architecture of a textbook refers to the “applications vs. axioms” approach of FLT (Christiansen & Rump, 2008). The first one unfolds the theory through a deductive methodology (e.g. Carathéodory, 1909), while the second gives prominence to the presentation of specific models and systems (e.g. Moran, Shapiro, Boettner, & Bailey, 2014).

The convergence of macroscopic-applications approaches is particularly evident in technical thermodynamics textbooks, that usually address novice and expert engineers. Such textbooks offer semi-quantitative energy distribution representations of theoretical and real engines, such as Sankey diagrams (e.g. Young & Freedman, 2012, p. 655). These representations are in-line with the historiographic analysis that illustrates the role of steam engines for the emergence of the FLT. At the same time, they allow the discussion to expand to crucial issues, such as engine efficiency and energy dissipation.

Cognitive analysis: students' alternative frameworks and reasoning patterns for the FLT

First- and second-year university students and upper secondary students hold similar conceptual frameworks regarding the FLT, as a result of their comparable reasoning patterns (Rozier & Viennot, 1991; Tiberghien, 1994). Students seek interpretations for the thermodynamic processes they encounter under the umbrella of linear causal reasoning. Linear causality leads them towards systematic neglect of variables, creation of preferential relations among variables and oversight of the symmetry between variables (Rozier & Viennot, 1991). Due to this reasoning pattern, students land on alternative frameworks that can belong in energy and/or non-energy frameworks.

The energy approach of a thermodynamic phenomenon through the FLT is adequate for the description of all thermodynamic processes. However, its use is limited and often inaccurate (Leinonen, Raesaenen, Asikainen, & Hirvonen, 2009; Meli et al., 2016). Within energy frameworks, students have difficulty in recognizing the energy entities that play a role in a thermodynamic process and also in identifying the increase or decrease of these entities (Meltzer, 2004; van Roon, van Sprang, & Verdonk, 1994). The above findings can be related to an inadequate representation of the thermodynamic system and its surroundings (Meltzer, 2004; van Roon et al., 1994).

In non-energy frameworks, students typically use the Ideal Gas Law or microscopic level approaches as stand-alone explanations or complementary to their perception of the FLT. The Ideal Gas Law is particularly favored, although it is inadequate in interpreting adiabatic processes. State entities are much more appealing to students than energy entities (Kautz, Heron, Loverude, & McDermott, 2005; Leinonen et al., 2009; Loverude, Kautz, & Heron, 2002; Meli et al., 2016) Micro-level descriptions are also used, as the "ultimate" explanation students can offer. However, due to their intrinsic complexity, it is difficult for students to handle them properly and provide an accurate and complete explanation for thermodynamic processes (Kautz, Heron, Shaffer, & McDermott, 2005; Leinonen et al., 2009; Meli et al., 2016; Meltzer, 2004). It should be noted that both the above non-energy frameworks are usually taught long before the FLT, undermining the exploratory power of the latter (Leinonen et al., 2009; Meli et al., 2016).

Pedagogical analysis: constructivism as a pedagogical approach of the FLT

Traditional instruction, in the sense of attempting to "transfer" knowledge to students, has poor learning outcomes in the field of thermodynamics (Meli et al., 2016). One feature of the traditional approach, that may influence these outcomes, is the presentation of many and diverse frameworks for the same section, without an in-depth analysis for any of them. Another feature is the "conveying" of this knowledge on an abstract basis, with no reference to real-life situations, thus jeopardizing students' engagement to the subject (Koliopoulos & Constantinou, 2005).

To deal with these issues, constructivism proposes teaching that facilitates students in constructing their own meaningful, yet scientifically accurate, representations (Tiberghien, 1997) in a restricted framework with cultural context. For achieving this, three interrelated levels for the teaching and learning of science should be taken into account: phenomena, theory, and models (Tiberghien, Psillos, & Koumaras, 1995).

The phenomenological field of introductory thermodynamics mainly refers to thermodynamic processes. These should be organically integrated into a phenomenological field that is relevant to students, pertinent to what they usually face, free of technical challenges and capable of developing a "cognitive need" (Devi, Tiberghien, Baker, & Brna, 1996). The theory describing the phenomena should be both in a qualitative and a quantitative form. Qualitative form refers to the proper use of wording for describing entities and principles, while quantitative form refers to mathematical formulas and/or diagrams.

However, even if students form the mathematical expression of the FLT correctly, this does not necessarily reflect a sufficient understanding of the processes at hand (Kautz, Heron, Loverude, et al., 2005). The levels of phenomena and theory should be properly linked for students to seamlessly match phenomena to theory and the other way around. This link refers to the level of models that intervene between phenomena and theory to create smooth, yet meaningful, connections. For the FLT, the Energy Chain Model (ECM) can work towards this direction, since it suggests a semi-quantitative model representing energy distribution between the thermodynamic system and its surroundings during a process.

The convergence of the epistemological, cognitive and pedagogical analysis for the design principles of the TLS

We make decisions informed by the above-described three-dimensional analysis (Ruthven et al., 2009) and we seek intersections that should lead to a coherent design of the TLS and also a feasible implementation of this TLS for the upper secondary school level. Based on the threefold "theory-phenomena-models" as the levels for the teaching and learning of science, our main conclusions unfold respectively as follows:

(a) *We exclusively employ the macroscopic (classical) approach of thermodynamics.* The epistemological analysis illustrates that this framework can efficiently describe the theory and applications of thermodynamics, as it was historically developed before the appearance of the microscopic (statistical) one and it often stands alone in contemporary textbooks (Meli & Koliopoulos, 2019). Cognitive analysis confirms the appropriateness of this choice for novice learners, as the microscopic approach is the source of various misinterpretations and it hinders the energy-related explanations of thermodynamic processes (Kautz, Heron, Loverude, et al., 2005; Leinonen et al., 2009). Finally, sticking to a single framework and deeply examining it is consistent with the pedagogical analysis (Koliopoulos, Adúriz-Bravo, & Ravanis, 2011).

(b) *We organically integrate the steam engine as a study object.* Historiographical analysis suggests that steam engines had a great contribution to the development of thermodynamics (Cardwell, 1971; Kuhn, 1977), while textbook analysis shows that they used to be and still are a standard component for physics and engineering education. Employing them as our basic phenomenological reference, students' frameworks can be more accurate and energy-oriented (Cochran & Heron, 2006). Additionally, steam engines bring thermodynamic processes in a real-life context, within which students can find common ground with the respective theory (Koliopoulos et al., 2011).

(c) *We give prominence to energy distribution representations of thermodynamic processes, through the ECM.* Epistemological analysis confirms the representational power of such models, especially in reference to steam engines. From a cognitive point of view, these representations are in-line with students' intuitive linear causal reasoning pattern (Rozier & Viennot, 1991), but they can also pave the road for students to overcome it. Versions of the ECM, like the one we propose, can work efficiently towards the meaningful connection between the levels of theory and phenomena (Delegkos & Koliopoulos, 2018; Tiberghien, 1996).

CONTENT OF THE TEACHING AND LEARNING SEQUENCE

Table of contents of the TLS

The TLS consists of three broad-sections (BS) that include twelve sub-sections (SS). Throughout the TLS we examine Newcomen's steam engine and we focus on the gas in its motor as an example of a thermodynamic system. On this account, we introduce the FLT as an energy explanation for the description of adiabatic, isothermal and isobaric processes. Lastly, we use these components to assemble the cyclic process and discuss the efficiency of the engine. Several additional elements are also examined during this course, such as the properties of thermodynamic systems and the Carnot cycle.

Table 1 presents the contents of the TLS. The "activity problem" column describes the issue students attempt to address throughout each sub-section. The "conceptual components" column refers to the thermodynamic concepts and processes that are being introduced in a sub-section. Finally, the "conceptual negotiation" column mentions the representations that students are expected to construct during the instruction of the sub-section.

Table 1. Sample of the TLS content table.

	ACTIVITY PROBLEM	CONCEPTUAL COMPONENTS	CONCEPTUAL NEGOTIATION
BS1	**Thermal engines and thermodynamic explanation**		
SS01	What is a thermal engine and how does it work?	Structure/function of Newcomen engine	Activation of pre-energy conceptions Qualitative representation of energy distribution Semi-quantitative energy distribution Introduction to the ECM
SS02	How can we explain the function of the Newcomen engine in terms of energy?	Work and heat	
SS03	How does the Newcomen motor work?	Thermodynamic system and surroundings	
BS2	**Gas processes and the first law of thermodynamics**		
SS04	Why did an ignition take place in the tube?	Adiabatic compression/ Change in internal energy	Qualitative and quantitative representation of energy distribution and conservation: • phenomenon ➞ ECM • phenomenon ➞ ECM ➞ mathematical expression • mathematical expression ➞ ECM ➞ phenomenon
SS05	Why was the air in the tube liquified?	Adiabatic expansion/ Work/ FLT	
SS06	Why did the piston move (I)?	Isothermal expansion/ Heat/ FLT	
SS07	Which alternative phenomenon does the expression on isothermal expansion describe?	Isothermal compression/ Heat and work/ FLT	

SS08	Why did the piston move (II)?	Isobaric cooling/ FLT	Distinction between heat and change in internal energy Overcoming linear causality
SS09	What will happen if we isobarically heat the gas?	Isobaric heating/ FLT	
BS3	**Improving a thermal engine: a historical issue**		
SS10	Which processes take place in Newcomen motor?	Cyclic processes	Qualitative and quantitative representation of energy distribution in complex systems Generalization of FLT as an expression of energy conservation Overcoming linear causality: energy dissipation
SS11	What is the efficiency of a Newcomen engine?	Real engine efficiency	
SS12	How can an engine's efficiency surpass Newcomen's?	Theoretical engine efficiency	

Presentation of a TLS sub-section

In Table 2, we take as an example SS3 to briefly describe the way the TLS is implemented. The first two columns ("teacher's activities" and "students' expected activities") refer to practical issues, while the last two columns ("conceptual components" and "conceptual negotiation") address the respective theoretical issues for this particular sub-section.

Table 2. Sub-section 3 "How does the Newcomen motor work?".

TEACHER'S ACTIVITIES	STUDENTS' EXPECTED ACTIVITIES	CONCEPTUAL COMPONENTS	CONCEPTUAL NEGOTIATION
Presentation: Animation of the engine in operation		Structure and function of a steam engine	
Activity sheet: Which part is the motor of the engine?			
Discussion: Motor as a thermodynamic system/ system's surroundings	Discuss the concepts of the system and its thermal-mechanical surroundings	Thermodynamic system and thermal-mechanical surroundings	Construction of the concepts of system and surroundings / Semi-quantitative ECM
Activity sheet: The motor's cycle is one uniform process or several diverse processes?			
Discussion: Components of a cyclic process - examples	Discuss the features of a cyclic process	Cyclic process in a steam engine	Construction of a qualitative approach of the cyclic process

RESULTS FROM THE IMPLEMENTATION OF THE TLS

In this paragraph, we briefly describe the results of the research in reference to the conclusions that were drawn from the convergence of the epistemological, cognitive and pedagogical analysis. This TLS was implemented as a case study in a class of 19 students of the second grade of upper secondary school in Athens (Greece). The results reported here derive from the qualitative and quantitative analysis of pre- and post-tests.

(a) The restriction of the TLS in macroscopic thermodynamics and with special focus on the energy framework was very much reflected in students' final explanations of thermodynamic processes. While in the pre-test they used a variety of alternative frameworks, including the microscopic one in significant percentages, in the post-test almost every student employed the FLT framework and many among them provided explanations at a high-efficiency level.

(b) Newcomen's steam engine suggested a functional phenomenological field for the introduction and application of the FLT. The quest for the operation of the engine facilitated the organic integration of several thermodynamic processes; through this real-life situation, representations that otherwise would be abstract, became meaningful and approachable. In the post-test, students provide energy explanations for thermodynamic processes by assessing their utility in the engine's motor.

(c) The ECM as a representation for the energy distribution between the targeted thermodynamics system (gas in the engine's motor) and its surroundings was at great extend used by students for explaining thermodynamic processes in the post-test. Therefore, it appears as a proper model for bridging the phenomena to the theory of the FLT that describes them.

DISCUSSION

For the design of a TLS addressing the FLT for the upper secondary school level, we thoroughly analyzed preceding works on the field of introductory thermodynamics (Ruthven et al., 2009). This analysis was unfolded in three different domains: epistemology, cognition, and pedagogy (Buty et al., 2004). We drew our basic design principles for the TLS through the convergence of these domains. All parts of the analysis agreed on the use of (a) the macroscopic thermodynamics approach (Meli & Koliopoulos, 2019), (b) steam engines (Cochran & Heron, 2006) and (c) energy distribution models (Koliopoulos et al., 2011). Based on these design principles, we formed and implemented a medium level TLS (12 sub-sections) with related conceptual components and issues for negotiation with students, for them to improve their respective representations. The quantitative and qualitative analysis of pre- and post-tests confirmed our choice of design principles, as students' representations were in-line with them and their representations achieved satisfactory levels of sufficiency.

REFERENCES

Baehr, H.-D. (1973). *Thermodynamik: eine Einführung in die Grundlagen und ihre technischen Anwendungen* (3rd ed.). Berlin: Springer.

Buty, C., Tiberghien, A., & Le Maréchal, J. (2004). Learning hypotheses and an associated tool to design and to analyse teaching–learning sequences. *International Journal of Science Education*, *26*(5), 579–604. https://doi.org/10.1080/09500690310001614735

Carathéodory, C. (1909). Untersuchungen über die Grundlagen der Thermodynamik. *Mathematische Annalen*, *67*(3), 355–386. https://doi.org/10.1007/BF01450409

Cardwell, D. S. L. (1971). *From Watt to Clausius: The Rise of Thermodynamics in the Early Industrial Age*. London: Heinemann.

Christiansen, F. V., & Rump, C. (2008). Three Conceptions of Thermodynamics: Technical Matrices in Science and Engineering. *Research in Science Education*, *38*(5), 545–564. https://doi.org/10.1007/s11165-007-9061-x

Clausius, R. (1854). Ueber eine veränderte Form des zweiten Hauptsatzes der mechanischen Wärmetheorie. *Annalen Der Physik Und Chemie*, *169*(12), 481–506. https://doi.org/10.1002/andp.18541691202

Cochran, M. J., & Heron, P. R. L. (2006). Development and assessment of research-based tutorials on heat engines and the second law of thermodynamics. *American Journal of Physics*, *74*(8), 734–741. https://doi.org/10.1119/1.2198889

Delegkos, N., & Koliopoulos, D. (2018). Constructing the "Energy" Concept and Its Social Use by Students of Primary Education in Greece. *Research in Science Education*, 1–26. https://doi.org/10.1007/s11165-018-9694-y

Devi, R., Tiberghien, A., Baker, M., & Brna, P. (1996). Modelling students' construction of energy models in physics. *Instructional Science*, *24*(4), 259–293. https://doi.org/10.1007/BF00118052

Harman, P. M. (1982). *Energy, force, and matter : the conceptual development of nineteenth-century physics*. Cambridge: Cambridge University Press.

Kautz, C. H., Heron, P. R. L., Loverude, M. E., & McDermott, L. C. (2005). Student understanding of the ideal gas law, Part I: A macroscopic perspective. *American Journal of Physics*, *73*(11), 1055–1063. https://doi.org/10.1119/1.2049286

Kautz, C. H., Heron, P. R. L., Shaffer, P. S., & McDermott, L. C. (2005). Student understanding of the ideal gas law, Part II: A microscopic perspective. *American Journal of Physics*, *73*(11), 1064–1071. https://doi.org/10.1119/1.2060715

Koliopoulos, D., Adúriz-Bravo, A., & Ravanis, K. (2011). El «análisis del contenido conceptual» de los currículos y programas de ciencia : una posible herramienta de mediación entre la didáctica y la enseñanza de las ciencias. *Ensenanza de Las Ciencias*, *29*(3), 315–324.

Koliopoulos, D., & Constantinou, C. (2005). The Pendulum as Presented in School Science Textbooks of Greece and Cyprus. *Science & Education*, *14*, 59–73. https://doi.org/10.1007/1-4020-3526-8_28

Kuhn, T. S. (1977). Energy Conservation as an Example of Simultaneous Discovery. In *The essential tension*. Chicago and London: The University of Chicago Press.

Landau, L. D., & Lifshitz, E. M. (1976). *Statistical Physics* (3rd ed.). Pergamon Press.

Leinonen, R., Raesaenen, E., Asikainen, M., & Hirvonen, P. E. (2009). Students' pre-knowledge as a guideline in the teaching of introductory thermal physics at university. *European Journal of Physics*, *30*(3), 593–604. https://doi.org/10.1088/0143-0807/30/3/016

Loverude, M. E., Kautz, C. H., & Heron, P. R. L. (2002). Student understanding of the first law of thermodynamics: Relating work to the adiabatic compression of an ideal gas. *American Journal of Physics*, *70*(2), 137–148. https://doi.org/10.1119/1.1417532

Meli, K., & Koliopoulos, D. (2019). Teaching and Learning of the First Law of Thermodynamics: The Sufficiency of the Macroscopic Framework from an Epistemological and Cognitive Perspective. In F. Seroglou & V. Kouloutzos (Eds.), *IHPST 2019 Conference "Re-introducing science: Sculpting the image of science for education and media in its historical and philosophical background"* (pp. 140–147). Thessaloniki.

Meli, K., Koliopoulos, D., Lavidas, K., & Papalexiou, G. (2016). Upper secondary school students' understanding of adiabatic compression. *Review of Science, Mathematics and ICT Education*, *10*(2), 131–147. https://doi.org/https://doi.org/10.26220/rev.2777

Meltzer, D. E. (2004). Investigation of students' reasoning regarding heat, work, and the first law of thermodynamics in an introductory calculus-based general physics course. *American Journal of Physics*, *72*(11), 1432–1446. https://doi.org/10.1119/1.1789161

Moran, M. J., Shapiro, H. N., Boettner, D. D., & Bailey, M. B. (2014). *Fundamentals of engineering thermodynamics*. Wiley.

Rozier, S., & Viennot, L. (1991). Students' reasonings in thermodynamics. *International Journal of Science Education*, *13*(2), 159–170. https://doi.org/10.1080/0950069910130203

Ruthven, K., Laborde, C., Leach, J., & Tiberghien, A. (2009). Design Tools in Didactical Research:

Instrumenting the Epistemological and Cognitive Aspects of the Design of Teaching Sequences. *Educational Researcher*, *38*(5), 329–342. https://doi.org/10.3102/0013189X09338513

Tarsitani, C., & Vicentini, M. (1996). Scientific Mental Representations of Thermodynamics. *Science & Education*, *5*, 51–68.

Tiberghien, A. (1994). Modeling as basis for analyzing teaching-learning situations. *Learning and Instruction*, *4*, 71–87.

Tiberghien, A. (1996). Construction of prototypical situations in teaching the concept of energy. In G. Welford, J. Osborne, & P. Scott (Eds.), *Research in science education in Europe: Current issues and themes* (pp. 100–114). London: The Falmer Press.

Tiberghien, A. (1997). Learning and teaching: Differentiation and relation. *Research in Science Education*, *27*(3), 359–382. https://doi.org/10.1007/BF02461759

Tiberghien, A., Psillos, D., & Koumaras, P. (1995). Physics instruction from epistemological and didactical bases. *Instructional Science*, *22*(1990), 423–444.

van Roon, P. H., van Sprang, H. F., & Verdonk, A. H. (1994). 'Work' and 'Heat': on a road towards thermodynamics. *International Journal of Science Education*, *16*(2), 131–144. https://doi.org/10.1080/0950069940160203

Young, H. D., & Freedman, R. A. (2012). *Sears and Zemansky's university physics: with modern physics* (13th ed.). Addison-Wesley.

DESIGNING A TEACHING-LEARNING SEQUENCE ABOUT SOUND FOR PRE-SERVICE PRIMARY TEACHERS

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Acoustic phenomena are closely related to our daily lives and many decisions related to health, the environment or technologies faced by citizens are related to sound. Sound is also a key concept in physics. Therefore, in accordance with most Primary Education curricula, acoustic phenomena must be understood, at least as far as their phenomenology is concerned. In that sense, many proposals and teaching materials to learn about sound in early childhood and primary education are available, but the differences in context and learning objectives to be evaluated make it difficult to apply them directly in pre-service primary science teacher education. We present a proposal for the design of a teaching-learning sequence (TLS) about sound in the aforementioned context. This proposal follows a Design-Based Research (DBR) methodology. We adopt the DBR methodology because of its characteristics: an iterative process of design, implementation, evaluation and refinement, in an attempt to get a specific product - in our case a TLS - explicitly based on research results. Furthermore, we chose DBR because it is a widely-used approach for tackling informed designed research in educational research in general and, increasingly, in science education research. In this paper, we present results derived from the design phase, which involves the analysis of the school context, definition of learning objectives and learning demands, of our TLS about sound using the DBR methodology.

Keywords: Teaching Learning Sequences, Physics, Teacher Education, Primary Education

INTRODUCTION

Sound is a common phenomenon that we experience every day and plays an important role in understanding physical phenomena that are relevant to students. In fact, sound properties and sound effects are typically covered in all stages of Science Education curricula (Eshach & Schwartz, 2006; Mazens & Lautrey, 2003; West & Wallin, 2013). However, students display numerous difficulties regarding this concept, specially when explanatory wave models and the particulate nature of matter are incorporated in sound conceptualization as shown by the extensive research on secondary and university students' difficulties on the concept of sound (Hrepic, Zollman, & Rebello, 2010). Interestingly, fewer studies asses Primary Education students' or pre-service primary teachers' (PSPT) ideas about sound. Nevertheless, pervading issues, such as, identifying and differentiating the properties of acoustic vibrations, assigning materialistic properties to sound or difficulties to use the wave model were also identified in PSPT (Rico et al., *submitted manuscript*).

Despite the fact that research-based innovative products, which follow a socio-contructivist approach and take into account student's ideas to approach the teaching of sound have been produced over the years, the majority of them are for Secondary Education (Hernández, Couso, & Pintó, 2012; West & Wallin, 2013) and they do not provide enough insight to translate the approach to other context. Science education research provides fundamental insights into the cognitive, social, and emotional processes involved in learning, and contributes to the generation of new techniques, strategies, and materials for classroom instruction. These works include sequences of teaching activities with the aim of improving the students' learning of specific topics at a small-scale level (for instance a few teaching sessions) or at a medium-scale level (a whole sequence of lessons on a particular topic) but typically not addressing the large-scale level of a whole programme (of one or several academic terms). The literature refers to such teaching activities as Teaching-Learning Sequences (TLS). A distinctive characteristic of the TLS is its dual character that implies both research and development, pointing at a strong link between the teaching and the learning of a particular topic. A TLS can be broadly defined as "both an interventional research activity and a product, like a traditional curriculum unit package, which includes well-researched teaching-learning activities empirically adapted to student reasoning" (Psillos & Kariotoglou, 2016). We, thus, propose a Teaching-Learning Sequence (TLS) for the context of PSPT education.

TLS design reflects the interlink between the development of learning tools and environments and the development of theory. This interlinkage is a complex, cyclical process in which general education principles are applied to the teaching of specific topics in specific contexts. As a consequence, researchers have elaborated frameworks, to be used by designers, as interfaces between grand theories and the needs associated with developing a TLS on specific topics (Lijnse, 2004). We will present our design process as an implementation of Design Based Research (DBR) methodology (Easterday, Lewis, & Gerber, 2014; Guisasola et al., 2017). An argument in favour of using DBR in TLS design is that it provides help in solving some methodological issues, such as deepening the theoretical considerations that inform the TLS design, specifying the teaching strategies to overcome students' learning difficulties and clarifying the relation between criteria of design and the evaluation and re-design process (Guisasola et al., 2017). The literature shows the benefits of DBR in science education research since it reports how DBR provides the basis for a scientific approach to science education research by overcoming some of problems in the design of the TLS. For example, Trna & Trnova (2014) argued that by providing a methodology that includes the evaluation of the efficacy of the TLS, DBR is part of the teachers' Pedagogical Content Knowledge toolkit. These examples, among others, support our proposal of DBR as a methodology to improve TLS and TLS research in science education. The DBR methodology of design, evaluation and iteration for TLS comprises three general phases: i) Design, ii) Teaching experiments, and iii) retrospective analysis (evaluation and refinement of TLS) (Guisasola et al., 2017).

As part of an ongoing project, which aims to use the DBR methodology as a process to design, implement and evaluate a TLS about "Foundations of sound" in the context of PSPT education at the university, we hereby present data derived from the design phase of our TLS, which include the analysis of the school context and definition of learning objectives and learning demands (Leach & Scott, 2002). The general theories that support the design phase include the social-constructivist cognitive psychology, the epistemology of physics curriculum for the context of teaching and the results of Physics Education Research on teaching and learning. In particular, we think that from the aforementioned elements that are critical to the success of the process of design, these are the ones deserving further research: i) the influence of the context of application of the TLS, ii) the definition of learning objectives based on epistemological analysis and iii) the gap between these objectives and students' alternative ideas (i.e. learning demands; Leach & Scott, 2002).

METHODS:

In this paper we will exclusively focus on the first phase of the process (i.e. TLS design), as shown in the following sections.

Definition of Learning Objectives and Identification of Learning Demands

This is a primordial step in the TLS design and several elements were taken into account in order to define the learning objectives: i) analysis of the Primary Education curriculum and educational context, which justifies the need to teach our PSPT in this topic, ii) an epistemological analysis of the concept of sound by looking at its historical development and the explanatory models that have been developed in accordance with current scientific theories.

Regarding the first point, the analysis of the school context determines the conditions in which the TLS will be implemented. This goes beyond a mere analysis of curriculum standards to be achieved by the students in a particular educational stage, but it includes as well the students' feedback and the socio-cultural parameters of the educational setting. This is paramount if results are going to be compared between different schools or countries. In fact, the lack of definition of the factors influencing the design and evaluation of the TLS has been highlighted in the literature as one of the barriers to generalize such TLS designs (Guisasola et al., 2017). In our case, our PSPT are third year undergraduate students from a 4-year BA on Primary Education at a public university, enrolled in a compulsory 9 ECTS course on Natural Sciences teaching, which covers pedagogical content knowledge about physical and chemical sciences for primary education. Students attend different type of sessions, including lectures in big groups of students (ca. n=40) and seminar or lab sessions (n <25).

Regarding the epistemological analysis of the theory of sound, it is relevant to consider not only the state of the art and current definitions about sound, but also the historical context where such concepts were developed and validated (Izquierdo-Aymerich & Adúriz-Bravo, 2003). In other words, scientific concepts and theories do not emerge miraculously but are the result of an arduous process of problem solving and rigorous testing of initial hypotheses.

Consequently, knowing the development of the explanatory ideas that gave rise to the current scientific model can provide important information when designing teaching sequences. Research supports the inclusion of History of Science in Science teaching, but there are fewer studies that explore the use of History of Science to select the knowledge to be included in a TLS (Izquierdo-Aymerich & Adúriz-Bravo, 2003). In this work we use the History of Science as an effective tool to examine the problems that arose in the development of concepts and theories and, thus, we can identify epistemological barriers that needed to be overcome, ideas that allowed moving forward and technological repercussions of the newly acquired knowledge. This allows defining learning goals based on the epistemology of the discipline, instead of relying on school tradition. Obviously, the historical analysis has to be carried out with an educational approach by taking into account students' difficulties on the topic. A clear and explicit definition of learning goals is a key step i) in order to evaluate effectively the achieved outcomes by the students and, ii) to obtain valid results from the evaluation of the TLS for future designs.

The second element in the design phase of our TLS, is the analysis of the gap between the defined learning goals and the students' learning difficulties, as shown in the literature. Leach and Scott (2002), define this gap as the learning demands. They are defined through an analysis of the ontological and epistemic differences between students' ideas and the scientific concept to be taught (Leach & Scott, 2002). These differences will guide the teaching layout of our TLS, by defining the type and level of difficulty that we expect the students to encounter. In consequence, the identification of learning demands is a useful guide in the design of activities, because a big learning demand should require a specific treatment in number of activities and structure, compared to a learning demand that is small. Figure 1 shows a flow chart depicting the design and didactic tools used in this phase.

The sequence was organized around a scenario that enquired about how sound is produced in a music box. After the engaging scenario was presented, driving problems were designed in order to guide the students to learn around three concepts: a) the nature of sound, b) sound's propagation; c) the sound wave model. According to the social perspective of learning, the teaching strategy involves posing situations to students, with directions that guide them to find solutions. The solution must be achieved in accordance with scientific practices that we want students to become familiar with (Guisasola et al., 2017). In the case of our TLS about sound for PSPT, it provides an interactive learning context that has four characteristics: (1) students were organized in groups of four, and they were asked to record all their observations and work in pairs in the tasks that involved predicting outcomes, designing and carrying out experiments; (2) the TLS is structured around several driving questions about the key ideas about sound; (3) in each driving question, there is a number of activities that guide students to make explanations for each key idea. They have opportunities to make argued decisions in the small group; (4) Different ways of solving the task are discussed, guided by the teacher, and a classroom summary is formulated. By carrying out these activities, students engage in scientific practices because we expect that students i) start assessing the question using a qualitative approach, avoiding straight mathematical operations; ii) design an experiment and predict the outcome before carrying it out; iii) collect data and explain the results; iv) Discuss the results.

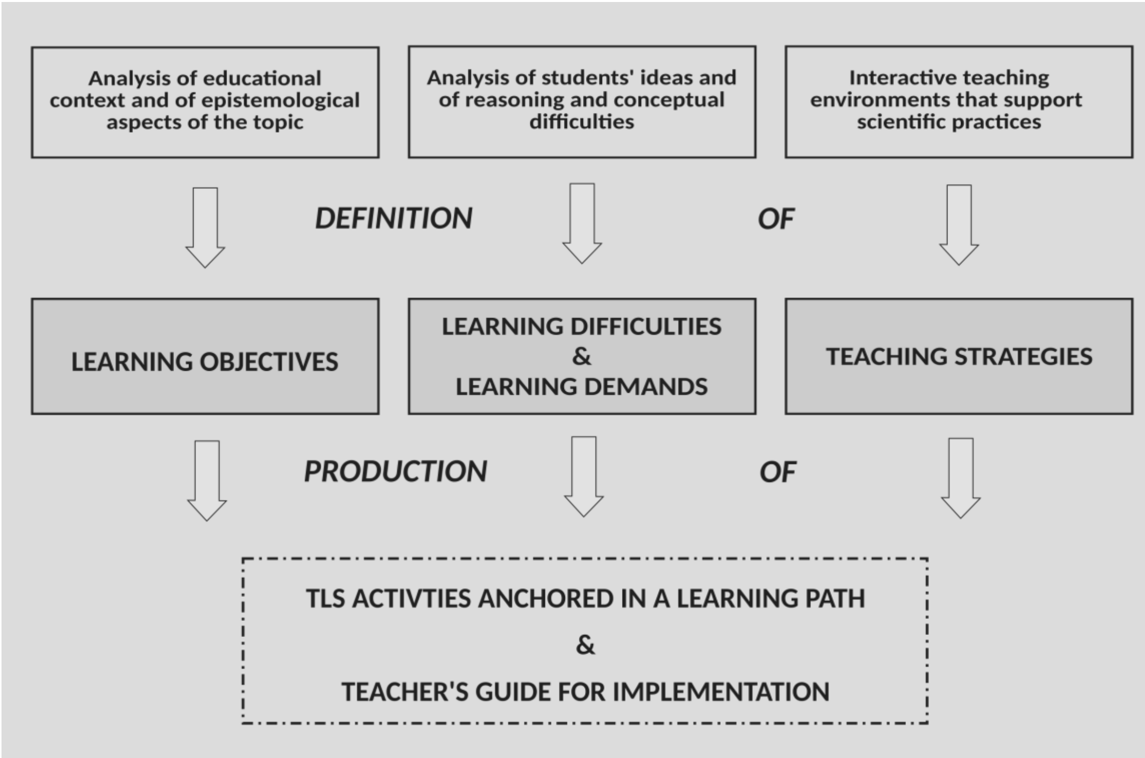

Figure 1. Flow chart depicting the didactic and design tools used in the Understand and Design Phases to sketch a TLS about sound for PSPT based on DBR methodology.

RESULTS

The results obtained with our educational tools will be shown in this section: i) epistemological analysis of school content and ii) Learning demands. It is important to highlight that not all the materials for the TLS are derived from these two educational tools, and hence, teachers that may use the TLS should be informed about which aspects come from previous research and which are personal contributions based on the designers' Pedagogical Content Knowledge.

An analysis that takes into account the epistemology of the theory of sound indicates that sound is defined as the event produced by the vibration of a body perturbed by an energy source. These vibrations cause a disturbance in the elastic medium in the form of a change of pressure or density without the transport of matter. As all waves, sound waves transport energy from one point to another but require some material medium for propagation (Rossing, Moore, & Wheeler, 2001). A deeper scientific understanding of sound involves the identification of its intrinsic properties, that is, loudness, pitch and timbre. Loudness depends mainly on sound pressure. Pitch, depends mainly on frequency, which is a magnitude that states the number of times that an event is repeated over a second and is measured in Hertz (Hz). Timber includes all those attributes that serve to distinguish sounds with the same pitch and loudness. In this sense, the theory of sound explicitly distinguishes: (i) between amplitude and volume; (ii) between frequency and pitch; and indicates (iii) that when evaluating sound energy it is necessary to take into account both properties (amplitude and frequency); (iv) that intensity, tone and timbre are interdependent properties.

Another fundamental aspect to be understood is that what is propagating through the elastic medium is the vibration itself (Hernández et al., 2012) and sound waves are disturbances that propagate through the air in a longitudinal way. Longitudinal means that the back-and-forth motion of air is in the direction of travel of the sound wave (Rossing et al., 2001). The case of sound and its propagation is an example of emergent process. Many patterns in the world are usually the result of the interactions of large numbers of smaller pieces that somehow combine in different ways to create the large-scale pattern. This mechanism is known as emergent process (Fazio et al., 2008).

Table 1 shows the key ideas about sound emerging from this epistemological analysis: 1)Sound and its properties; 2) Propagation of sound and 3) The wave model. A brief definition of each idea is shown in Table 1. Each key idea forms the basis for the definition of our learning objectives and constitute measurable indicators, which will inform the design of specific open-ended questionnaires and teaching strategies to evaluate students' learning.

Table 1. Learning objectives that define the concept of sound for a TLS in PSPT education.

Elements from the epistemology of physics	Learning objectives
Sound and its properties	
E1. Understanding that sound is generated when a typically audible vibration propagates through a medium and that the source of sound comes from a vibrating object. E2. This allows using the two properties of vibrations to characterise sound: the intensity (amplitude) and tone (frequency) of the vibration.	O1. The vibration of an object produces a sound, although not all sounds are perceptible to the human ear. O2. Objects of different shapes and materials generate different sounds. O3. The sound vibrations can be differentiated by their intensity (high/strong and low/soft) and pitch (low and high).
Propagation of sound	
E3. This vibrations are propagated through an elastic medium without transport of matter. E4. When a source vibrates, the surrounding air molecules do not go from the source to the detector during disturbance transmission, but oscillate back and forth over their electronic balance position and then return once the disturbance has passed. E5. Matter is composed of discrete particles (i.e. the particulate nature of matter).	O4. Sound vibrations need a material medium to propagate. O5. The speed of propagation depends on the medium (proof that it is the vibration or wave that is propagated).

The wave model E6. The propagation of this vibration is represented through the abstract concept of pressure wave.	O6. A sound can be represented by a wave (wave model) by establishing relationships between a) the intensity of the sound and/or the amplitude of a wave; b) The pitch of the sound and/or the frequency of a wave.

Table 2 shows how the definition of learning objectives and the identification of learning difficulties from a previous literature review allows for the identification of our student's expected learning demands. This is a pre-requisite to design appropriate teaching strategies and activities and evaluation tools, which will be used in the implementation phase. We show some examples illustrating the rationale behind the assigned level of the learning demands (Leach & Scott, 2002).

Table 2. Alignment of Learning Difficulties with learning objectives and identification of Learning Demands for a TLS about *Foundations of sound* for PPT**.**

Learning difficulties	**Learning objective**	**Learning Demand**
D1. An explanation that links sound with vibration is context-dependent (clear in a guitar string, confusing when hitting stones). Some students may not understand what "vibration" means (Küçüközer, 2009)	O1 (*vibration*)	Low
D2. Difficulties on differentiating tone from intensity or relating the sound's tone with its frequency and sound's intensity with its amplitude (Awad & Barak, 2018)	O2, O3 (*properties*)	Medium
D3. Sound does not need a medium to propagate (electromagnetic wave application; Linder, 1993) D4. Students associate materialistic properties to sound (e.g. carried entity by medium particles; Eshach & Schwartz, 2006; Hrepic et al., 2010) D5. Students cannot represent compression-rarefaction zones during sound transmission (Sözen & Bolat, 2016)	O4 (*propagation*)	Medium-High
D6. Difficulties in understanding/explaining sound propagation in solids (West & Wallin, 2013) D7. The louder the sound, the faster it propagates (Sözen & Bolat, 2016) D8. The denser the medium, the slower it propagates (Hernández et al., 2012)	O5 (*speed of propagation*)	Medium
D9. Confusion between longitudinal and transverse waves (Linder, 1993) D10. Sound and light are the same type of waves because their wave equation is identical (Linder, 1993) D11. Sound is not identified as a process (energy transfer) (West & Wallin, 2013)	O6 (*representation* of a *pressure wave)*	High

D12. Sound's properties are not correctly interpreted in graphic representations of the sound wave (Sözen & Bolat, 2016)	
D13. Coexistence of the wave model with the "entity" model (Hrepic et al., 2010)	

Regarding the first learning objective (O1, Tables 1 and 2), the literature on students' difficulties shows that the understanding that sound is originated due to the vibration of an object is context-dependent in primary students or PSPT (Küçüközer, 2009). We consider that this objective poses a low learning demand because providing different contexts for sound production and linking sound with everyday situations can help understanding sound phenomena (West & Wallin, 2013). We also predict that all learning objectives that involve understanding sound propagation (Learning Objectives O4 and O5) will present medium to large learning demands (Table 2), due to the persistent "materialistic" conception of sound in students of all ages (Hrepic et al., 2010). Lastly, we also predict that the representation of sound as a pressure wave or as a sinusoidal wave (Learning Objective O6, Table 2) can pose a high learning demand due to the mathematical abstraction and the confusion with transversal wave representations (Linder, 1993).

DISCUSSION

We have presented an application of the DBR methodology for a TLS of sound for pre-service primary teacher education that will form the basis of a research program on the validity of evidence-based TLS in PSPT science education. As stated previously, the first phases of the DBR methodology allow to anchor robustly a TLS addressed to a specific audience, which takes into account the historical development of the concept to be studied and the reported difficulties in the literature (Guisasola et al. 2017). Taking into account current paradigms of science education, the designed TLS should give opportunities for the students to engage in scientific practices, with the aim to provide strategies that foster both learning of science and about science. Further work, that will be presented in the future, involves the definition of guiding problems and strategies to foster learning about sound in pre-service Primary teachers. In the subsequent phase, the obtained results regarding the quality of the sequence and the evaluation of learning will inform the refinement of the proposed TLS and provide empirical evidence regarding pre-service teacher's understanding of sound.

ACKNOWLEDGMENTS

This research has been supported by the Basque Government through the call: *Ayudas Actividades de Grupos de Investigación 2016-2018, ref IT025-16*. Arantza Rico was funded by the University of the Basque Country (UPV/EHU) to attend ESERA19 through a conference attendance fund.

REFERENCES

Awad, N., & Barak, M. (2018). Pre-service Science Teachers Learn a Science, Technology, Engineering and Mathematics (STEM)-Oriented Program: The Case of Sound, Waves and Communication Systems. *Eurasia Journal of Mathematics, Science and Technology Education*, *14*(4), 1431–1451.

Easterday, M. W., Lewis, D. R., & Gerber, E. M. (2014). Design-based research process: Problems, phases, and applications. *Proceedings of International Conference of the Learning Sciences, ICLS*, *1*, 317–324.
Eshach, H., & Schwartz, J. L. (2006). Sound Stuff? Naïve materialism in middle-school students' conceptions of sound. *International Journal of Science Education*, *28*(7), 733–764.
Fazio, C., Guastella, I., Sperandeo-Mineo, R. M., & Tarantino, G. (2008). Modeling Mechanical Wave Propagation: Guidelines and experimentation of a teaching–learning sequence. *International Journal of Science Education*, *30*(11), 1491–1530.
Guisasola, J., Zuza, K., Ametller, J., & Gutierrez-Berraondo, J. (2017). Evaluating and redesigning teaching learning sequences at the introductory physics level. *Physical Review Physics Education Research*, *13*(2), 020139.
Hernández, M. I., Couso, D., & Pintó, R. (2012). The Analysis of Students' Conceptions as a Support for Designing a Teaching/Learning Sequence on the Acoustic Properties of Materials. *Journal of Science Education and Technology*, *21*(6), 702–712.
Hrepic, Z., Zollman, D. A., & Rebello, N. S. (2010). Identifying students' mental models of sound propagation: The role of conceptual blending in understanding conceptual change. *Physical Review Special Topics - Physics Education Research*, *6*(2), 020114.
Izquierdo-Aymerich, M., & Adúriz-Bravo, A. (2003). Epistemological Foundations of School Science. *Science & Education*, *12*(1), 27–43.
Küçüközer, A. (2009). Prospective science teachers' understanding of sound. *Procedia - Social and Behavioral Sciences*, *1*(1), 1889–1894.
Leach, J., & Scott, P. (2002). Designing and Evaluating Science Teaching Sequences: An Approach Drawing upon the Concept of Learning Demand and a Social Constructivist Perspective on Learning. *Studies in Science Education*, *38*(1), 115–142.
Linder, C. J. (1993). University physics students' conceptualizations of factors affecting the speed of sound propagation. *International Journal of Science Education*, *15*(6), 655–662.
Lijnse, P. (2004). Didactical structures as an outcome of research on teaching–learning sequences? *International Journal of Science Education*, *26*(5), 537–554.
Psillos, D., & Kariotoglou, P. (2016). Theoretical Issues Related to Designing and Developing Teaching-Learning Sequences. In D. Psillos & P. Kariotoglou (Eds.), *Iterative Design of Teaching-Learning Sequences: Introducing the Science of Materials in European Schools* (pp. 11–34).
Rossing, T. D., Moore, R. F., & Wheeler, P. (2001). *The Science of Sound* (3rd ed.).
Sözen, M., & Bolat, M. (2016). Developing an Achievement Test for the Subject of Sound in Science Education. *Journal of Education and Learning*, *5*(2), 149.
Trna, J., & Trnova, E. (2014). Design-based research as an innovation approach in the construction and evaluation of IBSME. *Proceedings of the Frontiers in Mathematics and Science Education Research Conference*, 186–191.
West, E., & Wallin, A. (2013). Students' Learning of a Generalized Theory of Sound Transmission from a Teaching–Learning Sequence about Sound, Hearing and Health. *International Journal of Science Education*, *35*(6), 980–1011.

BIODIMOD: A DIALOGIC PROCESS OF MAKING SENSE OF BIODIVERSITY THROUGH MODELLING-BASED TEACHING IN SECONDARY EDUCATION

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Science education has acknowledged the need to consider modelling as a key process in teaching and learning. Despite scientific modelling has been gaining traction within science education studies, there is relatively little research on the modelling of biological diversity. Our goal was to better understand teacher and students' modelling-related talk when constructing and reaching consensus on subrogant representations of biodiversity. We further aimed to identify how the teacher allowed the construction of a shared understanding and the occurrence of metamodeling talk. We report on four recursive analytical categories that were inductively identified in our registers of an instructional unit, which included fieldwork and classroom biodiversity modelling (32 students, 17-18 years old). The findings show that the representations of biodiversity became increasingly complex, integrating more and more components, and bridging the abstract, material and real planes of the model through different pathways. Teacher's role was characterised by a continuous guidance and dialogic inquiry, by which students were able to hypothesise, predict, describe and explain phenomena related to ecosystem processes in the context of a socioscientific issue.

Keywords: Modelling-based learning, Socioscientific Issues, Classroom Discourse

INTRODUCTION

Modelling and models are important scientific activities and products for scientific disciplines. Constructing, testing, and revising models is at the heart of the scientific endeavour, since models can be used descriptively, as a means of showing or explaining something, and predicatively, as hypothetical entities and research tools (Gogolin & Krüger, 2017). One of the best-known positions within the semantic view of theories is Giere's constructive realism (Koponen & Tala, 2014), that defines models as any subrogant representation, in any symbolic medium, which allows us to think, speak and act with rigor and depth on the system being studied (Giere, 1988). Hence, the purpose of theories, which is composed of a set of models, is to describe the phenomena within their "expected scope", so that one can answer questions about the phenomena under study and their underlying mechanisms (Koponen & Tala, 2014). Subrogant representations may consist not only of highly-sophisticated abstract models, but also of mock-ups, images, drawings, graphs and analogies. However, there is a need to avoid reducing these representations to mere phenomenological "traces" of the subrogated objects (Adúriz-Bravo & Aymerich, 2009).

From an educational perspective, models can be conceived of as intermediaries between children's capacity of interpreting natural facts and the multiple aspects of these facts that substantially work by representing hidden semantic connections and organising them in a comprehensive meaning (Acher, Arca, & Sanmartí, 2007). Therefore, modelling requires adjusting the imaginary or *abstract plane* (AP) with the observed objects (*real plane*, RP) by means of representations (*material plane*, MP), which allow sharing and negotiating semiotic registers with others (Chamizo, 2010; Gómez Galindo, 2013). Nonetheless, teachers tend to refer to the representational forms of the material plane as "models" themselves, rather than referring to representational systems as a whole (Passmore, Gouvea, & Giere, 2014).

Biological diversity was defined as "the variability among living organisms" by the Convention on Biological Diversity (CBD) (1992, p. 3). Since then, biodiversity conservation has been acknowledged to be a socioscientific issue (SSI) due to the intricate and complex links between social concerns (moral, ethics, etc.) and conceptually-influenced scientific practices (Evagorou, Jimenez-Aleixandre, & Osborne, 2012). Empirical research on SSI-based instruction has shown learner gains in ecology concepts, science practices, and learners' epistemic engagement around environmental topics (Kinslow, Sadler, & Nguyen, 2019). Following CBD's definition, biodiversity includes three components, *i.e*., genetic, species and ecosystem diversity ("*biodiversity trilogy*"), but recent contributions have further specified its meaning to include other components, such as species evenness, species composition, functional composition, and landscape units (Bermudez & Lindemann-Matthies, in press). Although students have a range of frameworks related to biodiversity, with some of them being in agreement with scientific conceptualisations (Bermudez & Lindemann-Matthies, in press; Campos et al., 2012), research on teaching and children's understanding of biodiversity has seldom addressed the material or representational challenges that modelling pose for students or how modelling might be used in conceptually fruitful ways (Manz, 2012; *cfr*. Kampourakis & Reiss, 2018).

From a sociocultural perspective, the classroom discursive interaction has gained great relevance as a mediator and privileged indicator of teaching and learning processes (Edward & Mercer, 1987). Language and talk enable us to understand the world around us, communicate with peers, express and share ideas and experiences, as well as to knowledge-building (Evagorou & Osborne, 2013). Therefore, the development of mental contexts, terms of reference and shared forms of speech through which participants construct senses and meanings gain importance in order to achieve a *shared understanding* (Edward & Mercer, 1987; Gray & Rogan-Klyve, 2018).

In this framework, we aimed to fill the gap in the knowledge of modelling of biodiversity and the features of teacher's and students' talk in a teaching and learning sequence (TLS) by answering the following questions: 1. What characterises modelling activities of biodiversity and which is the teacher's role? 2. Which are the functions of teacher's talk and how shared understanding is achieved? 3. How teacher and students reach consensus on the semiotic registers? 4. Are metamodeling ideas explicit or remain implicit throughout modelling activities?

METHODS

In order to analyse the process of biodiversity modelling, a didactic unit or TLS was designed and implemented. These are used as research and innovation tools, and are included in the so-called *developmental research* (Méhuet & Psillos, 2004). The TLS was centred on the meaning-making of an updated concept of biodiversity and getting to know local plants and animals. We implemented the TLS in the last course (32 students aged 17-18) of a state secondary school in the city of Córdoba (1.5 M inhabitants), Argentina. All of the students came from families of low socioeconomic status. Three lessons out of 8 of the TLS were dedicated to the modelling of biodiversity (80 min/lesson). The TLS was co-designed by the first and the third author, who was also the teacher, holds a degree in biology and a M.Sc. in environmental impact assessment, and has 15 years of experience in secondary schools. The first author was the research team's primary liaison with the teacher and class, designing lessons and often coteaching. This researcher's role has also been the case in Gómez Galindo's (2013) and Mans' (2012) developments. Our school reference scientific model of biodiversity was an adaptation of the conceptualisation put forward by the Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES, www.ipbes.net; Bermudez & Lindemann-Matthies, in press).

Data collection included audio recordings of all sessions, photographs of classroom dynamics, students' and teacher's productions (written and material), and the researchers' (first and second author) field notes. Conversations were audio-taped and transcribed verbatim by the second author. We have also punctuated the transcribed speech, in accord with our own intuitions, to make it easier to read. The approach of analysis of the modelling activities followed by the secondary-school students, the generated material representations and the teacher's role was qualitative (Patton, 2014), with a method of discourse analysis (Acher et al., 2007; Bahamonde & Gómez Galindo, 2016; Edwards & Mercer, 1998; Gómez Galindo, 2013).

Based on a descriptive and analytic account of the sequentiallity of the communication, we dialogued with our research registers aimed to characterise the modelling process and then generate assertions for this particular case that were grounded in the data. The research registers were treated as "situated." The analysis was developed respecting the sequentially of the oral communication conducting qualitative discourse analysis (Acher et al., 2007).

Through discourse analysis (Edwards & Mercer, 1998) the ideas introduced during the modelling activity and the role of the teacher were identified. For each representation the entities, represented relationships and properties were identified. Considering the totality of the data, a first proposal of categories was generated after a *recursive analysis* (Patton, 2014) in which all the analytical units were considered and, giving meaning to the modelling activity, they were reformulated. The analytical categories that we established are: (i) Modelling opportunities: contexts, entities and their relationships; (ii) semiotic registers bridging the planes of the modelling of biodiversity: A platform of common understanding; (iii) teacher's role and talk: From a guide to a dialogic inquirer; and (iv) metamodeling talk: Explicit reference to modelling. This particular selection has been made in order to illustrate the ways we observed participants constructing and manipulating models. We report the most representative sequences, including photographs and oral expressions, so as to produce a characterisation of the key aspects that lead to the modelling process in each of these units (Acher et al., 2007).

FINDINGS

Modelling opportunities: From the real to abstract and material planes of biodiversity

In order to analyse the process of modelling, this category describes the teaching activities that allowed the introduction of model entities and the construction of more and more abstract subrogant representations of biodiversity. The first modelling task took place in an urban park (lesson 3), after students had used dichotomous keys to identify native plants, and started with students' identification of high and low-biodiversity areas (HBA and LBA, respectively), within which 2 one-square-meter quadrats were selected. Inside of them, rubber tokens of different colours, forms and textures were provided by the teacher and used by the students in order to represent biodiversity components. By starting with this activity, students used the RP (i.e. plant individuals) with a subrogant representation of biodiversity (semiotic register of the MP, *i.e.* tokens), according to their conceptual understanding (AP, *i.e.* species richness) (Figure 1). Hence, *species richness* was explained, in terms of the initial model, as the number of tokens of different colours. Later, *functional groups* were conceptualised by the teacher as an emergent category of a set of species, based on shared significant characters because of their effect on ecosystem functioning or their response to environmental changes. The same tokens that students had used to represent species richness allowed us to represent functional groups, by the usage of the token shape. Therefore, the hexagonal and square shapes (MP) was interpreted to be the analogical bridge to the growth-form functional group (AP), and allowed us (cognitive agents) to distinguish between elements of the RP (e.g., grasses and forbs, with the latter being all herbaceous dicotyledonous species that are not graminoids). Trees and shrubs were not tackled with the MP, but we talked about them as part of the ideational AP of biodiversity. Finally, *genetic diversity* was also recognised as a component of biological diversity, with important links to species interactions, but we ran out of time to represent this feature with the MP in the fieldwork (Figure 1).

Back to the classroom (lesson 4), we continued the modelling of biodiversity. We decided to refer to HBA and LBA as "scenarios" of high and low biological diversity (HBS and LBS, respectively), since we started using photographs of the RP and because this approach considers plausible alternative situations that are based on particular assumptions (Bermudez & Lindemann-Matthies, in press). As a first step, students had to represent photographs of the same quadrats of HBA and LBA identified in the fieldwork (lesson 3), by the use of rubber tokens on an expanded polystyrene sheet, where two separate places had been previously delineated for HBS and LBS (Figure 2). The second task consisted of the modelling of a brand new component of biodiversity (species evenness), by presenting and discussing a pair of photographs of the same studied area (RP), each showing high and low *species evenness* (HBS and LBS), Figure 2). Both activities provided the opportunity to describe actual biodiversity scenarios, conjecture about the causes of their current condition, make predictions about the future and past events of the scenarios (retrodictions), and decide which scenario was better for protection. In order to gain complexity in the AP, other components of biodiversity were also represented, such as *genetic diversity*, *functional divergence* (richness and variability) and species *interactions*. It is also worth noting that HBS and LBS were always associated with ecosystem processes (such as rainwater infiltration, soil formation and fertility, biotic pollination, etc.) and the influence of ecosystem disturbances (e.g., biological invasions, human trampling, forest fires, etc.) (Figure 2).

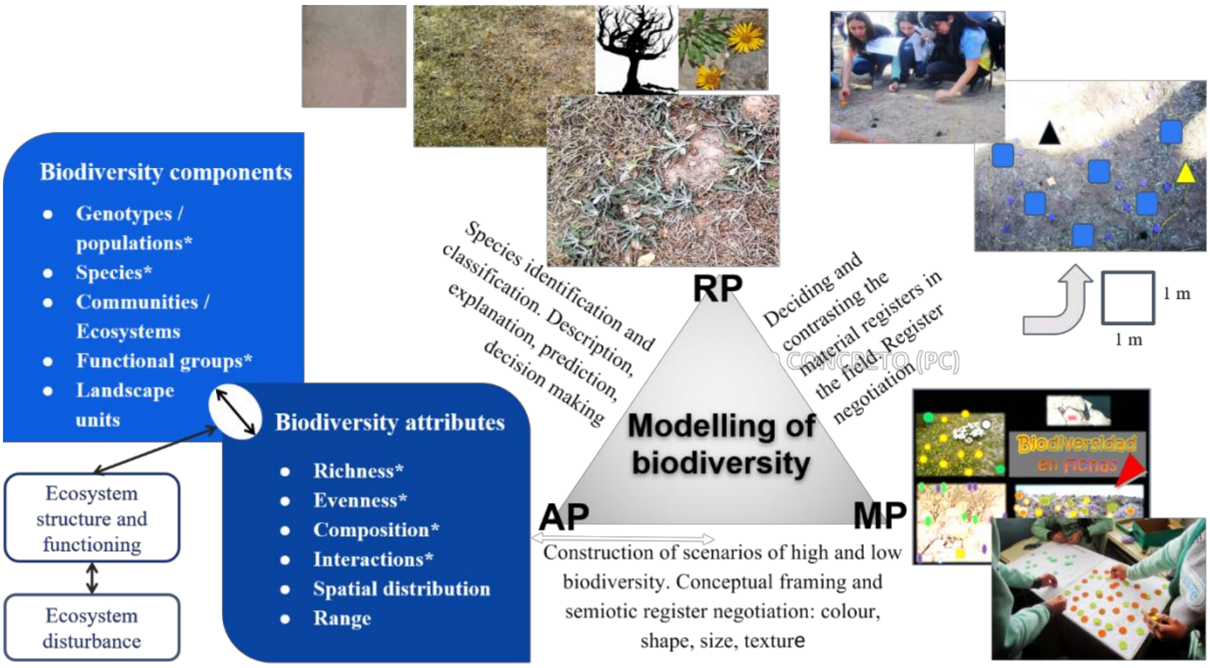

Figure 1. Triadic structure of the modelling of biodiversity in a teaching-learning sequence (TLS), linking the Abstract (AP), Real (RP) and Material Planes (MP) of the model. * Indicates the components of biological diversity that were dealt with in the current TLS.

Semiotic registers bridging biodiversity modelling planes: A platform of common understanding

With this analytical category we identify and describe the material and symbolic representations that were put into play during the modelling of biodiversity, according to teacher's specifications and agreements *with* and *between* students in small-group work and entire-class discussions. We were able to recognise three different *pathways* by which the abstract, material and real planes (AP, MP and RP) were bridged together:

a) AP→RP→AP: At the beginning of lesson 3, students defined biodiversity as the number of species. After a small talk by which the teacher introduced the genetic variability and discussed about the ecosystem processes implicated in forest fires (a patch of the park had recently burned) and droughts, students had to identify areas of high and low biodiversity in the field, and to delimitate and compare quadrats within. After a while, the teacher asked the students how many species were there in each quadrat. References: T = teacher, S = Student (Arabic numbers are used to differentiate them, e.g. S1), numbers before S and T indicate the talk turn within the same lesson.

56 A4: Oh! There are about a million [species]!
57 T: Let's see.
58 A4: But I'm not going to count grass by grass!
59 T: [Towards other students] He tells me if we to count grass by grass [...]
61 T: There may be grass of more than one species but we are confusing, it seems to me, species with individual.
62 A6: What is an individual?

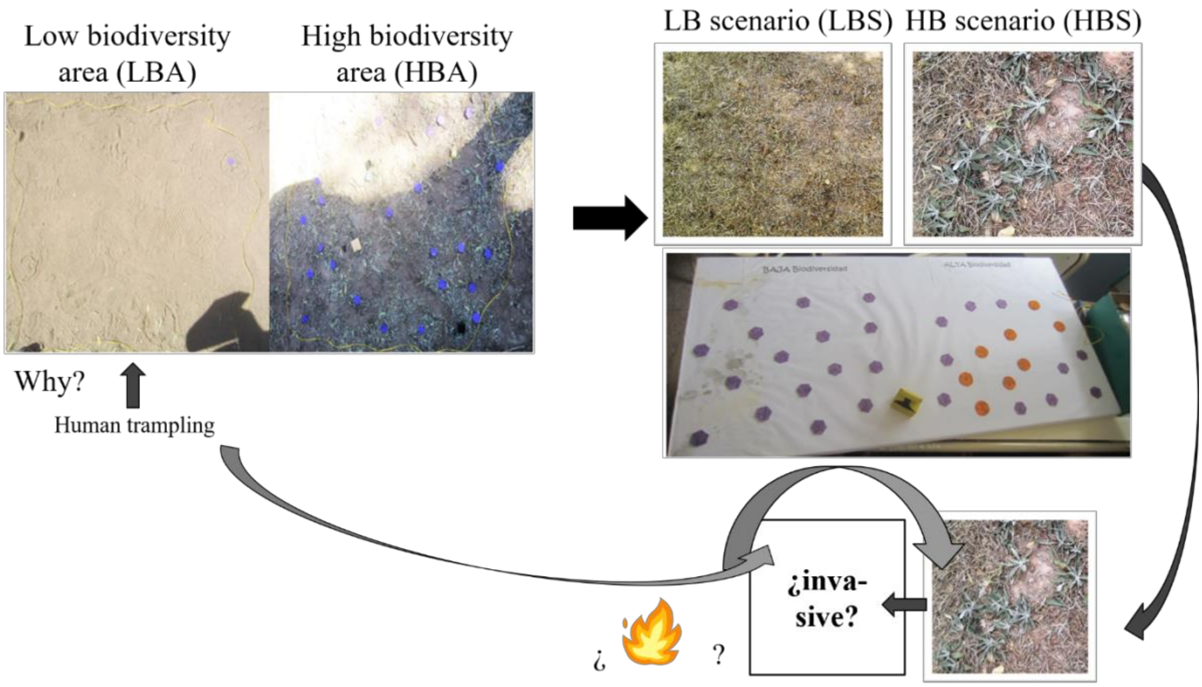

Figure 2. Biological diversity modelling sequence: From real areas in the field (upper left corner) to the construction of material subrogant representations in scenarios of high and low biodiversity (right). See description in the main text.

b) AP→MP→RP: After the aforementioned sequence in 'a' (lesson 3), the teacher presented the material representation of biodiversity by the introduction of rubber tokens. Students had to represent species richness within.

119 T: "What I want now is for us to represent […] We are going to use the tokens to put on top of the species, of the individuals, actually, to make a representation of the biodiversity we can see within these quadrats. [...]
130 A7: […] [You said to] Put the tokens on top of each individual, using different colours.
131 T: Exactly.
132 A3: We have to use one color per species.

c) AP→RP→MP: In lesson 3, after conceptualising the plant growth-form as a functional group (AP), the teacher promoted the recognition of different expressions of this component within the quadrats (RP). Later, a certain quality of the tokens (MP) would be used to represent HBS and LBS:

223 T: Now, that we have differentiated these two categories of plants called forbs and grasses, how can we represent them in the quadrat with our tokens? [5 sec] Well, until now we have concentrated on the color…
224 S1: With token form, then.
225 T: Exactly! Tokens have circular, hexagonal, square shapes…

d) MP→AP→RP: In the classroom, the teacher discussed with a group of students, after they had modelled species evenness, about the semiotic register of genetic diversity (lesson 5).

426 T: Well, how can you represent genetic diversity within a species with your tokens?
427 S4: By the size or colour of the tokens?
428 S3: The color.
429 S4: No, no, the colour corresponds to the species. That's why I said we could use size.
430 T: Well, let's say that we have assigned color to another component of biodiversity: the species one. [...]
435 S3: With the design of the tokens. Because some of them have a smooth surface and others have...
436 S7: … and others have those black wrinkles!
437 S3: Yeah ... they have those stripes!
438 T: Well, we can call that 'texture' [...].

Teacher's role and talk: From a guide to a dialogic inquirer

The teacher had the role of *organising* the activities, *moderating* students' interventions and *guiding* the modelling activities, constantly taking up the existing relationships among the modelling planes (RP, AP, and MP). Of special interest were teacher's interventions that helped to set the relationships among the semiotic registers and facilitated the reaching of consensus. Two subcategories teacher's role have been identified:

a) Teacher as a *guide*: When the teacher gave orientations for the modelling assignment, specifying what to see, compare and experiences to recall. For instance, lessons (L) 3 and 5:

L3. 97 T: All right. If we compare this sector [2 sec], what do you see?
L3. 98 S6: Soil… not much, stones... and may be two clumps of grass.
L3. 99 T: Yes, very few indeed. And what do we have to identify here within this quadrat? [4 seconds] What are we watching, indeed?
L5. 158 T: What did colour mean according to our previous activities?

b) Teacher as a *dialogic inquirer*. This role was found when the teacher identified difficulties in representing components and attributes of biodiversity due to material constrains, inquired students' comprehension of their statements and of academic knowledge under construction, talked about and compared the entities in the subrogant representations (asking for explanations, predictions and retrodictions), synthesised students' contributions and translated them from everyday formulations to academic terms. For example in lesson 4, when talking about the possible influence of human trampling on the modelled scenarios, the following dialogue was registered at a whole-class level:

345 T: Ok then, we could take out the "creeping daisies" [*Trichocline reptans*]. What would that mean?
346 S4: That there is only one species left.
347 T: Which means that…, in terms of biodiversity...

348 S5: That biodiversity is lower.
349. T: That biodiversity is lower than... [2 sec] Well, that's what probably happens when there is a disturbance like [2 sec] human trampling. [After the conceptualisation of "ecosystem disturbance"] Now, let's think what could happen if it rains torrentially here and here? [Talking about a LBS and a hypothetical condition].
350 S4: The water could be infiltered here and not there.
351 S6: That [...] will have better infiltration since biodiversity is higher. […]
360 T: Ok, then, how could you represent that hypothetical scenario with our tokens?

Metamodeling talk: Explicit reference to modelling

Metamodeling talk points out teacher's explicit reference to what is being done with the models and their representations, in order to understand the activity implications. For example (lesson 4):

188 T: […] Last session we used these tokens in the fieldwork, because biologists often use a tool called modelling to work on or make representations of nature, with objects that allow them to explain or predict certain things. For example, have you ever made a mock-up of the cell or the digestive system?
189 S: Yes. [Numerous students]
190 T: Ok, all these are ways of creating models... those models that one builds allows the recognition of the components and the studying of placement, size, structure and functions of the organs. Sometimes the colours have a specific meaning based on certain agreements. Right? Biologists use models very frequently as scientists do, including models of biodiversity, and that's what you have started constructing the last session. So now we will move forward with our modelling processes by using some photos I took in the fieldwork… Have you taken photos of your own?

DISCUSSION AND CONCLUSIONS

Throughout the modelling sequence, representations of biodiversity increased in abstraction and complexity, given that the students moved away from the experiential observation in the fieldwork (Manz, 2012), integrated and re-signified concepts through progressive representations (Bahamonde & Gómez Galindo, 2016; Gómez Galindo, 2014) by including more and more components of biodiversity. This progressive abstraction was at the centre of the modelling activity and implied going from/to the material - abstract - real planes (Chamizo, 2010) along different circuits: AP→RP→AP, AP→MP→RP, MP→AP→RP, and MP→AP→RP, among others not presented here.

In agreement with Passmore et al. (2014), we kept focus on reasoning and making sense *with the model,* as a dynamic entity along the didactic sequence, rather than reducing our model to just another thing to be learned by rote. This is why the distinction between the modelling *of/for* was used to construct situated models that were evaluated in the context of cognitive activities, toward a clear sense-making goal (Passmore et al., 2014). With this regard, teacher's talk through modelling activities allowed students to formulate hypotheses, predictions, explanations and to justify claims (Acher et al., 2007). These processes were framed by the usage of talk, the main teacher's support to achieve shared understanding (Bahamonde & Gómez Galindo, 2016; Edwards & Mercer, 1998).

Teacher's guidance as modelling directions was associated with setting and negotiating registers, keeping track of the task and promoting small-group- and whole-classroom interactions (Gray & Rogan-Klyve, 2018; Gómez Galindo, 2013). Related to this, classroom dynamics seemed to be constructed on the basis of constant questioning, shifting attention toward what was being analysed (Acher et al., 2007). Teacher's inquiry moves seemed to be guiding students to evaluate the value of a specific point of view, providing opportunities to problematise and deepen the understanding of biodiversity and the interconnected ecological processes (Gómez Galindo, 2014; Manz, 2012).

The experiences introduced throughout this study allowed the students not only to manipulate objects, observe properties and changes, and recognise similarities and differences, but also to do so by constructing subrogant representations which conditioned both their perceptions and their explanations (Svodova & Passmore, 2013). These experiences can thus be described as a process from which the students manipulate, talk, and think according to a school science model that is under permanent construction (Acher et al., 2007).

The treatment of biodiversity as a socially-situated modelling practice builds from and extends perspectives on engaging students in disciplinary practice (Manz, 2012). Scarce explicit metamodeling talk indicated few conceptualisations of modelling itself (Gray & Rogan-Klyve, 2018; Schwarz & Gwekwerere, 2007), possibly because of teacher's focus on modelling directions and task fulfilment (Krell & Krüger, 2016). This emphasises the need of modelling training for teachers, especially for the teaching of biodiversity in innovative and conceptually fruitful ways (Blanco-Amaya, Justi & Díaz de Bustamante, 2017). In light of the present findings, we recommend that teachers use modelling-based teaching in order to conceptualise more up-to-date biodiversity definitions than the traditional concept stated by CBD (1992), and as an attempt to deal with students' centrism in species richness (Bermudez & Lindemann-Matthies, in press).

ACKNOWLEDGEMENTS

Special thanks to Universidad Nacional de Córdoba, Secretaría de Ciencia y Tecnología (project codes 92830720150100024CB and 33620190100028CB), Agencia Nacional de Promoción Científica y Tecnológica de Argentina, FONCYT (project code PICT-2015-1903), and ESERA (European Science Education Research Association, 2019 Fellowships) for financial support.

REFERENCES

Acher, A. (2014). Cómo facilitar la modelización científica en el aula [How to facilitate the scientific modeling in the classroom]. *TED: Tecné, Episteme y Didaxis*, *36*, 63-75. https://revistas.pedagogica.edu.co/index.php/TED

Acher, A., Arcà, M., & Sanmartí, N. (2007). Modeling as a teaching learning process for understanding materials: A case study in primary education. *Science Education*, *91*, 398-418. doi:10.1002/sce.20196

Adúriz-Bravo, A., & Aymerich, M.I. (2009). Un modelo de modelo científico para la enseñanza de las ciencias naturales [A model of scientific model for science teaching]. *Revista Electrónica de Investigación en Educación en Ciencias*, *4*(1), 40-49. http://ppct.caicyt.gov.ar/reiec
Bahamonde, N., & Gómez Galindo, A.A. (2016). Caracterización de modelos de digestión humana a partir de sus representaciones y análisis de su evolución en un grupo de docentes y auxiliares académicos [Characterization of human digestion models from its representations and analysis of its progress in a group of teachers and supporting academic team]. *Enseñanza de las Ciencias*, *34*, 129-147. doi: 10.5565/rev/ensciencias.1748
Bermudez, G.M.A., & Lindemann-Matthies, P. (in press). "What Matters Is Species Richness"—High school students' understanding of the components of biodiversity. *Research in Science Education*, 1-29. doi: 10.1007/s11165-018-9767-y
Blanco-Anaya, P., Justi, R., & Díaz de Bustamante, J. (2017). Challenges and opportunities in analysing students modelling. *International Journal of Science Education*, *39*, 377-402. doi: 10.1080/09500693.2017.1286408
Campos, C. M., Greco, S., Ciarlante, J. J., Balangione, M., Bender, J. B., Nates, J., & Lindemann-Matthies, P. (2012). Students' familiarity and initial contact with species in the Monte desert (Mendoza, Argentina). *Journal of Arid Environments*, *82*, 98-105. doi: 10.1016/j.jaridenv.2012.02.013
Chamizo, J. A. (2010). Una tipología de los modelos para la enseñanza de las ciencias [A typology of models for teaching science]. *Revista Eureka sobre Enseñanza y Divulgación de las Ciencias*, *7*, 26-41. https://revistas.uca.es/index.php/eureka/index
Convention on Biological Diversity (CBD) (1992). Retrieved from https://www.cbd.int/doc/legal/cbd-en.pdf
Edwards, D., & Mercer, N. (1987). *Common Knowledge. The Development of Understanding in the Classroom*. Cambridge: University Press.
Evagorou, M., & Osborne, J. (2013). Exploring young students' collaborative argumentation within a socioscientific issue. *Journal of Research in Science Teaching*, *50*, 209-237. doi: 10.1002/tea.21076
Evagorou, M., Jimenez-Aleixandre, M.P., & Osborne, J. (2012). 'Should we kill the grey squirrels?' A study exploring students' justifications and decision-making. *International Journal of Science Education*, *34*, 401-428. doi: 10.1080/09500693.2011.619211
Giere, R. N. (1988). *Explaining Science: A Cognitive Approach*. Chicago: University of Chicago Press.
Gogolin, S., & Krüger, D. (2017). Diagnosing students' understanding of the nature of models. *Research in Science Education*, *47*, 1127-1149. doi: 10.1007/s11165-016-9551-9
Gómez Galindo, A. (2014). Progresión del aprendizaje basado en modelos: la enseñanza y el aprendizaje del sistema nervioso [Progression of learning based on models: teaching and learning about the nervous system]. *Bio-grafía, Escritos sobre la Biología y su Enseñanza*, *7*(13), 101-107. doi: 10.17227/20271034.vol.7num.13bio-grafia101.107
Gómez Galindo, A.A. (2013). Explicaciones narrativas y modelización en la enseñanza de la biología [Narrative explanations and modelling in biology teaching]. *Enseñanza de las Ciencias*, *31*, 11-28. https://ensciencias.uab.es/
Gray, R., & Rogan-Klyve, A. (2018). Talking modelling: examining secondary science teachers' modelling-related talk during a model-based inquiry unit. *International Journal of Science Education*, *40*, 1345-1366. doi: 10.1080/09500693.2018.1479547
Kampourakis, K., & Reiss, M. J. (Eds.). (2018), *Teaching Biology in Schools. Global Research, Issues, and Trends*. 1º edition. Abindgon, UK: Routledge.
Kinslow, A.T., Sadler, T.D., & Nguyen, H.T. (2019). Socio-scientific reasoning and environmental literacy in a field-based ecology class. *Environmental Education Research*, *25*, 388-410. doi: 10.1080/13504622.2018.1442418
Koponen, I. T., & Tala, S. (2014). Generative modelling in physics and in physics education: From aspects of research practices to suggestions for education. In M.E. Matthews (Ed.), *International Handbook of Research in History, Philosophy and Science Teaching* (pp. 1143-1169). Dordrecht, Netherlands: Springer. doi: 10.1007/978-94-007-7654-8_35

Krell, M., & Krüger, D. (2016). Testing models: a key aspect to promote teaching activities related to models and modelling in biology lessons? *Journal of Biological Education*, *50*, 160-173. doi: 10.1080/00219266.2015.1028570

Manz, E. (2012). Understanding the codevelopment of modeling practice and ecological knowledge. *Science Education*, *96*, 1071-1105. doi: 10.1002/sce.21030

Méheut, M., & Psillos, D. (2004). Teaching–learning sequences: aims and tools for science education research. *International Journal of Science Education*, *26*, 515-535. doi: 10.1080/0950069032000070306

Passmore, C., Gouvea, J. S., & Giere, R. (2014). Models in science and in learning science: Focusing scientific practice on sense-making. In M.E. Matthews (Ed.), *International Handbook of Research in History, Philosophy and Science Teaching* (pp. 1171-1202). Dordrecht, Netherlands: Springer. doi: 10.1007/978-94-007-7654-8_36

Patton, M.Q. (2014). *Qualitative research & evaluation methods: Integrating theory and practice.* Fourth edition. London, UK: SAGE Publications.

Svoboda, J., & Passmore, C. (2013). The strategies of modeling in biology education. *Science & Education*, *22*, 119-142. doi: 10.1007/s11191-011-9425-5

ENHANCING STUDENTS' EPISTEMOLOGICAL BELIEFS ABOUT MODELS IN SCIENCE THROUGH A MODEL BASED TLS ABOUT THE OPTICAL PROPERTIES OF MATERIALS

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Models and modelling practices have been systematically and extensively used in Physical Sciences curriculum for more than three decades. Yet students' epistemological beliefs about their nature, role, change and multiplicity often deviate from the scientifically acceptable ones. This research aims to enhance their epistemological beliefs regarding models in science with the use of an inquiry, model based, Teaching Learning Sequence as an intervention method. The latter contains modelling processes and practices of expressive, experimental and exploratory modelling pedagogies which are formed in a cyclic manner. The activities incorporated consist of real world and virtual experiments all of which explicitly adopt the geometrical optical ray model for the interpretation and prediction of light phenomena. In addition, it is this study's goal to unveil the criteria by which students distinguish and categorize images representing science models from non-science models representations. Results indicate an increase in students' performance regarding their epistemological beliefs about science models. Moreover, they reveal three criteria -axes- which provide us with an insight into students' ideas about models in science.

Keywords: scientific, models, TLS

INTRODUCTION

Despite models' significance in Science and Science Education, students hold a variety of misconceptions towards them. Accordingly, researchers are investigating approaches to enhance their awareness of features of scientific models and particularly their purpose, nature, multiplicity and change (Oh & Oh, 2011). From a number of studies it appears that engaging students in modelling activities is not sufficient for enhancing their model awareness unless metacognitive activities are embedded in teaching concerning these features of models (Schwarz & White, 2005). In another study these effects were investigated by an inquiry model based Teaching Learning Sequence (TLS) in optics, enriched with metacognitive activities and found significant improvements on student teachers' epistemological beliefs about models (Soulios & Psillos, 2016). In this research the abovementioned TLS is further adapted to junior high school students' level in an attempt to enhance their epistemological beliefs about the nature, purpose, multiplicity and change of models. In addition, an issue that warrants investigation is the ability of students to distinguish visual representations of scientific models from images portraying non-scientific models e.g. technological devices (Grosslight, Unger, Jay, & Smith, 1991). Within this context the research questions of the present study are:

Research questions

- What are the changes on students' epistemological beliefs about the nature, purpose, multiplicity and change of models?
- What are the changes on student's ability to recognize and distinguish images depicting non-models from images representing obvious and non-obvious models?

METHODOLOGY

The Teaching Learning Sequence

The TLS used in this research is the product of iterative modifications of a previous one focusing on the optical properties of optical fibers originally developed during a European program on Materials Science (Testa, Lombardi, Monroy, & Sassi, 2011). After its adaptation to the Greek curriculum the TLS was enriched by incorporating cyclic modeling practices suggested in the literature (Campbell, Oh, & Neilson, 2013). These consist of exploratory modeling practices in which students use pre-designed models, inquiry modelling practices in which models are used to make predictions which later on will be submitted to tests for validation and a continuous process of designing, testing and revising the models created. Moreover, metacognitive episodes are also embedded as a means of reflection and feedback to students (Soulios & Psillos, 2016). For the purposes of the present investigation, the TLS is further modified in terms of expression regarding the metacognitive questions and their content. Regarding the second matter, the basic conversions include adding more reflection questions and integrating the "Bending Light" application from Phet Website ("Bending Light," 2019). The notion of the scientific model is introduced explicitly throughout the TLS with the use of the geometrical optical ray model. The TLS intervention lasted 8 weeks in a total of 12 teaching hours. The sample consists of 35 second grade junior high school students (8th grade), from two classes of a public school in Greece, who share the same cognitive skills and difficulties thus similar didactic approaches were followed.

Instrumentation

Two questionnaires are used both before and after the implementation of the model-based TLS. The first questionnaire is a closed-ended one which consists of 18 visual representations (Table 1). Below each image students can fill in either the "yes" or the "no" box as to whether the image depicted represents a scientific model or not. The pictures are divided into three clusters; the first one consists of images that do not represent scientific models but rather technological devices. The second cluster comprises of visual representations of static scientific models such as a human cell replica while the third cluster consists of images of abstract scientific models usually that of a procedure, e.g. the photosynthesis mechanism. The classification of the these representations in three different clusters is based on previous studies (Grosslight et al., 1991; Schwarz & White, 2005).

The second questionnaire consists of seven open-ended questions regarding the nature, purpose, multiplicity and the ability of a scientific model to change. The questionnaire was been developed and used in a previous study (Soulios & Psillos, 2016). Apart from the two questionnaires, semi-guided interviews were also conducted between the researcher and a random sample of 15 students, before and after the completion of the TLS.

Table 1. Visual representations classification into clusters

Cluster 1	Cluster 2	Cluster 3
Camera	Globe	Graph
F1 race car	Human skeleton 3D representation	An equation
TV personalities	Cell 3D representation	Water molecules simulation
TV set	Earth's interior sketch	Blueprints
Cell phone	Sketch of plant's parts	Chemical compound simulation
House	Functional miniature of a car	Photosynthesis sketch

RESULTS

Students' answers to the open-ended questionnaire and interviews are categorized according to the hierarchical three-level classification framework which was developed and utilized in earlier studies (Crawford & Cullin, 2004; Grosslight et al., 1991; Soulios & Psillos, 2016). The first level includes answers that deviate from the scientifically acceptable ones whereas the second level consists of intuitive answers that tend to approach the scientifically correct ones. Third level's answers are those that are in compliance with the scientifically acceptable ones. Students' failure of presenting an answer is categorize in a different level that of "No Answer" (NA). Students' answers percentages in the aspects of nature, purpose, multiplicity and change of scientific models before and after the implementation of the TLS are presented on Table 2.

Table 2. Percentage of students' answers per epistemological level

Level of epistemological beliefs	% Before TLS				% After TLS			
	NA	**1**	**2**	**3**	**NA**	**1**	**2**	**3**
Nature	5,7	68,6	25,7	0,0	0,0	40,0	48,6	11,4
Purpose	5,7	65,7	25,7	0,0	0,0	28,6	71,4	0,0
Multiplicity	5,7	11,4	74,1	11,4	0,0	20,0	68,6	11,4
Change	11,4	22,9	62,9	2,9	2,9	11,4	57,1	28,6

The abovementioned results are treated with paired sample parametric T-test and bootstrap method with 1000 sample Bias Corrected and Accelerated (BCa) at 95% confidence intervals. Their analysis reveals that students' epistemological beliefs are improved in three out of four aspects of scientific models after the completion of the model-based TLS (Table 3). In specific, students understanding of the nature, purpose and the ability of a scientific model to undergo changes are enhanced except for multiplicity which appears impervious to the effects of the TLS.

Table 3. Paired sample t-test about epistemological beliefs

Paired sample T- test	Scientific model's aspects			
	Nature	Purpose	Multiplicity	Change
T-statistic	**-4,29****	**-3,90****	-0,63	**-4,06****

*p ≤ .05, **p≤ .001

The analysis of students' answers on the closed-ended questionnaire reveals a 22% decline in students' positive answers regarding first cluster visual representations, a 6% rise in the second cluster ones and a 16% increase in the third cluster images (Table 4). A paired sample parametric T-test with bootstrap method was conducted on the abovementioned answers. The test confirms statistically important improvement in the cases of cluster 1 and 3 visual representations (Table 5). These results suggest that the TLS has a profound effect on students' ability to discard the visual representations of cluster 1 as scientific models. Simultaneously it enables students to acknowledge cluster 3 visual representations as scientific models. Finally, despite the increase of the correct answers percentage in cluster 2 images no statistically significant improvement is identified.

Table 4. Average percentage of positive answers per cluster

	% Before TLS	**% After TLS**	**% Change**
Image cluster 1	50,48	28,10	-22,38
Image cluster 2	66,19	71,90	5,71
Image cluster 3	57,62	73,33	15,71

Table 5. Paired sample t-test per image cluster

Paired sample T- test			
	Cluster 1	Cluster 2	Cluster 3
T-statistic	**3,36***	-1,10	**2,90***

*p ≤ .05, **p≤ .001

Moreover, students' transcribed interview analysis unveils certain criteria -axes- by which they recognize and sort images into obvious science models, non-obvious ones and non-science models. To begin with, the first axis takes into consideration a model's purpose meaning that students categorize images into models according to what models are supposed to do. Students who mistakenly accept visual representations of cluster 1 as scientific models believe that models are technological devices that help us in our everyday life. On the other hand, the same criterion-axis is used by other students in order to justify their answers in cluster two and three images. According to those students' answers a scientific model is used as a means of understanding, interpreting physical phenomena and teaching.

The second criterion -or axis 2- takes into consideration the nature of a model and its construction. According to students, scientific models are sophisticated designs that only scientists can construct. Therefore, many technological devices depicted in the visual representations are considered as such. On contrary, students who reject images of technological devices as scientific models claim that a model presents a theory, an idea or even a process which helps us discovery something else. In addition, some students explicitly stress that models are simulation of reality rather than the reality itself.

Finally, a third criterion is identified as combination of the first two axes and the notion of evolution meaning that students attribute to scientific models the ability to change. On one hand students who mistakenly consider technological devices as scientific models propose that upgrades can be made to "models". On the other hand, students who reject the abovementioned visual representations as scientific models support the view that models can change when they contradict experiments or when a new, more suitable theory is presented.

DISCUSSION AND CONCLUSIONS

By comparing students' pre and post answers in the open-ended questionnaire it is evident that their epistemological understanding of scientific models is promoted in all aspects except for multiplicity. It is our belief that this inconsistency could be attributed to an intrinsic design feature of the TLS; the single use of one and only scientific model for light propagation i.e. that of geometrical optical ray. By analyzing students' answers on the closed-ended questionnaire, we conclude that their ability to discriminate scientific models from non-model representations is also improved (cluster 1). Furthermore students appear more capable of acknowledging abstract visual representations of scientific models (cluster 3). Yet no statistically important effect is recorded about cluster 2 visual representations. Interview analysis also reveals three main axes regarding students' reasoning about models' nature, purpose and ability to change. Further investigation into these axes and students' reasoning is required.

In conclusion, we consider that the application of this inquiry model-based TLS in the field of optical properties of materials promotes students' epistemological beliefs about scientific models. In addition, the TLS enables students to recognize and distinguish visual representations of non scientific models from images depicting such while it also enhances their ability to identify more sophisticated and abstract scientific models from relatively understandable ones. In line with other studies (Soulios & Psillos, 2016), current results suggest that it is feasible to enhance secondary students' awareness about certain aspects of scientific models by using an inquiry model-based TLS related to a specific content.

ACKNOWLEDGEMENT

The authors would like to thank Dr E. Petridou and Dr I. Soulios for their permission to use the original closed-ended questionnaire and Dr A. Taramopoulos for his insight and comments regarding data analysis.

REFERENCES

Bending Light. (2019). Retrieved from https://phet.colorado.edu/en/simulation/bending-light

Campbell, T., Oh, P. S., & Neilson, D. (2013). Reification of five types of modeling pedagogies with model-based inquiry (MBI) modules for high school science classrooms. In M. S. Khine & I. M. Saleh (Eds.), *Approaches and strategies in next generation science learning* (pp. 106–126). Hershey, PA: IGI Global.

Crawford, B. A., & Cullin, M. J. (2004). Supporting prospective teachers' conceptions of modelling in science. *International Journal of Science Education*, *26*(11), 1379–1401.

Grosslight, L., Unger, C., Jay, E., & Smith, C. L. (1991). Understanding models and their use in science: Conceptions of middle and high school students and experts. *Journal of Research in Science Teaching*, *28*(9), 799–822.

Oh, P. S., & Oh, S. J. (2011). What Teachers of Science Need to Know about Models: An overview. *International Journal of Science Education*, *33*(8), 1109–1130.

Schwarz, C. V., & White, B. Y. (2005). Metamodeling Knowledge: Developing Students' Understanding of Scientific Modeling. *Cognition and Instruction*, *23*(2), 165–205.

Soulios, I., & Psillos, D. (2016). Enhancing student teachers' epistemological beliefs about models and conceptual understanding through a model-based inquiry process. *International Journal of Science Education*, *38*(7), 1212–1233.

Testa, I., Lombardi, S., Monroy, G., & Sassi, E. (2011). An innovative context-based module to introduce students to the optical properties of materials. *Physics Education*, *46*(2), 167–177.

DEVELOPING STUDENTS' CRITICAL THINKING: LIKELIHOOD AND UNCERTAINTY ANALYSIS IN PARTICLE PHYSICS

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Likelihood and uncertainty analysis (LU) is an important aspect of critical thinking (CT). It is relevant in everyday life, but also in science outside and inside the classroom. However, students have difficulties in applying the LU skill. We tested this skill before and after a teaching intervention, investigating how our content-specific instruction can promote this important aspect of CT. The topic is antimatter and the target group is German high school students of grade 10. To develop and optimize our instructional design, we use a Design-Based Research (DBR) cycle. Here, we focus on the design of a worksheet about alternative interpretations of a cloud chamber photograph. To assess the effectiveness of the design of the worksheet in teaching LU skill, we compare the hypothetical learning trajectory (HLT) with the actual learning trajectory (ALT). Furthermore, we introduce a content specific critical thinking test was developed to assess the extent to which students' LU skill improve during the intervention. Our example from particle physics may help physics teachers to develop students' LU skill in other contexts.

Keywords: Cognitive Skills, Design-Based Research, Training and Development

INTRODUCTION

Very few events in life can be known with certainty. Teaching students to use likelihood and uncertainty analysis (LU) skill for making a decision about uncertain events is very important. Furthermore, it is important to differentiate between the general LU skill, which requires knowledge of everyday life (Ennis, 1989), and the domain-specific LU skill, which requires content-specific expertise (McPeck, 1990), e. g. in a particular domain of physics.

LU in mathematics is called "probability". High school students learn the necessary rules and skills to calculate probability in a mathematical context. However, it might be hard for students to transfer their mathematical knowledge about probability to other subjects, such as physics. For example, in a cloud chamber experiment, a given track can be caused by a muon or an electron. Without further data, the scientist can only make a probability judgement about these two hypothetical processes. Thus, particle physics is a suitable topic for teaching the LU skill. Our aim was to design (and re-design) teaching activities about antimatter to increase students' general and domain-specific skills in Critical Thinking (CT). One of the 5 CT skills is likelihood and uncertainty analysis on which we focus.

METHODS

The lack of concrete guidelines for designing a high quality intervention in the abstract area of particle physics encouraged us to choose Design-Based Research (DBR) approach to develope our content-specific instruction in an iterative cycle of design-enactment-analysis-redesign (Collins, Joseph, & Bielaczyc, 2004; Nieveen, 2010). We have already designed a content-specific instruction for training Critical thinking (CT) skills. The instruction comprises 10 lessons about antimatter for high school students of grades 10, 11 &12 (Sadidi & Pospiech, 2019). Here we focus on the evaluation of the instruction with respect to LU skill. As an example we present the design of a worksheet about the “discovery of the positron” and we analyes students’ discourse to get insight into how the teaching-learning activities promote students’ LU skill. To support our qualitative analysis, we also present an analysis of pre- and posttest data.

Design of worksheet

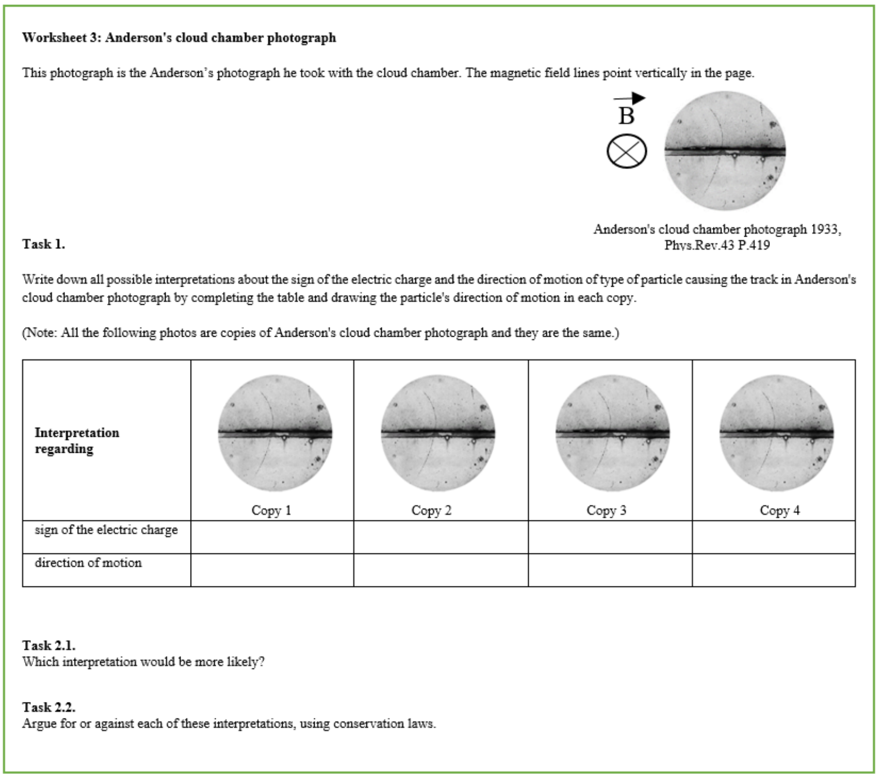
To design teaching-learning activities for promoting LU, we needed first to generate hypothetical learning trajectories (HLTs). This implies to specify students’ prior knowledge, define learning goals, outline a hypothetical learning process, and design a task (Simon & Tzur, 2004). Regarding learning goals, we focused on the 4 outcomes of applying LU skill in everyday life defined by Halpern (2009) and made them domain-specific (see learning goals in table 1), *cf.* Tiruneh et al. (201**6**). Halpern (2009) defines these LU-related outcomes as: (1) estimating the probability of occurrence of an event, (2) using probability judgement to improve decision making, (3) understanding the limits of extrapolation, and (4) understanding the need for relevant and valid information for being able to conclude about the most probable event in everyday life. To provide a task for the students, we designed a worksheet about Anderson’s cloud chamber photograph of the positron. The design of the worksheet was inspired by Anderson’s discussion of four ways in which his photograph might be interpreted (Anderson, 1933).

Table 1 shows an example of a generated HLT to design a worksheet about “Anderson’s photograph” which was used in teaching about the “ discovery of the positron”.

Table 1. Hypothetical learning trajectory (HLT) to design the “Anderson’s photograph” worksheet.

Students’ prior knowledge	Lorentz force, conservation of energy and momentum, relationship between radius of the track and momentum and energy of particles, and definition of range in particle physics.
Learning goals	Making multiple possible interpretations. Estimating the likelihood of occurrence of an event(s). Making decision about the most likely event. Recognizing the need for relevant and valid information to be able to conclude about the most likely event.
Hypothetical learning trajectory	<u>HLT 1</u>: Students will apply their knowledge about the Lorentz force and the right-hand rule to **make different interpretations** about the sign of the charged particle and the direction of particle motion. <u>HLT 2</u>: Students will apply their knowledge about conservation laws to **evaluate their interpretations** and to **discuss the likelihood** of a certain type of particle causing the track. <u>HLT 3</u>: Students will **make decision about the most likely event**. <u>HLT 4</u>: Students will discuss and reflect on the activity to **realize the importance of having relevant and valid information for final conclusion**.
Tasks (for the worksheet)	This photograph is the Anderson’s photograph he took with the cloud chamber. The magnetic field lines point vertically in the page. **Task 1.** Write down all possible interpretations about the sign of the electric charge and the direction of motion of type of particle causing the track. **Task 2.** Which interpretation would be more likely? Argue for or against each of these interpretations, using conservation laws.

Figure 1 shows the worksheet about "Anderson's photograph" designed based on the hypothetical learning trajectory.



Worksheet 3: Anderson's cloud chamber photograph

This photograph is the Anderson's photograph he took with the cloud chamber. The magnetic field lines point vertically in the page.

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Anderson's cloud chamber photograph 1933, Phys.Rev.43 P.419

Task 1.

Write down all possible interpretations about the sign of the electric charge and the direction of motion of type of particle causing the track in Anderson's cloud chamber photograph by completing the table and drawing the particle's direction of motion in each copy.

(Note: All the following photos are copies of Anderson's cloud chamber photograph and they are the same.)

Interpretation regarding	Copy 1	Copy 2	Copy 3	Copy 4
sign of the electric charge				
direction of motion				

Task 2.1.
Which interpretation would be more likely?

Task 2.2.
Argue for or against each of these interpretations, using conservation laws.

Figure 1. Worksheet about "Anderson's photograph".

In the *"discovery of the positron" lesson students did not receive the first and the second task simultaneously. After completing the first task and an in-group and in-class discussion, students learned the necessary content knowledge e.g. calculating the radius of the track, relationship between radius of the track and energy of particle, and definition of range in particle physics. Next they receive the task 2.*

Participants

The course has been implemented with 10 students from grade 10 in a high school for particularly gifted pupils in mathematics and science. The teacher had been teaching for 35 years and she had experience in teaching particle physics. The teacher was given a teacher package provided by the researcher including content knowledge, worksheets, guidelines for teaching, students' difficulties, and the most common student questions. The teacher package is the result of data analysis of the last implementation in our Design-Based Research project. The teacher was informed during several meetings and discussion with the researcher about the goal of the project as a whole and each session specifically.

Data sources and analytic methods

We refer to two types of data here. One data source includes video-recording of teaching sequences, audio-recording of students' discussions, and students' answers on the worksheet during *teaching the "discovery of the positron" lesson (45 minutes) in May 2019. Analysis of these data enabled us to observe* the actual learning trajectories (ALTs). Comparing the ALTs with the HLTs (Dierdorp, Bakker, Eijkelhof, & Maanen, 2011) gives us an impression of how students' LU skill develops during the lesson and an insight into the effectiveness of the teaching-learning activities. *We considered two criteria to analyze the ALTs. The first was the extent to which students use LU skills and the second was to evaluate the quality of students' reasoning when using LU skills (Thinking in discipline). The other data source includes pre- and posttest items. The results from pre- and posttest are used to answer the question of whether or not students' LU skill improved over the course of 10 lessons.*

Pre- and posttest

As alluded to before, to *investigate whether our content-specific instruction can promote general and domain-specific LU skill, we assigned a pre- and posttest.* We used the Halpern Critical Thinking Assessment (HCTA) (Halpern, 2016) as pre- and posttest, with 4 items for evaluating LU skill in everyday life. It is necessary to mention that we translated the original version of the HCTA from English to German. We validated the German version of the HCTA by retranslating it to English for the purpose of this study. The purpose of this study was not to check the validity of the German version of the HCTA test in a large scale.

Furthermore, to evaluate the development of students' LU skill in particle physics, we needed to develop a content-specific critical thinking test as posttest. To design a Particle Physics Critical Thinking (PPCT) test, we used the structure of the HCTA as a framework. The PPCT contained 17 items, from which 3 items evaluate the LU skill. We also defined a relevant scoring rubric for the PPCT test. To validate its content and practicality, we used expert reviews, small-scale paper-pencil administration with physics teacher students (N= 8) and a cognitive interview with high school students (N= 4) (Adams & Wieman, 2010). To check the reliability, we calculated the internal consistency of these 3 items, Cronbach's $\alpha = .97$. In addition, 8 students' answers have been selected and corrected independently by two raters. Table 2 shows the results of calculating inter-rater reliability and item difficulty of the 3 LU-related items.

To assess the convergent validity of the PPCT items evaluating LU, we calculated Pearson's correlation coefficient between the PPCT test and the HCTA test as a standard test. Therefore, the participants' performance on the LU-items of the PPCT was compared to their performance on the corresponding items in the HCTA test. The result showed a positive correlation between the two sets of the scores ($r = .35$, $p = .04$, N= 34).

Figure 2 shows a sample item of the PPCT test for evaluating LU. The item objective is that students understand the limits of generalization and the need for relevant and valid information to make a more accurate prediction.

Table 2. Inter-rater reliability (Cohen's kappa coefficient) and item difficulty of 3 items of Particle Physics Critical Thinking (PPCT) test to evaluate Likelihood and Uncertainty Analysis (LU) skill.

Item related to LU skill	Cohen's kappa coefficient (n=8)	Item difficulty

7	.60	.32
9	.82	.50
12	.71	.53

In one lecture at CERN you hear about the GBAR experiment. GBAR measures free fall acceleration of neutral antihydrogen atoms in the terrestrial gravitational field with the accuracy of 1% of g.

You ask yourself:
if we release a neutral Anti-Apple above our Earth, does it fall up or fall down?

You share your question with your friend.
He says: "As neutral antihydrogens fall down in the GBAR experiment, we can conclude that Anti-Apple will fall down."

Task 7.1: Would you agree with your friend?

- ☐ Yes, I agree
- ☐ No, I do not agree.

Task 7.2: Explain your reason.

Figure 2. Sample item 7 of the Particle Physics Critical Thinking (PPCT) test.

Table 3 shows the corresponding scoring rubric for item 7 of the PPCT test.

Table 3. Corresponding scoring rubric for the sample item of the Particle Physics Critical Thinking (PPCT) test.

Item weight: 5 points

The complete answer that we expect from students is:
Gravity acts only on mass. There is no negative mass for antimatter and antimatter has the same mass as matter. Therefore, the Anti-Apple will fall down. However, this generalization has some limitations e.g. GBAR experiment was run in a vacuum while here, annihilation of falling Anti-Apple in the air is a challenge. Furthermore, we should differentiate between antihydrogen and the complex system of Anti-Apple.

Scoring rubric:

<u>Task 7.1</u>
Yes: if there is consistency between "Yes" and the answer to the task 7.2: 1 point, otherwise 0.
No: if there is consistency between "No" and the answer to the task 7.2: 1 point, otherwise 0.
<u>Task 7.2</u>

- Did the student mention that gravity acts on the Mass explicitly?
  # Yes: 2 points.
  # Not explicitly: e.g. gravity exists, 1 point.
  # No: 0 point.
- Did the student mention the limitation of generalization?
  #Yes: 2 points e.g. annihilation or difference between antihydrogen and Anti-Apple.
  #No: 0 point. Go to the next question.

• Did the student make assumption like "if antihydrogen behave like matter, all antimatter would behave like this"? Or "anti-apple contains anti-hydrogen"? # Yes: 1 point. # No: 0 point.

RESULTS

Here, we present the results of a comparison between the HLTs and students' ALTs (Dierdorp, Bakker, Eijkelhof, & Maanen, 2011) during working on the "Anderson's photograph" worksheet. Ultimately, we report students' performance in pre- and posttest.

Making different interpretations

In the first task the teacher gave students 4 copies of Anderson's photograph and asked them to make different interpretations about the sign of the charged particle and the direction of the particle motion causing the track. First all 4 groups of students did apply content knowledge to make two interpretations but not more. Data analysis showed us the overconfidence problem defined by Halpern (2009) as that "people tend to be more confident in their decision about probabilistic events than they should be." Here the teacher encouraged students to overcome this problem and make more interpretations. This is a big step that requires students' persistency in solving complex tasks. During brainstorming for making more interpretations different ideas including students' misconceptions were discussed and the teacher as facilitator encouraged students to reflect on their own ideas to correct their understanding of particle physics. Finally, one group ended with 4 interpretations, 2 groups with 3 interpretations and one group did not go further and stopped after making 2 interpretations. It might be interesting to analyse more deeply why this group did not develop further interpretations.

Figure 3 shows different students' interpretation about the particles cause the track in the cloud chamber photograph.

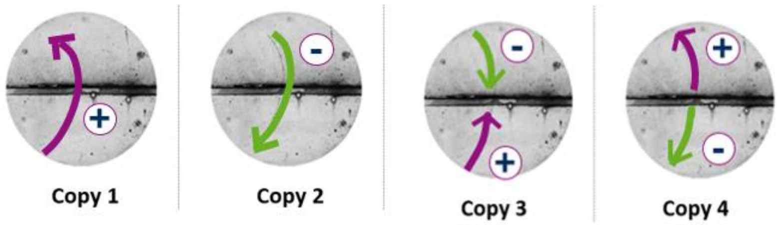

Figure 3. Different students' interpretations in the cloud chamber photograph.

Evaluating interpretations and discuss the likelihood

Tasks 2.1. & 2.2. (see the worksheet) asked students to make a decision about the most probable event. But before making the decision we expected that students apply their content knowledge to evaluate their interpretations (see figure 3) and understand that two of the four interpretations could be correct but the probability of occurrence of one is very low.

Analysis of transcripts from video and audio data and students' answers on the worksheet showed us that students made efforts to evaluate their interpretations. Some wrong ideas were changed along discussion and reflection in the group and with time students came up with more reasonable ideas. Moreover, analysing students' dialogues showed us that they used more frequently the words related to applying probability in making decision e.g. most likely, likely, unlikely. This showed us that the goal of the task that is developing LU skill was clear for students and was accepted by them.

Table 4 presents an example of student' argument for or against different interpretations in figure 3 to answer the task 2.2. on the "Anderson's Photograph" worksheet (The student's answer was translated from German to English). The student was in the group with 4 interpretations.

Table 4. An example of student' written answer to the task 2.2. on the "Anderson's photograph" worksheet.

Interpretation	*Student's answer*	*clarification*
Copy 1	The positive particle loses energy passing through the lead plate, so the radius gets smaller.	The student argued **for** interpretation 1.
Copy 2	I had considered unlikely that the negative particle gain energy passing through the lead plate.	The student argued **against** interpretation 2.
Copy 3	Why would two particles meet at exactly the same point?	The student considered the **probability** of occurrence of this event **low**, therefore she argued **against** interpretation 3.
Copy 4	Particles would have to split in the lead plate and were not before in the alcohol vapour.	The students argued **against** interpretation 4. The argument does not sound reasonable. **Note:** The concept of pair production was taught after this lesson. Therefore, the student did not use the correct terminology.

Making decision about the most likely event

All students concluded that the interpretation 1 is the most likely event. They argued for this interpretation by discussing about changing radius of the particle in two sides of the plate and energy loss of the particle passing through the plate.

Realizing the importance of having relevant and valid information for final conclusion

Analysis of students' discussion during evaluating different interpretations showed us that students realized the importance of focusing on the relevant information. When an idea came up in a group students looked for reasons, discussed and reflected on their reasons to collect relevant and valid information to evaluate their interpretations. Some ideas were rejected and at the end the ideas reported in the worksheet remained as accepted ideas by the group.

As considering the credibility of a source of information is an important topic for developing critical thinking skills and in this context LU skill, an in-class discussion was planned to emphasize explicitly on the topic.

Pre- and posttest scores

Preliminary analysis of the HCTA pre- and posttest (N=9) showed us different trends in the development of students' general LU skill: progress, stand-still, or regress for each individual student. Furthermore, on average, there was no significant difference in the score of LU skill (**Pretest** *M=11.33, SD=2.50*; **Posttest** *M=11.11, SD=2.08*).

Moreover, the PPCT results were good, with an average of 8.22 out of 12 points. Table 5 shows an overview of sample student responses and awarded scores for item 7 of the PPCT test.

Table 5. Sample student responses and awarded scores for item 7 of the Particle Physics Critical Thinking (PPCT) test.

Student 1	Yes, I agree. Because it is shown, that antiparticles have mass like particles, so the gravity acts on them. Therefore, the Anti-Apple would fall towards the earth. • Awarded 3 points (consistency between "Yes" and the reason= 1, gravity acts on the mass= 2)
Student 2	Yes, I agree. The charge has no effect on the gravitational force. • Awarded 0 point.
Student 3	No, I do not agree. We cannot conclude from neutral antihydrogen atoms to Anti-Apples. • Awarded 3 points (consistency between "No" and the reason= 1, considering limitation of generalization= 2)

DISCUSSION

The aim of this study was to learn whether, and how, students' LU skill develops during working on the "Anderson's photograph" worksheet. From a comparison between the HLTs and ALTs (Dierdorp, Bakker, Eijkelhof, & Maanen, 2011), it became clear that the "Anderson's photograph" worksheet provided students with the opportunity to work on the likelihood and uncertainty analysis skill. In addition, the students' results in the Particle Physics Critical Thinking (PPCT) test confirmed that they have learned the LU skill and could apply the skill in a specific domain of particle physics. Although we cannot conclude from the results of the HCTA pre- and posttest that the design of teaching-learning activities was appropriate to promote students' general likelihood and uncertainty analysis (LU) skill, the analysis of the students' difficulties in the test will allow us to reconsider the HLTs, and to re-design the teaching-learning activities within our Design-Based Research cycle. However, the time distance of 6 weeks between working on the "Anderson's photograph" worksheet and the assignment of the HCTA posttest may explain the ambiguous results of the HCTA posttest.

As alluded to before, we realized that students in one group were unable or unwilling to provide more than two interpretations of the given photograph. Conducting further analysis of video and audio data of this group can give us hints for making teaching-learning strategy more practical and efficient. Furthermore, when interpreting Anderson's cloud chamber photograph, some students strove for a single, definite answer. Thus, the teacher should emphasize the importance of considering alternative interpretations, even if they seem less likely.

The teaching materials proposed here can also be used in grades 11 and 12. Teachers can implement the proposed activities to develop students' domain-specific LU skill. Teachers should be aware of the complexity of the task and of their essential role as motivator and facilitator to appreciate students' efforts, to encourage them, and in this way to promote students' persistency.

ACKNOWLEDGEMENT

This project was funded by the European Social Fund (ESF) and the Free State of Saxony (100235479).

REFERENCES

Adams, W. K., & Wieman, C. E. (2010). Development and validation of instruments to measure learning of Expert-Like thinking. *International Journal of Science Education, 33*(9), 1289-1312. doi:10.1080/09500693.2010.512369

Anderson, C. D. (1933). The positive electron. *Physical Review, 43(6),* 491. doi: 10.1103/ PhysRev. 43.491

Collins, A., Joseph, D., & Bielaczyc, K. (2004). Design research: Theoretical and methodological issues. *Journal of the Learning Sciences, 13*(1), 15-42. doi:10.1207/s15327809jls1301_2

Dierdorp, A., Bakker, A., Eijkelhof, H., & Maanen, J. V. (2011). Authentic practices as contexts for learning to draw inferences beyond correlated data. *Mathematical Thinking and Learning, 13*(1-2), 132-151. doi:10.1080/10986065.2011.538294

Ennis, R. H. (1989). Critical thinking and subject specificity: Clarification and needed research. *Educational researcher*, *18*(3), 4-10.

Halpern, D. (2009). *Critical thinking across the curriculum: A brief edition of thought and knowledge*. New York: Routledge.

Halpern, D. (2016). *Halpern critical thinking assessment (HCTA)*. Mödling: Schuhfried GmbH

McPeck, J. E. (1990). *Teaching critical thinking: Dialogue and dialectic*. Routledge.

Sadidi, F., & Pospiech, G. (2019). *Teaching critical thinking in the physics classroom: High-school students think about antimatter*. Manuscript submitted for publication.

Simon, M. A. & Tzur, R. (2004). Explicating the role of mathematical tasks in conceptual learning: An elaboration of the hypothetical learning trajectory. *Mathematical Thinking and Learning,* 6(2), pp 91-104. doi: 10.1207/s15327833mtl0602_2

Tiruneh, D. T., Weldeslassie, A., Kassa, A., Tefera, Z., De Cock, M., Elen, J. (2016). Systematic design of a learning environment for domain-specific and domain-general critical thinking skills. *Educational Technology Research and Development,* 64(3), 481-505. doi:10.1007/s11423-015-9417-2

ANALYSIS OF THE PRODUCTION OF SCIENTIFIC PROJECTS BY UNDERGRADUATE BIOLOGY STUDENTS FROM AN OPEN INQUIRY-BASED SEQUENCE IN PHYSIOLOGY

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We investigated the production of scientific projects by undergraduate biology students concerning the theme of animal physiology using the structure of a sequence of open-ended investigative classes. The analysis of the final reports of the students showed that the open inquiry-based sequence provided a significant mobilization of abilities and the construction of qualitative and quantitative methods for research in physiology and their relationship with living beings and the environment.

Keywords: biology inquiry-based teaching, open inquiry-based activities, non-formal education in zoo.

INTRODUCTION

Science education is necessary and important in people's lives at all stages of human development and can occur in different spaces and modalities, among which non-formal education spaces (Rocha & Terán, 2010). Generally, the interest of science and biology teachers in using these spaces, such as the zoo, for example, has some connection with what is developed in class (Marandino, 2001) and with the possibility of having a more active participation and an engagement of the students in scientific practice. Non-formal education can be defined as an organized approach to provide formal school content learning in spaces outside the formal education system or beyond school boundaries. The non-formal spaces of education are characterized by a more flexible educational proposal and show themselves able to attend, at least in part, some school deficiencies, such as direct contact with nature that can stimulate learning. Examples of these spaces are institutions such as museums, science centers, aquariums and zoos. Especially in zoos, in recent years, the social role of these places has shifted from a space for viewing, leisure and recreation to a place that is also concerned with conservation, research and education. Nevertheless, there is a need for studies that show the potential of using zoos for scientific education (Vieira, Bianconi & Dias, 2005; Marin, Carvalho & Freitas, 2017).

Regarding the Brazilian educational system, statistics have shown that it has failed to provide adequate scientific learning to its students. Some of the difficulties found in Brazilian schools are related to a misconception about science, often presented as reductionist, decontextualized, infallible and absolutely true. There is a need to provide realistic and meaningful scientific education, leading to the development of critical individuals. Due to the high impact that scientific education has in social development, the use of different approaches of science teaching in Brazilian schools may contribute to the advance of scientific knowledge and social development in the Brazilian society (Santos, 2007).

To the school and universities, in turn, different positions have been required in order to include their students in the scientific culture of the contemporary world, so that these institutions could not only transmit knowledge but also form critical and conscious individuals. It is from this epistemological perspective that inquiry-based teaching is inserted, an active problem-solving methodology in which students can mobilize scientific practices and use relevant data and information to find scientific solutions and explanations for practical problems. Since it is not restricted to a purely theoretical approach, research-based learning has a great significance in teaching comparative animal physiology, since this discipline, due to its high complexity, is often uninteresting and monotonous to students due to the use of traditional and exclusively theoretical methodologies (Almeida, Marzín-Janvier &Trivelato, 2016; Marin, Carvalho and Freitas, 2017).

In fact, for a long time it has been sought to innovate in animal physiology classes through practical demonstrations with the use of live animals in laboratories. Although the number of animals used in teaching is lower than in the research, this practice has been discontinued in several countries due to new laws and policies considering that nonhuman animals are sentient beings. Several legislations have emerged around the world restricting the use of animals in education and promoting the adoption of alternative methods of comparable efficacy. Thus, we believe that the development of inquiry-based learning methodologies using the resources of non-formal educational spaces and not using animal manipulation is essential, not only to minimize animal suffering, but also to develop responsible postures toward other animals and to provide a more meaningful learning process (Valk et al., 1999; Oliveira et al., 2018).

Our research problem is defined in this article through the following question: how can we teach complex subjects of biology, e.g. physiology, in non-formal spaces of education? Thus, the aim of the present study was to evaluate the construction of research projects and instruments in physiology by undergraduate students of the biological sciences course in the non-formal science education space.

METHODOLOGY

The present study is an analysis of a case study. The development of the inquiry-based learning sequence was based on Banchi and Bell (2008) that establish four levels of inquiry-based activities. For the authors, level one consists of the question, methods and conclusions provided by the teacher; level two consisting of the question and methods provided by the teacher and the conclusion made by the students; level three composed of the question provided by the teacher, but method and conclusions constructed by the students; and level four consists of all steps proposed from the student engagement. Here, our option was to work with level 4, also known as “open research”, to provide students with greater freedom, engagement and creativity in research proposals. Thus, the inquiry-based learning sequence was structured for application in 6 weeks (6 steps),3 hours of classes each week, given to two different classes (total of 42 students) in the course of Practices in Biological Systems for undergraduate Biological Sciences students. This course consists of several practical laboratory classes and field activities with diverse subjects in biological sciences. Practical classes with subjects of comparative physiology of living beings is one of the topics covered in the classes of this academic course. It was only established the biological theme - comparative physiology - and the place of data collection - the zoo of the city of São Paulo.

In step 1 the students read texts of animal physiology and environment. At this stage, important concepts were discussed about the relationship of the physiological functioning of living beings (vertebrates) and their relationship with the environment and biological evolution. In step 2, the students were informed of the field activity in the zoo and engaged in building hypotheses and scientific questions involving animal physiology for the zoo visit. In step 3, students were encouraged to think creatively to construct methodological ways to study the physiology of living zoo animals. In step 4, the students made a 3-4-hour visit to the São Paulo Zoo to collect data using the methodological tools designed and developed in Step 3. In step 5, in the classroom, the students re-analyzed the data collected during the zoo visit. In Stage 6, the last phase was divided into 3 classes in which the students orally presented their projects in poster presentations, communicating their scientific results to the classmates (Table 1).

To record students' findings during the investigative activity throughout the classes, field research notebooks were developed for students. These notebooks were structured on three levels. The first level consisted of notes and hypothesis development, scientific questions and research methodologies by the students. The second level consisted of research field notes, visiting the zoo. The third level consisted of the analyzes performed by the students from the data collected in the field classes.

The students' final written reports were used for analysis in this study (total of 42 reports). The students' writings were analyzed under two perspectives: i) regarding the physiology subtheme chosen and approached as a research theme and the justification for choosing the subtheme. The objective of this analytical perspective was to verify how the students chose the subject of study in physiology for the study of living beings in a non-formal space. The subthemes used as categories of our analysis of animal physiology were: Nervous system, Digestive system, Cardiac system, Respiratory system, Excretory system, Locomotor system and Reproductive system; the second perspective of analysis: ii) What were the data collected and the methodological analysis used by the students to perform the research in physiology? The purpose of this analytical perspective was to understand the creativity and development of methodological tools that students mobilized to study the physiology of living beings without the use or direct contact with animals. Thus, the final reports were analyzed individually with a focus on the analysis of the subjects of physiology. In addition, it was categorized the methodological tools of research that were mobilized by the students and the percentages of appearance of the subthemes and methodologies in the reports were computed.

Table 1. Steps of classes, activities e learning goals.

Steps of classes	Activities	Learning goals
1	Class on physiology and adaptations of vertebrates to the environment	Discuss key concepts in physiology and adaptation of vertebrate animals to the environment
2	Engagement in research questions and hypothesis	Mobilizing the emergence of scientific issues in students
3	Planning in research methods	Provide the construction of methods for data collection by students
4	Collection of data in the São Paulo Zoo	Visiting and providing data collection by students
5	Analysis and discussion of data collected	Organize the collected data and produce explanations for the phenomena observed
6	Presentation of the final report	Report the results found

RESULTS AND DISCUSSION

Analyzes of the student's writings showed that the open inquiry-based activity sequence allowed the students to articulate subjects of physiology with alternative methods of collection, without manipulation of living beings, and data analysis in non-formal spaces of education, for example, in a visit to the zoo.

A characterization of the reports was performed as the first analysis of the students' written reports. The first set of results shows the diversity of subjects of physiology that was mobilized by the students, having the subjects about digestion the highest percentage of research projects built with this theme. The projects proposed by the students with this theme touch the interest on the feeding habits of vertebrate animals in captivity with comparison with their wild territory; or another example of animal eating habits and their anatomical and physiological structure. The second theme most approached on student's projects is related to the vertebrate nervous system, for example, the state of sleep-wake and sense organs of animals in captivity and their relation to the wild environment of these groups of animals; Another example is the possible damage to the nervous system of animals kept in captivity. (Figure 1). The second set of results shows the diversity of instruments mobilized by the students to collect, analyse and support the establishment of the relations of different physiological systems among vertebrates with the environments they live in. We can see that in order to answer research questions the students mobilized a variety of instruments to collect data, such as photography, filming and observation of the animals and their captivity in the zoo (Figure 2). The decision making of the students in choosing and creating the methodological tools for studying the subjects of animal physiology was variable (Table 2). This data set shows the mobilization of important scientific practices, for example, linked to the production, communication and assessment of knowledge for decision making. For example, to study the eating habits of birds, a student opted for filming at specific times and catalogue the foods sought by these animals and related them to their digestive physiology. Another student interested in the cat's sleep-wake habits interviewed animal handlers regarding feeding times. Using video record, she analysed the behaviour of different groups of cats during a day of visitation in the zoo and finally correlated it with the wild habits of these animals described in specialized literature. In this same set of results, it can be observed the comparison of data collection methodologies: photographs, videos, questionnaires, observations of animals, body structures, locations, eating habits, modes of locomotion, etc. This data is interesting because the comparison of data between distinct groups of animals is a common epistemic practice in the scientific culture of biology researchers in comparative physiology. Another important methodological practice used by the students is the comparison of the data collected during the visit to the zoo with published data in scientific literature: a basic scientific practice. In resume, it suggests that the research activity promoted the incorporation of this logic of research practice by the students.

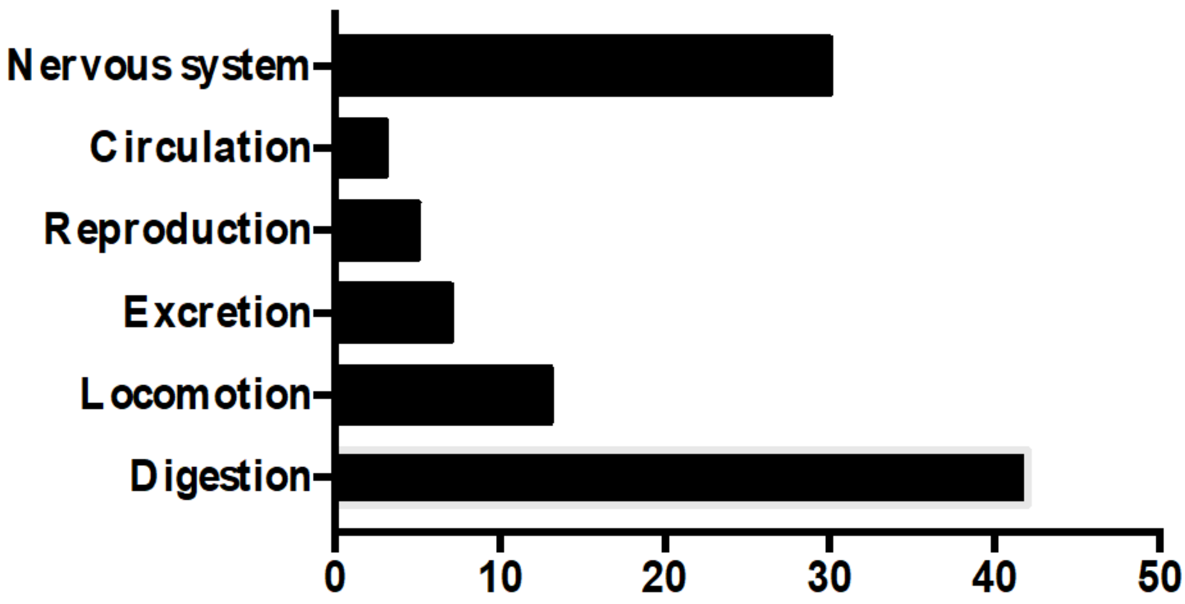

Figure 1. Percentage of subjects of comparative physiology mobilized in the research projects of the students during the open inquiry-based sequence.

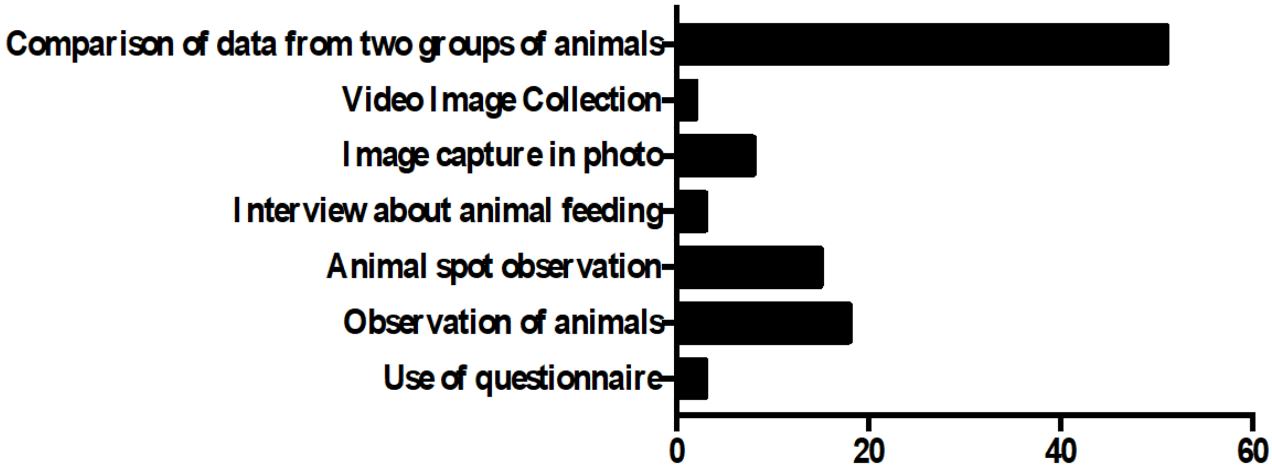

Figure 2. Percentage of research instruments constructed or mobilized by students in the research projects for the open inquiry-based sequence in comparative physiology.

Table 2. Examples of justifications used by students to use the instruments formulated for research.

Research instruments constructed or mobilized by students in the research projects	**Summary of the justification of the methodological approaches made by the students**
Comparation of data from two groups of animals	Animals have different anatomical and physiological structures.
Video image collection	The possibility of capturing sounds, behaviors and animal movements.
Image capture in photo	Recording images of animals, food and enclosures.
Interview with the keeper on the animal's feeding behavior	Habitat capture and animal behavior
Animal spot observation	Notes on the environment and its influence on habitats and behavior of captive animals.
Observation of animals	Notes on the habits and behavior of captive animals
Use of questionnaire	Registration of scientific knowledge about habitats and behavior of captive animals.

A second analysis of the reports was performed to describe the research carried out by the students. Here we will show three significant examples that can contribute to the physiology inquiry-based learning.

Research on the digestive system of animals in the zoo

The first most prevalent sub-theme in the students' final reports was research on the theme of animal digestive system (40% of research projects). The projects developed by students with this theme focused on investigating the food habits of vertebrate animals (mammals in their entirety) and relating them to the physiological mechanisms of digestion of these animals. To carry out this research, the projects had as methodological tools the use of photography of the food available to animals (e.g., lion, zebra and elephant), interviews with people who distribute food to the animals about the types of food provided, and the comparison between food and eating habits between groups of animals. For example, the project of a student had the research question: "What is the difference in the digestive system between monkeys and zebras?" For this, the student observed and recorded the eating habits and foods that were provided in the monkey cage (chimpanzee) and in the zebra's enclosure. In these places he noticed and recorded that chimpanzees were provided with fruits and vegetables, but for zebras they were provided with foliage and grasses. He also found that zebras were allocated in pasture enclosures which allowed these animals to consume grasses. With these data, the student researched anatomical and physiological differences between these groups of animals, making comparisons that allowed him to realize significant differences in architecture and physiology between these groups of animals.

Research on the nervous system of animals in the zoo

The analysis of the reports showed that the students also showed interest in investigating the theme of the vertebrate nervous system (30% of the projects carried out). The projects developed by students with this theme focused on studying the nervous system of vertebrates, mostly mammalian animals, using the observation methodology, video recording and interviews with the staff responsible for the care of the animals' cages, behavior of the captive animal, think about possible alterations or damage to the nervous system of the animals. For example, large cats that need large physical space for their living are kept in cages that reduce the locomotion of these animals. One student had the following research question: "Why does the jaguar move in circles inside the cage?". The student watched the animal inside the cage for approximately forty minutes and recorded videos of the animal's movements in the enclosure. He interviewed veterinarians and confronted the video with researched videos about the animal's locomotion in the enclosure. He conducted theoretical research in physiology, argued and concluded in his report that the behavior of the animal in the enclosure was due to captive breeding that could cause significant changes in the animal's nervous system.

Research on the Animal Locomotion System at the Zoo

The third research theme in which 12% of the projects were engaged is about the locomotion system of vertebrate animals (mostly mammals). For this theme the projects used, mainly, the recording of videos in the zoo enclosures and comparison between groups of animals. For example, two students developed a project in which the research question was the speed of displacement of the "spider monkey" using the tail as a form of locomotion. This species of monkey lives in a tree canopy and uses its tail as a form of support and locomotion through the tree branches. In the zoo, these monkeys are housed in a high-tree enclosure and are located on an island in the center of an artificial lagoon. This geography enables the isolation of these animals. Thus, the students observed and recorded in the camera of their cell phones for about 30 minutes the interaction of these animals in the trees. The students, by means of the analyzes, calculated the average velocity of displacement of these animals when they used the tail to move around the tree canopy compared to those that displaced otherwise, for example, using their paws. They then conducted a research on the importance of the tail for these monkey species as an aid to feeding and locomotion. The students, with their common project, concluded that this species of monkey moved faster using the tail through the tree canopy compared to other forms of locomotion.

In conclusion, the open inquiry-based sequence in physiology in a non-formal teaching environment provided students with the creative possibility and immersion in the scientific culture of the biological sciences, especially physiology and environment, with the construction of instruments for the collection and analysis of data in biology, important in literacy and scientific training in higher education. In addition, the activity made it possible for students to mobilize knowledge in different themes (which conferred genuine interest and engagement in the studies of each student); the proposition and use of research strategies and methodologies (which represents the sharing of specific scientific practices and also the creative search for ways to solve selected research questions); and finally, the articulation with theoretical knowledge already established by the scientific literature (which occurred according to the interests of the students, allowing the appropriation of this knowledge to establish explanations for their research questions).

REFERENCES

Banchi, H; Bell, R. (2008). Inquiry comes in various forms. Science and children, 27, 26-29.

Manzoni-Almeida, D; Marzin-Janvier, P. &Trivelato, S. L. F. (2016). Analysis of epistemic practices in reports of higher education students groups incarrying out the inquiry-based activity of immunology. Investigações em Ensino de Ciências, 21(2), 105-120.

Marandino, M. (2001). Interfaces na relação museu-escola. Caderno Brasileiro de Ensino de Física, 18(1).

Marin, Y. A. O., Carvalho, Y. K., & Freitas, A. M. F. (2017). Escolas e Zoológicos: Uma relação de continuidade no ensino da biologia e na educação ambiental.XI Encontro Nacional de Pesquisa em Educação em Ciências, Florianópolis, SC, 11.

Oliveira, J. V., Lopes, S. F., Barboza, R. R. D., & Alves, R. R. N. To preserve, or not to preserve, that is the question:urban and rural student attitudes towards wildvertebrates. (2018). Environment Development and Sustainability, 15, 1-22.

Rocha, S. C. B. &Terán, A. F. (2010). O uso de espaços não-formais como estratégia para o ensino de ciências. Manaus: UEA/Escola Normal Superior/PPGEECA, 136 p.

Santos, W. L. P. Educação científica na perspectiva deletramento como prática social: funções,princípios e desafios. Revista Brasileira de Educação, 12(36), 474-550.

Valk, J., Dewhurst, D., Hughes, I., Atkinson, J., Balcombe, J., Braun, H., Gabrielson, K., Gruber, F., Miles, J., Nab, J., Nardi, J.,Wilgenburg, H., Zinko, U., Zurlo, J.Alternatives to the Use of Animals in Higher EducationThe Report and Recommendations ofECVAM Workshop. (1999). Alternatives to laboratory animals, 27(1), 39-52.

Vieira, V., Bianconi, M. L.,& Dias, M. (2005). Espaços não-formaisde ensino e ocurrículo de ciências.Ciência e Cultura, 57(4), 21-23.

THE IDEAS-COSMOS-EVIDENCE MODEL AND THE TEACHING OF THE EVOLUTION THEORY: A FIRST APPROACH

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The purpose of this paper is to analyze educational activities based on the Ideas-Cosmos-Evidence (ICE) model and to search for a correlation between the effectiveness of an activity and the links between the individual entities of the model the activity promotes. A Teaching Learning Sequence (TLS) was designed, implemented and evaluated for the teaching of the Evolutionary Theory (ET) in junior high school students. All TLS activities were analyzed based on the ICE model. The analysis of the results obtained from the evaluation of the TLS shows that the most successful activities, both in the course of their implementation and in achieving their learning objectives, were those that promoted connections of all types between the individual entities of the model

Keywords: Teaching Learning Sequences, Ideas-Cosmos-Evidence Model, Evolutionary Theory

INTRODUCTION

The teaching of the Evolutionary Theory (ET) presents a number of problems that are related both to the students' alternative ideas (Driver et al., 2000, Zogza et al, 2009, Zabel & Gropengiesser, 2011, Wallin & West, 2013) and to the respective ideas of the teachers, as well as to the issues of acceptance both face (Berkman & Plutzer, 2010). Systematic educational interventions aiming at conceptual change require the organization of inquiry-type activities in the framework of a Teaching Learning Sequence (TLS) (Psillos & Kariotoglou, 2016). According to the proposal of Tselfes (2003), the choice of educational activities in designing a TLS can be guided by the Ideas-Cosmos-Evidence model (ICE) based on Hacking Laboratory Classification (1992). As reported by this classification, the activities of laboratory sciences are characterized by an almost autonomous "inner life" in which three individual entities - Ideas, Cosmos and Evidence - are in constant interaction and subject to constant transformation as a result of this interaction. Ideas include theoretical concepts and models, theories, and beliefs. In the Cosmos category, physical entities such as the sample, data capture devices and raw data are included. Data of all types that have undergone any form of processing are referred as Evidence. Conforming to Hacking the practice of scientists is to link the individual entities of the model together. The adjustment of the model for the teaching practice is based on the hypothesis that if students become familiar with scientific practices, it will be easier for them to understand scientific texts, since the concepts contained therein make sense only in this context. To this end, specific teaching activities are suggested that will guide students to create links between all the individual entities in the ICE model (table 1). Since science is doing (intervening) as well as knowing (representing), in the same way teaching activities may be interventional or representational.

Table 1: Activities that promote the creation of links between entities (Kallery, Psillos, Tselfes, 2009)

Linked entities	Link Type	Didactical activities
Ideas - Evidence	R	Linking Ideas with expected Evidence. Predictions of Evidence based on one's own ideas
Evidence - Ideas	R	Linking of Evidence with Ideas. Explaining specific Evidence in terms of some specific Ideas. These Ideas can be scientific or common
Cosmos - Evidence	R	Linking a piece of Cosmos with a piece of Evidence. Description of what is happening in Cosmos in terms of observed or recalled Evidence
Evidence - Cosmos	I	Linking Evidence with a piece of Cosmos. Constructing, intervening or modifying a specific segment of the material world on a basis of a specific piece of Evidence
Ideas - Cosmos	I	Linking Ideas with Cosmos. Interventions to the material world. Using scientific ideas, construct a piece of Cosmos with specific characteristics
Cosmos - Ideas	R	Linking Cosmos with Ideas. Describing a piece of Cosmos on the basis of one's own ideas

R: representational - I: intervational

In this study, we sought to relate the effectiveness of an educational activity to the number and type of links between the individual entities created during its implementation. The ICT model has been used in the past on two occasions (Psillos et al, 2004, Kallery et al, 2009). In both cases the model was used to analyze a posteriori the teaching activities and attempted to correlate their effectiveness with the type and number of connections of the model entities included. The first research group (Psillos et al, 2004) came to the conclusion that a long, persistent, empirical effort to develop improved teaching activities on a given topic gradually leads to the implementation of the expected links from the model. This fact is considered proof of its validity.

METHOD

A TLS of 5 teaching hours was designed, implemented and evaluated for the teaching of the ET to junior high school students. A parallel visit was also made to a Museum of Palaeontology. The participants of this developmental research were 20 ninth grade high school students in northern Greece. All activities were epistemologically analyzed on the basis of the ICE model and the links of all individual entities created were recorded (Table 2).

Description of the TLS

Each activity of the TLS' s scenario (Table 2, 1st column) dealt with a central concept that was basically approached through an inquiry type activity. Of the 5 activities included in the TLS, two were observations and 3 were simulations.

At the introductory activity (observation), biodiversity was the central concept. The students were asked to look for similarities and differences between the organizations given to them in the photographs and to compare their specific hereditary characteristics with those of their classmates and the teacher. A discussion followed in which they expressed their thoughts, ideas, and concerns about the origins of all of these organisms that resemble and differ at the same time.

The sequence was followed by a simulation activity, focused on the randomness of the mutations. It was essentially the well-known and popular "chinese whispers" game. One phrase was transferred from one student to another and its information changed as was the case with genetic information when it was passed down from generation to generation. The purpose of the activity was to help students understand that any reproduction mechanism involves the possibility of errors occurring at random.

The third activity had natural selection as a central concept. The students represented the birds with different beaks. Some had a beak like a spoon, a knife, a fork or a toothpick. Each group of birds was each time in a different seed environment. Candies were used as seeds that differed in shape, size and texture and students had one minute to compete for the "seed" collection. The worksheet helped students record their data, compare them and, through appropriate questions, arrive at the desired conclusions about how natural selection works.

The next activity, which was also simulation, was about random genetic drift. Through an initial population of pom pom of different colors, students chose at random to create their own subpopulations. They then compared their subpopulations with both the original population and that of their peers, and through appropriate worksheet questions were guided to conclude that something similar happens in nature when under certain conditions, e.g. in a natural disaster, chance chooses which organizations will survive and give the next generation, not the natural selection, whose role is traditionally exaggerated in teaching evolution.

The last activity (observation) took place inside the Museum of Paleontology and involved the recording of specific exhibit information. It was framed by pre- and post-visit activities to enhance learning outcomes. Specifically, prior to the visit, the students searched for information about the museum's exhibits and recorded questions that they would like to address to the guide, and after the visit they presented in the classroom in a manner of their choice two of the exhibits that impressed them.

Evaluation method

The main tool of the TLS's evaluation was a questionnaire with closed and open-ended type questions filled out by the students before and after the teaching, which was created for the purposes of the present study. Especially it included 7 closed type questions and 3 evolutionary phenomena for interpretation, while in its final form as it was given after teaching it was enriched with 7 additional questions aimed at recording students' views on ET and teaching. The design of the main evaluation tool was based on two questionnaires - by Price et al. (2014) and Anderson, Fisher & Norman (2002) - which measure the degree of understanding of random genetic drift and natural selection respectively. Information on the course of activities was mainly recorded in the teacher's diary: whether the time was sufficient, if language, conceptual or other difficulties arose, data that could be formative assessment material. The worksheets completed by the students provided some initial clues as to whether they understood the concepts they were dealing with. The whole set of data collected from the assessment tools was analyzed qualitatively, based on 5 main axes: The scientific concepts that students correctly refer to in their justifications, the alternative ideas that students rely on in their interpretations, the improvement of understanding the role of chance in evolution, the way natural selection works, the minimum unit that can evolve, and the existence of intraspecific diversity. The last points of analysis were the students' views on the ET and the method of teaching followed.

Results

Activities' analysis with ICE model

The results of the activities' analysis on the base of ICE model are shown on table 2. It was found that each activity had a different number and kind of relationships, and only representational (knowledge) relationships were included.

Table 2. Analysis of activities in the I-C-E model.

Teaching scenario (TS) / Activity	Ideas	Cosmos	Evidence	Links
1. Comparison of hereditary features	Intra-species diversity, common descent Characteristics of organisms	Photos of organizations, people in the classroom, cupboards	similarities, differences of organisms	C → E; I
2. A phrase is transferred from student to student (chinese whispers game)	Generations, mutations, transfer of genetic information, alleles	Students, the phrases being transferred from one student to another	sentence' s change from one student to another	C → I, C → E, E → I
3. Simulation of natural selection (students represent birds with different beaks)	Different survival rate, different conditions, competition, diversity	candies, spoons, forks, knives, toothpicks	Different number of candies collected from each "tool"	C → I, C → E, E → I, I → E
4. Create subpopulation by random choice from original population (pom pom use)	Random genetic drift, sampling error, drastic reduction in population size	different colors' Pom pom	Initial population formation, subpopulation formation, Subpopulation differences	C → I, C → E, E → I, I → E

5. Visit to the Museum of Palaeontology - observation of exhibits	Common descent, evolutionary relationships	Fossils	similarities of organisms	C I E

C-E= Cosmos – Evidence, I-E= Ideas-Evidence, C-I= Cosmos - Ideas

The evaluation of TLS

After TLS' s implementation the reinforcement of certain scientific concepts that the students use correctly in their justifications (Figure 1) and the retreat of most of their alternative ideas (Figure 2) were observed. The main reinforcement was observed in the use of the concept of mutations (TS 2) while a more significant retreat occurs in the alternative idea related to the survival of the strongest (TS 3).

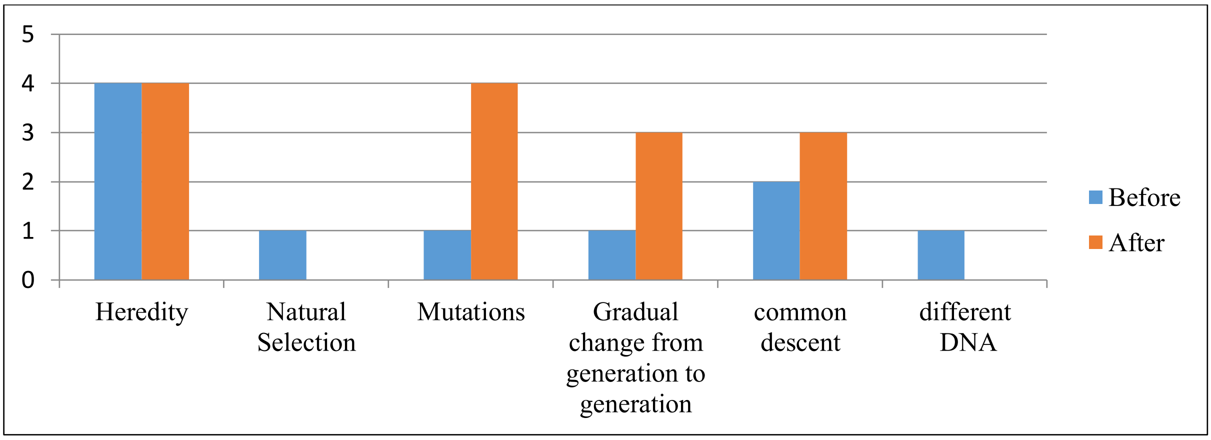

Figure 1. Frequency of reference for each scientific concept

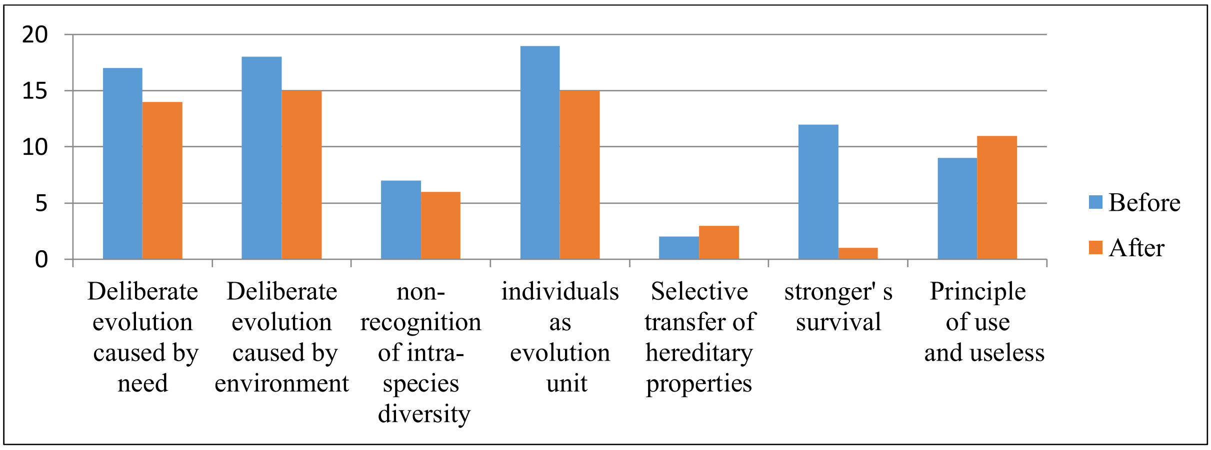

Figure 2. Frequency of reference for each alternative idea

Of the 20 students, 7 increased the number of scientific concepts they use correctly in their explanations. Among these, 5 used for the first time a scientific concept in the right way after teaching (Figure 3). Taking in mind that all of the alternative ideas found in the students' responses had been taken into account while designing TLS, it seems that their teaching management was rather effective and indeed for the majority of the students, since 13 of the 20 have reduced the number of their alternative ideas since the implementation of the TLS (Figure 4).

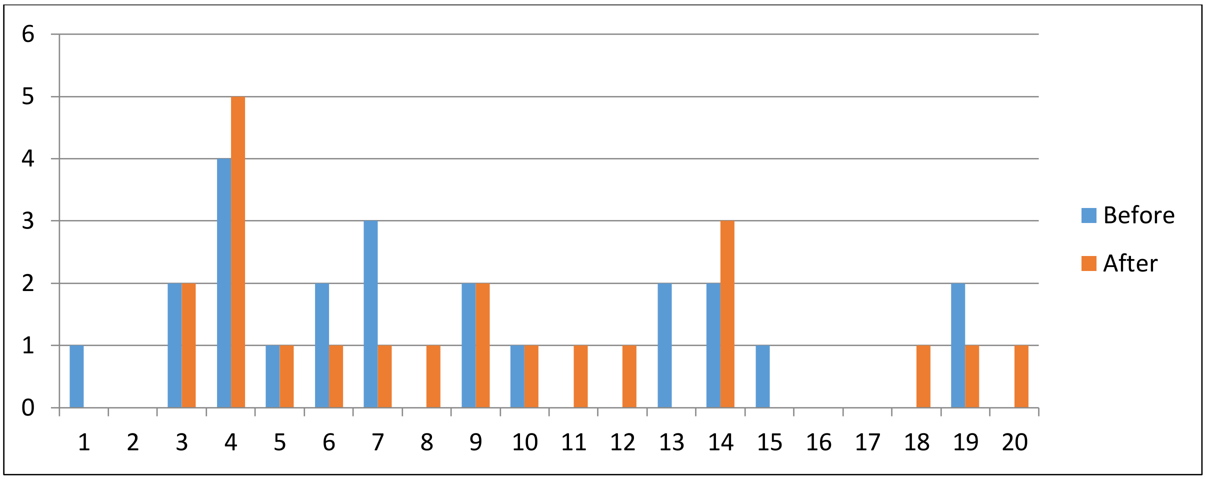

Figure 3: Number of scientific concepts used by each student in their explanations

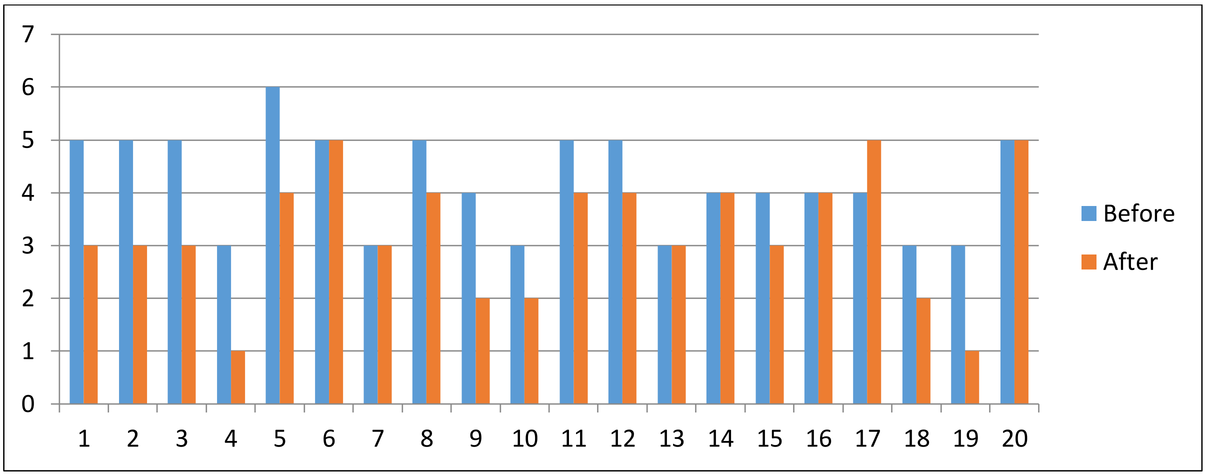

Figure 4: Number of alternative ideas per student, before and after teaching

Most of the students understood the role of chance in evolution - through random genetic drift (TS 4) – as it was clear from the analysis of the answers to the relevant questions (Figure 1 & 2), while they showed a superficial understanding of the way natural selection works and the existence of intraspecific diversity, since similar questions with different contexts resulted in contradictory responses. As far as the evaluation of teaching is concerned, the students distinguished the most interesting activities of inquiry nature that promoted connections among all the individual entities.

Discussion – Conclusions

The general finding drawn from the analysis of the results was that the TLS had an overall positive impact on improving understanding of evolutionary phenomena. Going further, with a closer look at the results, one finds that some of the teaching scenarios were more effective in achieving their learning goals. In particular, teaching scenarios 2,3,4, in the course of which were created links between all the individual entities, according to the ICE model (Table 2), were more successful in their implementation. They motivated students and stimulated their interest, and they seemed to improve their understanding of the concepts they were dealing with. On the contrary, activities 1 and 5 which lacked links were not performed by the students with the same willingness and did not substantially influence the understanding of the concepts with which they were related.

The short duration of the TLS, due to the limitations imposed by the Curriculum, did not allow for delving deeper into important concepts related to the ET. However, the evaluation of its pilot application revealed that the teaching had some encouraging results. In the next stage of the research empirical data will be used for the development of the TLS and the adaptation of activities to students' thinking (Psillos & Kariotoglou, 2016). The activities will be enriched with new types of links between individual entities - such as interventional ones - to investigate their impact on increasing the effectiveness of the TLS. Our results indicated that the ICE model could be an effective tool for evaluating activities at the design and development phase of a TLS. Although further research is needed to analyze a larger number of activities and to determine the kind of links that may be associated with better learning outcomes of a teaching activity. This process will reveal whether the model could be used as a tool to predict the effectiveness of an educational activity for the teaching of the ET, based on the number and type of connections created.

REFERENCES

Anderson, D., Fisher, K. & Norman, G. (2002) *Development and Evaluation of the Conceptual Inventory of natural Selection*. *Journal of Reasearch in science Teaching*, 39, 10: 952-978

Berkman, M., Plutzer, E. (2010). *Evolution, Creationism, and the Battle to Control America's Classrooms*. London: Cambridge University Press

Driver, S., Squires A., Rushworth P & Wood-Robinson V. (2000) *Building on the concepts of the natural sciences, A global summary of students' ideas.* (M. Chatzi, transl.) Athens: Typothito (In Greek)

Hacking, I. (1992), The self vindication of the laboratory sciences. In A. Pickering (Ed), *Science as practice and culture*, Chicago: The University Chicago Press.

Kallery, M., Psillos, D., & Tselfes, V. (2009). *Typical didactical activities in the Greek early years science classroom: Do they promote science learning? International Journal of Science Education*, 31, 1187-1204.

Price, R., Andrews, T., McElhinny, T., Mead, L., Abraham, J., Thanukos, A., Perez, K. (2014) *The Genetic Drift Inventory: A Tool for Measuring What Advanced Undergraduates Have Mastered about Genetic Drift. CBE- Life Sciences Education* 13, 65-75

Psillos, D, Tselfes, V., Kariotoglou, P., (2004) *An epistemological analysis of the evolution of didactical activities in teaching–learning sequences: the case of fluids*. *International Journal of Science Education*, 26, 5: 555-578.

Psillos, D., Kariotoglou, P. (2016) *Theoretical Issues Related to Designing and Developing Teaching-Learning Sequences*. In: Psillos D., Kariotoglou P. (eds) Iterative Design of Teaching-Learning Sequences. Dordrecht: Springer,

Tselfes, V. (2003). *A proposal for the teaching of the Laboratory Natural Sciences based on its Ian Hacking approach of their "inner life",* to K. Skordoulis & L. Chalkias (Ed.), The Contribution of the History and philosophy of Natural Sciences in their Teaching Physical Sciences, Athens: PDPE, NKUA, 259-271.

Wallin, A. & West, E. (2013) *Design and validation of teaching- learning sequence: Content – oriented theories about transmission of sound and biological evolution*. In T.Plomp, & N.

Nieveen (Eds), *Educational design research* – Part B: illustrative cases (pp. 179- 198). Enschede, the Netherlands: SLO

Zabel, J. & Gropengiesser, H. (2011) *Learning progress in evolution theory climbing a ladder or roaming a landscape? Journal of Biological Education* 45, 143-149

Zogza, V., Kampourakis, K. & Notaras, D. (2009) *Teaching evolution theory: theoretical and pedagogical issues*. Athens: Child services, Geitona schools (In Greek)

USING A PHYSICS BASED CAREER SCENARIO TO PROMOTE FEMALE SCHOOL STUDENTS' INTEREST IN PHYSICS AND PHYSICS CAREERS

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Studies have shown that students' interest in physics at secondary school tends to decline as they get older. The number of students, particularly female students, who participate in further study of physics is worryingly low. Interest has been found to be an important determinant for students when they make their choice of subjects for post-compulsory education in the UK. The decisions they make are also related to their ideas about how useful a subject is for a particular career. Contextualisation in school science has been shown to promote interest in science. The Horizon 2020 MultiCO project aimed to raise awareness about knowledge and skills used in STEM based careers and how they are linked to the science curriculum through intervention lessons using a STEM career-based scenario. This study investigates the use of a scenario of a female Nuclear Medicine Technologist for a class of 15 years old school students. The results show that the majority of students gained knowledge about the working skills and use of nuclear radiation in a real-world setting that promoted interest in the physics topic, particularly that of the female students.

Keywords: Physics, Student Interest, Context-Based Learning

INTRODUCTION

Students' deteriorating interests in science subjects as they progress through compulsory secondary school science education has been well documented in the UK (Osborne, Simon and Collins, 2003) and internationally (Sjøberg and Schreiner, 2010). Participation in Science, Technology, Engineering and Mathematics (STEM) subjects has been categorised as a leaky pipeline (Clark Blickenstaff, 2005). This has created, what media in the UK describe as, a STEM skills deficit (Morris, 2016) that may threaten national prosperity due to the reduction of qualified specialists involved in STEM industries. Vidal Rodeiro's (2007) survey into students' reasons for choosing A-level subjects in England found that students rated interest in a subject and a subject's usefulness for a future career as the primary factors in deciding what subjects to choose. DeWitt, Moote and Archer (2019) state that the utility value of a subject in relation to a future career was the most common reason for choosing a subject for post-compulsory education at school from the results of a survey of 13,000 students in England. The number of students choosing to study to A-level physics in England in 2018 was 37,806 representing 4.7% of the total entrants into A-level studies. The approximate ratio of male to female physics entrants was 4:1 which has been a consistent proportion for many years (since 2001) despite attainment in GCSE physics for females being equivalent to that of males (IOP, 2018).

In order to reverse the decline in interest, DeWitt and Archer (2015) emphasise the importance of teaching physics in a way that highlights its relevance to students' lives to promote interest in physics, particularly amongst female students, in order to help students to consider choosing a career in physics. Potvin and Hasni's (2014) findings recommend contextualised learning, i.e. relating science content to students' real-world experiences, as a way to promote students' interest in science. Students are generally unaware of science related occupations and can tend to have stereotypical conceptions of scientists and science related work (Cleaves, 2005). The EU Horizon 2020 MultiCO project investigated if students' interest in science and science careers could be enhanced by using context-based science learning interventions using STEM career-based scenarios that linked science curriculum content to the knowledge and skills required for a variety of careers.

In relation to young people choosing STEM careers, Sadler et al. (2012) report that the biggest factor for children is their initial interest in science when they start secondary school. Tai et al. (2006) affirm this notion for people in science-based careers remembering the influence that an interest in science careers from primary school age had on their choice of career. However, Hidi and Renninger (2006) contend that this perspective of an early developed interest expounds a misconception that interest in STEM subjects or careers cannot be developed in older students, especially as young people frequently change their minds about their futures. If the utility value of a subject is a factor in students' choice of subjects the information and guidance that they obtain about careers is very important.

Careers advice in schools

School career guidance provided by state funded organisations in England has suffered cuts in funding in recent years and the responsibility for providing such guidance has been placed on individual schools. However, Moote and Archer (2018) report that there is concern over the lack of career guidance resources on offer in schools and that more support is required to help teachers develop their skills and confidence to deliver careers education and advice. According to Hutchinson et al. (2011), school students who are interested in science/STEM careers are more likely to make enquiries about careers to their science teachers than any other source. Hall et al.'s (2011) study in the US found that students felt that their teachers' encouragement to pursue STEM based courses, as well as the teachers' knowledge about careers, were important factors in their consideration of future career paths. However, the teachers involved in the study felt that they only held limited knowledge of possible STEM careers. Hutchinson et al. (2011) noted that careers advice provided to students tended to be limited and focussed on traditional choices. Similarly, Cleaves (2005) reported how students are generally unaware of careers related to their science education and can tend to have stereotypical conceptions of scientists and science related work which is echoed in surveys of school students' knowledge of science careers (Porter and Parvin, 2008). One way of increasing teachers' knowledge and confidence about

STEM based careers is to have resources that link the science curriculum to STEM based careers which can also highlight the utility of the subject content to students who will be considering their subject options after compulsory education.

MultiCo project

The EU project, 'Promoting Youth Scientific Career Awareness and its Attractiveness Through Multi-Stakeholder Cooperation' (MultiCo) aims to develop: students' knowledge, understanding of, and interest in, STEM-related careers; the skills and qualifications required for STEM-related careers; the links between career knowledge and skills and the science curriculum in secondary schools. MultiCo is based on the development of career-based scenarios that focus on STEM-related careers that are primarily linked to the European Challenge Areas, i.e. energy, water, waste, climate change, food, health, technology and transport. Each scenario provides contextual information about people working in a particular STEM career that includes the factors that interested them to work in their field, their route through education to work in that profession, and the types of knowledge and skills required in their career. Each scenario is designed to provide a platform in which students engage in an investigation or an enquiry that links curriculum content with the science career during a series of intervention lessons.

RESEARCH AIMS

This case study of a science class in a London school details the use of a physics-based career scenario involving a female Nuclear Medicine Technologist in intervention lessons to investigate the impact of the scenario on students' (particularly female) interest in a nuclear radiation topic as well as a novel and unfamiliar physics career. Using a mixture of observation and a questionnaire, quantitative and qualitative data were collected about the students' interest in, and relevance of, the career used in the scenario.

METHODS

The scenario-based intervention was conducted in the science lessons of a London secondary school with a Year 10 class (15 years old) of 31 students (12 female and 19 male). The intervention lessons coincided when the teacher, a biology specialist, had scheduled to teach the nuclear radiation topic of the school's GCSE scheme of work. The scenario and intervention lessons were developed by the lead author in conjunction with the biology teacher. The scenario introduced students to a female Nuclear Medicine Technologist (NMT) highlighting her educational pathway by detailing the subjects she studied in school and university which included physics at A-level. It also included information about the typical activities she conducted on a day to day basis and the students were asked to consider the working skills required for her profession as well as the physics knowledge that would be useful. Students were tasked with developing a role play where the NMT interacts with a patient to inform them about an upcoming procedure to diagnose and treat a tumour in the patient's thyroid using radiotherapy. Students chose a partner to work with to develop a script for the role play that had to utilise technical terms from the physics content as well as showcasing the working skills of the NMT and how they dealt with the patient's concerns. Once the students had developed their script, three pairs were invited to either read or enact their script to the rest of the class. The students also researched the types of radioisotope that would be suitable for a variety of procedures based on the penetration, ionisation and half-life characteristics of radioisotopes. Although the scenario with the female NMT was introduced in the first intervention lesson, the teacher made constant reference to the scenario and the NMT throughout.

This study used a mixed methods approach to collect data about students' interest in the physics topic and the physics-based career. The intervention lessons were observed by a UCL MultiCo researcher who made fieldnotes during the lessons providing a narrative of the lesson as well as providing comments relating to interest and engagement of the students throughout. The lessons were also video recorded for posthumous analysis by the authors using a framework devised by Andersen and Nielsen (2013) for video-based analyses of students' motivation and interaction in science classrooms. The entire lessons were observed and divided into episodes (e.g. role-playing activity) that were analysed and coded. A transcript describing the episodes was made separately by each author and codes were linked to dialogue and actions. The video was watched together by the authors and the analyses were compared and triangulated with the fieldnotes of the UCL MultiCo researcher (see Table 1).

At the end of the second intervention lesson, students were asked to complete a Scenario Evaluation of Relevance and Interest (SERI) questionnaire that was devised to measure students' knowledge, engagement and interest in relation to the scenario (Kotkas, Holbrook and Rannikmäe, 2017). The questionnaire consisted of 28 items with 3 and 4-point Likert scales to state their level of agreement regarding cognitive and affective aspects of the scenario including interest levels with space to elaborate on their responses for the final five items. Descriptive statistics from the evaluation questionnaire were used with independent t-tests utilised to discover any statistically significance differences between the female and male responses.

RESULTS

Table 1 shows the results of the analyses of the fieldnotes and the video of the role-playing activity of the first intervention lesson.

Table 1 Analysis of students' motivation and engagement for the NMT scenario using Andersen and Neilsen's (2013) framework.

Categories		Code	
Students' actions and engagement	Content of students' talk	Subject matter	Students confidently discussed the physics content and related it to the NMT career correctly (role play and scripts). Demonstrated understanding of the links between the physics curriculum content and the physics knowledge required for the NMT career.
		Social organising	Development of character roles. Enacting their role play.
	Indicators of motivation	Students generating ideas	Used correct physics knowledge to inform the conversation between the NMT and the patient (scripts).
		Content related questions	Questions about the NMT career and nuclear radiation and its uses in medicine.
	Initiative and Engagement	Non-procedural display	Students weren't just "doing school". No indications of boredom or off-task behavior. Students enjoyed the lesson.

The students demonstrated that they were able to apply their knowledge of nuclear radiation and the working skills of the NMT to develop their scripts for the role-playing activity. They utilised correct knowledge of the physics and the procedures used to diagnose and treat a thyroid condition of a patient. The students demonstrated their understanding of the personal skills required by the NMT to assuage a patient's fears and concerns of the procedures using nuclear radiation. Throughout this activity the students were motivated and were judged to not to have just gone through the motions of completing the activity; they demonstrated enjoyment and an eagerness to engage in the role-playing activity (most pairs were keen to read or enact their role-playing scripts) as well as the rest of the intervention lessons. There was no perceived difference in motivation, engagement and enjoyment between female and male students.

Table 2 shows the students' evaluation questionnaire responses for the scenario used in the intervention lessons. Only the items that are pertinent to this study in relation to interest in the topic and the career have been used. The mean and standard deviation for each item is displayed as well as the proportion of female and male students who agreed with each item. Table 3 shows the written response of female students to the item 'I found this scenario interesting'.

Table 2 Results of the evaluation questionnaire

Evaluation statement	**Mean**	**SD**	**% agree (F,M)**
The knowledge I gain from the scenario may be useful in the future.	2.83	0.58	100, 68**
From this scenario, I am able to gain new knowledge about possible career(s).	2.94	0.72	100, 53**
This scenario enables me to understand the skills that are necessary in this profession.	3.03	0.65	83, 79
I found this scenario topic helped me develop understanding of subjects studied at school	2.65	0.70	75, 47
I feel my future career may be related to the topic covered in the scenario.	1.93	0.83	42, 11*
I think my future studies at university level may be connected to the topic covered in the scenario.	1.97	0.90	42, 16*
I predict that I will need to perform skills described in the scenario in my future career.	2.13	0.87	58, 16 **
I predict I will need to use the science related skills described in the scenario in my future career.	2.13	0.83	58, 21*
	Yes (F, M)	**No (F, M)**	**Not Sure (F, M)**
I found this scenario interesting	8, 10	0, 5	4, 4
This scenario makes me want to learn more about the topic	5, 4	2, 6	5, 9

*$p<0.05$, **$p<0.01$

It is notable that all the female students agreed that they gained knowledge that may be useful for the future as well as about a new career. Both these items had a statistically significant difference for the female students compared to the male students. Three quarters of the female students agreed that the scenario helped them to understand the physics content covered in the intervention lessons. Though the majority of students did not agree that the topic covered would be one that they would study or relate to their work in the future, a higher proportion of females did agree with these questionnaire items which was a statistically significant difference. The majority of female students also identified that the skills (working and physics based) would be useful for their future careers. Though it is difficult to discern what the students were considering when responding to the questionnaire, the scenario introduced the students to a novel career that was able to promote a positive representation of physics content. Of the 58% of students who found the scenario to be of interest, 8 were female (66% of total females) and 10 were male (53% of total males). Table 3 shows a selection of comments from the female students about why they found the scenario interesting.

Table 3 Female students' written responses to the questionnaire item, 'I found this scenario interesting'.

Yes	Not Sure
It helped me to understand the topic and it helped to know what happens, which is interesting.	It didn't appeal to me personally, don't know when I will use it, but it wasn't too bad.
I like science and feel my future career may be linked to it.	I don't know if I found it interesting.
Because I got to learn about nuclear medicine.	
Because it was intriguing to learn about it. I wasn't already aware of this.	
As I have never thought about this line of career and it was quite interesting knowing about how it is used to diagnose and treat.	
Because it gives good examples of real-life situations and informs of new things.	
I was intrigued as it gives you good information and a good insight on what radioactive atoms can help with.	

The variety of responses shown in table 3 indicates how the use of scenario based teaching focussed on a new career that promotes practical applications of physics and links topics to the real world can promote students' interest in physics as well as physics based careers. Some students were unaware of the practical application of radioisotopes in diagnosis and treatment and some had already considered this to be an area that they would like to work in. Of the 10 students who responded that they felt motivated to learn more about the topic, five were female. This highlights the possibilities of promoting physics to overcome the anachronistic and stereotypical representations and views of physics and physics based careers as masculine and engineering focussed.

In developing the scenario and the intervention lessons, the class teacher learned about a new career and gained confidence in discussing relevant information about pathways to become a NMT to the students. Anecdotally, the teacher commented that the scenario provided a novel and interesting way of teaching nuclear radiation that they had previously taught using slides about the characteristics of radio isotopes and their uses.

DISCUSSION

The career-based scenario of the nuclear medicine technologist and the associated intervention lessons provided participating students with an opportunity to explore the working skills and knowledge used in this career as well as the links between the career and the pertinent physics curriculum content. By using the context of someone using physics in their day to day working life, it is possible for teachers to provide relevant career information in lessons as well as providing a real-world context to teach physics topics. The results from this study support the findings of Hazari et al. (2010) regarding the use of contextualised learning to promote the students' interest in physics. The Relevance of Science Education (ROSE) report (Sjøberg and Schreiner, 2010) states that girls tend to be more interested in health and medicine aspects of science whereas boys are more interested in technology and dramatical aspects of physics. Research has also shown that girls tend to aspire to medical careers more so than boys (Shapiro et al, 2015). This study tends to support these findings about girls' being interested in topics associated with health and medicine but it also shows that it is possible to use this interest to promote girls' interests in physics and a physics based career.

Due to the relatively limited time of the intervention lessons and use of the scenario, it is only likely that the students are expressing a situational interest (Hidi and Renninger, 2006) towards the scenario and its contents relating to the NMT career and the nuclear radiation topics covered. This interest is unlikely to be sustained unless more lessons are focussed on this same topic. However, recent empirical evidence indicates the importance of triggering situational interest in science lessons in order to allow for knowledge acquisition (Ayotte-Beaudet, Potvin and Riopel, 2019). Gaining knowledge about new careers associated with the physics curriculum has the potential for more students to consider physics for future study due to students being able to perceive the utility value of physics and a wider range of career prospects in physics.

LIMITATIONS

The evaluation questionnaire used in this study was designed to evaluate the career-based scenario. However, by completing the questionnaire at the end of the intervention lessons, it is unclear if the students were evaluating just the career-based scenario or the whole intervention. Whether students disaggregated ideas about medicine from the physics content is unclear but there was scope for female students to see a practical application of physics to medicinal careers. The sample size in this case study was too small to be able to generalise the findings but is useful to highlight the impact of a career related scenario and intervention on this particular class.

CONCLUSION

This career-based scenario and intervention lessons used in this study allowed students to gain knowledge about a STEM-related career that was new to the majority of the students. The novelty of the career along with the contextualization of the nuclear radiation concepts involved in the career appeared to be the factors that sparked the students' (particularly the female students) interest, as it allowed them to relate acquired physics knowledge to a real-world situation. The results from this case study highlight the potential of increasing interest in physics in secondary schooling, particularly female students' interest by connecting fields of interest, in this case medicine, to school physics content. This corresponds with the findings of Haussler and Hoffman (2002) who reported the benefits of linking physics concepts to contexts of interest to female students to augment their relevance. The findings also demonstrates the potential of ensuring that the practical applications of physics can be used to support students' ideas about working life beyond school and provide a conduit that connects the physics curriculum content to the skills and practices of working lives with the intention of promoting physics as a subject for further study and a future career.

REFERENCES

Andersen, H.M. & Nielsen, B.L. (2013). Video-based analyses of motivation and interaction in science classrooms. *International Journal of Science Education*, *35*(6), pp.906-928

Ayotte-Beaudet, J.P., Potvin, P. & Riopel, M. (2019). Factors Related to Middle-school Students' Situational Interest in Science in Outdoor Lessons in their Schools' Immediate Surroundings. *International Journal of Environmental and Science Education*.

Clark Blickenstaff, J. (2005). Women and science careers: leaky pipeline or gender filter?. *Gender and education*, *17*(4), pp.369-386.

Cleaves, A. (2005). The formation of science choices in secondary school. *International Journal of Science Education*, *27*(4), pp.471-486.

DeWitt, J. & Archer, L. (2015). Who aspires to a science career? A comparison of survey responses from primary and secondary school students. *International Journal of Science Education*, *37*(13), pp.2170-2192.

DeWitt, J., Archer, L. & Moote, J. (2019). 15/16-Year-Old Students' Reasons for Choosing and Not Choosing Physics at a Level. *International Journal of Science and Mathematics Education*, *17*(6), pp.1071-1087.

Hall, C., Dickerson, J., Batts, D., Kauffmann, P. & Bosse, M.,(2011). Are We Missing Opportunities to Encourage Interest in STEM Fields?. *Journal of Technology Education*, *23*(1), pp.32-46.

Häussler, P., & Hoffmann, L. (2002). An intervention study to enhance girls' interest, self-concept and achievement in physics classes. *Journal of Research in Science Teaching*, 39(9), pp. 870–888.

Hazari, Z., Sonnert, G., Sadler, P.M. & Shanahan, M.C. (2010). Connecting high school physics experiences, outcome expectations, physics identity, and physics career choice: A gender study. *Journal of research in science teaching*, *47*(8), pp.978-1003.

Hidi, S. & Renninger, K.A. (2006). The four-phase model of interest development. *Educational psychologist*, *41*(2), pp.111-127.

IOP, 2018. Why not physics? A snapshot of girls' uptake at A-level, Institute of Physics

Kang, J., Keinonen, T., Simon, S., Rannikmäe, M., Soobard, R., & Direito, I. (2018). Scenario Evaluation with Relevance and Interest (SERI): Development and Validation of a Scenario Measurement Tool for Context-Based Learning. *International Journal of Science and Mathematics Education*

Kotkas, T., Holbrook, J. & Rannikmäe, M. (2017). A theory-based instrument to evaluate motivational triggers perceived by students in STEM career-related scenarios. *Journal of Baltic Science Education*, *16*(6).

Moote, J. & Archer, L. (2018). Failing to deliver? Exploring the current status of career education provision in England. *Research Papers in Education*, *33*(2), pp.187-215.

Morris, J. (2016, February 5). UK Skills Shortage: Misconception about STEM subjects are failing young people. Retrieved from https://www.cityam.com/uk-skills-shortage-misconception-about-stem-subjects-are-failing-young-people/

Osborne, J., Simon, S. & Collins, S. (2003). Attitudes towards science: A review of the literature and its implications. *International journal of science education*, *25*(9), pp. 1049-1079.

Porter, C. and Parvin, J. (2008). Learning to love science. *The Chemical Industry Education Centre*.

Potvin, P. & Hasni, A. (2014). Interest, motivation and attitude towards science and technology at K-12 levels: a systematic review of 12 years of educational research. *Studies in science education*, *50*(1), pp.85-129.

Sadler, P., Sonnert, G., Hazari, Z., & Tai, R. (2012). Stability and volatility of STEM career interest in high school: A gender study. *Science Education, 96*(3), pp. 411-427

Shapiro, M., Grossman, D., Carter, S., Martin, K., Deyton, P. & Hammer, D. (2015). Middle school girls and the "Leaky Pipeline" to leadership: An examination of how socialized gendered roles influences the college and career aspirations of girls is shared as well as the role of middle level professionals in disrupting the influence of social gendered messages and stigmas. *Middle School Journal*, *46*(5), pp.3-13.

Sjøberg, S. & Schreiner, C. (2010). The ROSE project: An overview and key findings. *Oslo: University of Oslo*, pp.1-31.

Tai, R.H., Liu, C.Q., Maltese, A.V. & Fan, X. (2006). Planning early for careers in science. *Science*, *312*(5777), pp.1143-1144.

Vidal Rodeiro, CL. (2007). *A level subject choice in England: patterns of uptake and factors affecting subject preferences*. Cambridge, England: Cambridge Assessment

STRENGTHENING STUDENTS' INTEREST IN SCIENCE: THE CASE OF 'SAVING THE POLAR BEARS'

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Increasing students' interest in science remains a critical issue in efforts to address the mismatch between demand and supply for professionals in Science, Technology, Engineering and Mathematics (STEM). As part of project MultiCO, this study aims to explore the impact of career-based scenarios, on students' situational interest in science and career awareness. Career-based scenarios are teaching innovations which when integrated in science classrooms can enhance the potential to influence students' future study choices and career aspirations. The study adopted a design-based approach implementing the same scenario in three classrooms (14-15 year-old students) using a variety of data collection methods for quantitative and qualitative analysis. The main sources of data included two questionnaires and interviews with students and teachers reflecting on the scenario implementation. The findings illustrated that career-based scenarios succeeded in generating students' interest and improving career awareness when active engagement was promoted and connections between theory and practice were established fostering meaningful interaction with experts. These findings hold important implications for educational practice in science education as they offer insights into how to design career-oriented instructional material in order to have an impact on students' interest, career awareness and aspirations in science.

Keywords: Science education, Situational interest, Career awareness

INTRODUCTION

Interest in science has been considered a fundamental attribute influencing decisions on future science-related study and career choices (Potvin & Hasni, 2014). In contrast, young people's declining interest in science is a predictor of future shortages in the STEM sector. Recent policy papers have issued an urgent call to increase the proportion of STEM graduates and confront the mismatch between supply and demand, especially in Europe and the US (OECD, 2017). A review of the literature in science education highlights empirical evidence showing a number of interrelated factors that influence students' study and career aspirations in relation to science. These factors relate to the individuals per se - intrinsic factors - as well as their surrounding environment - extrinsic factors. Intrinsic factors concern affective reaction towards science (i.e. positive feelings and fascination), being interested in science, as well as self-efficacy beliefs and are related to race, gender and science identity (e.g., Lykkegaard & Ulriksen, 2019; Gottlieb, 2018; Holmegaard, Madsen & Ulriksen, 2012; Cleaves, 2005). On the other hand, extrinsic factors pertain to socio-economic status, the role of significant others, school-related factors such as the teacher's expertise and the teaching practices and most importantly the lack of career counseling (Vincent-Ruz & Schunn, 2018; Stets, Brenner, Burke & Serpe, 2017; Blotnicky, Franz-Odendaal, French, & Joy, 2018). Research has shown that middle school students' knowledge of STEM careers is limited, and this might impact their interest in pursuing a STEM career (Taskinen, Schutte & Prenzel, 2013; Blotnicky et al., 2018). Towards this end, science education research suggests several teaching strategies that result in fostering positive attitudes towards science and related careers. In an endeavor to contribute to this effort, this study aims to explore the impact of career-based scenarios, as teaching innovations integrated in secondary science classrooms, on students' interest in science that may serve as an option for further studies and a career.

The study draws on three theoretical domains: the Social Cognitive Career Theory (SCCT) model, Situational Interest (SI) and Problem-based Learning (PBL) (Drymiotou, Papadouris & Constantinou, 2018). The SCCT model derives from Social Cognitive Theory (Bandura, 1986) and suggests that interest is a predictor of career goals and choices and can be developed within a learning environment (Brown & Lent, 1996). Interest is conceptualized as "a psychological state and a predisposition to re-engage particular disciplinary content over time that develops through the interaction of the person and his/her environment (Hidi & Renninger, 2006). Based on this conceptualization, this study aligns with Hidi and Renninger's (2006) four-phase interest development model according to which SI is initially triggered and maintained (Phases 1 & 2) and then individual interest emerges and develops (Phases 3 & 4). The emphasis is on SI defined as a short-term form of motivation elicited by aspects in a specific situation that stimulate focused attention and consists of affect (Phase 1) and value components (Phase 2) (Hidi & Renninger, 2006). PBL could be considered as an environment that is conducive to utilizing stimuli in the form of career-based scenarios as driving questions to advance learning. More specifically, based on the assumption that students' aspiration to pursue science-related careers is highly related to their interest, and given that regular experiences of SI can be the starting point for individual interest in science (Palmer, Dixon & Archer, 2016), this study aims to answer the following research questions: Under what conditions and how does the integration of career-based scenarios in science class:

(a) generate students' situational interest and,

(b) raise students' awareness about science-related careers?

METHODS

The case study involved 67 student participants attending the 9th grade (14-15 years) from three secondary schools in Cyprus. School A is a private secondary school located in the capital of the island and it follows the National Curriculum of England Key Stage 3 up to the end of Year 9. School B is located in West Cyprus and School C in the centre of the capital. Both are public secondary schools (grades 7-9) that follow the national curriculum established by the Cyprus Ministry of Education and Culture.

The classroom interventions were extended over 3-4 teaching periods (35-50 minutes each) using the same scenario titled 'Save the Polar Bears'. Framed in the context of PBL, the scenario was integrated in the teaching unit of Heat transfers in Physics and concerned the issues of climate change stressing the need for energy efficiency as a possible solution. In particular, the scenario presented how climate change threatened the lives of polar bears due to the rise in temperatures and the melting of polar ice caps. This was illustrated by showing a video from National Geographic. The scenario helped classroom discussions to make the case that climate change threatened not only the lives of polar bears, but it also affects the entire planet (e.g., photos from floods, droughts, fires). It had established the link that the extensive energy needed for heating and cooling our houses came largely from fossil fuels making a connection to the increase in global temperatures due to the increase in carbon dioxide levels in the atmosphere. At that point, the mission of the students was to test energy-efficient model-houses to address global warming and save money by assuming the roles of architects and engineers who specialized in energy-efficiency.

The classroom interventions were structured as follows: scenario presentation as an introduction to the unit, scenario link to the teaching unit and a reflection/consolidation phase that wraps up the teaching unit and revisits its connection to the scenario. In each classroom case there were some adjustments based on the teacher's perspective about the achievement of the learning objectives as well as curriculum and time constrictions. Table 1 summarizes each case and scenario adaptations following a design-based research approach.

Table 2. Description of each Classroom Intervention in Chronological order

Structure	Case A (School A)	Case B (School B)	Case C (School C)
Focus	Link between theory and practice though the scientific method		& interaction with experts
Scenario presentation: Introduction to the teaching unit	National Geographic video showing a starving polar bear and follow up discussion about climate change consequences focusing on how energy can be saved: link to energy efficiency		
	Text-based career-related information (PP slides)	Video showing interviews with the experts	Video was trimmed
Scenario link to the teaching unit: Experimentation	Mission: to test energy-efficient model-houses and address global warming assuming the role of architects and engineers specialized in energy-efficiency. Students divided in groups test the insulation of different materials using temperature sensors and a software program.		
	Each group tests out 3 materials	Each group tests out 1 material (different in each group)	
Reflection phase: Revisit of the scenario link to the teaching unit	Experts' visit to school: PP Another lesson followed to continue experimentation	No experts' visit Discussion about the best material to use for insulation	Experts' visit to school: planned in collaboration with the researchers

For this classroom-based research, both quantitative and qualitative data were collected. The primary data collection methods included (a) two questionnaires consisting of Likert scale items and open-ended questions and, (b) interviews with 22 students and 3 teachers reflecting on the scenario implementation and the added value in terms of triggering interest and raising awareness about science-related careers. In addition, field notes served in both facilitating the triangulation of the primary data and supplementing interpretation. The first questionnaire (MultiCO Scenario Evaluation) was administered at the end of Lesson 1 consisting of items related to the two phases of SI: Triggered (measuring students' affective reaction to the scenario) and Maintained (measuring the value/importance/relevance of the scenario), as well as career-related items. The second questionnaire (Lesson Questionnaire) was given at the end of each lesson to measure the intensity of SI throughout the intervention and consisted of four items regarding students' focused attention and affection (Rotgans & Schmidt, 2011). Quantitative data were analyzed using descriptive statistics and qualitative data were coded based on the Triggered and Maintained SI developing a coding tool according to SI sources emerged from the literature (RQ1a) and career awareness-related information (i.e. job duties, skills) (RQ1b). The analysis of qualitative data with respect to whether the career-based scenarios generate students' SI (RQ1a) aim to give further insights on the sources of triggering and sustaining SI.

FINDINGS

Regarding the first research question, Table 2 depicts the descriptive statistics of students' SI emerged from the analysis of students' responses to MultiCO Scenario evaluation questionnaire with respect to Triggered SI (TSI) and Maintained SI (MSI). Table 3 displays the frequencies of students' responses in the open-ended questions in the MultiCO scenario evaluation questionnaire and the interviews based on the content analysis. Hence, from the content analysis derived four (4) sub-categories and thirteen (13) codes under the categories of TSI and MSI denoting affective and value-related facets respectively.

Table 3. Descriptive Statistics in terms of Triggered and Maintained SI

	Situational Interest	Case A[a]		Case B[b]		Case C[c]	
	Items[e]	Mdn	Mode	Mdn	Mode	Mdn	Mode
TSI	The scenario was fun	3.00	3	3.00	3	3.00	3
TSI	I like the format of the scenario	3.50	4	3.00	3	3.00	3
TSI	I find the topic of the scenario interesting[d]	2.00	2	2.00	2	2.00	2
MSI	I find this topic important for me personally	3.00	3	3.00	2	3.00	3
MSI	I find this topic important for learning at school	4.00	4	3.00	3	2.00	2
MSI	I find this topic important for the society	4.00	4	3.00	3	3.00	3
MSI	The topic has something to do with me	3.00	3	2.00	2	2.00	2

a. N= 14, b. N= 25, c. N= 25; d. 0= no, 1= cannot decide, 2= yes
e. 1= totally disagree, 2= disagree=, 3= agree, 4= totally agree. The findings are discussed with respect to the two extremes

Table 4. Findings from the Content Analysis with respect to TSI and MSI

Triggered SI (Affect)		Case A	Case B	Case C	Sum
Novelty	Visual aids	2	5	17	24
	Setting the goal	11			11
	Something different		1		1
	Use of ICT	4			4
	Interaction with experts	1		10	11
	Ambiguity			1	1
Total					**52**
Topic interest	Interest in the topic	5	2	4	11
	Interest in careers		8	5	13
Total					**24**
Practical Activities	Experiments	5	4	7	**16**
Total					***92***
Maintained SI (Value)					
Learning	Learning in general	9	7	5	21

	Learning career information	2	13	4	19
	Learning about social issues		5	2	7
Total					**47**
Relevance	Personal value	4	5	5	14
	Global value	15	2	4	21
Total					**35**
Total					***82***

Triggered SI

As can be seen on Table 2, in all the cases the students expressed positive feelings towards the scenario (mdn≥3.00, mo≥3) and found its topic interesting to the highest degree (mdn=2.00, mo=2). The statement 'I like the format of the scenario' tended towards a positive extreme in all the cases (mdn≥3.00, mo≥4). The content analysis of the qualitative data collected from the questionnaire, indicated that *novelty* was considered by the students as the main source of triggering SI (52 times). In particular, in Case A the most frequent code was *setting the goal* (11 times) which refers to students' responses indicating that they liked the idea to take on a mission as 'experts' (e.g. *"The mission seems very fun to do!"*). In Case C, *visual aids* was the most frequent code that refers to the use of the video to introduce the scenario (e.g. *"I liked the video with polar bear"*) followed by the *interaction with experts* (e.g. *"Most of all, I liked it when the architect came and talk to us. We were talking to an expert and he answered to all the questions."*). On the other hand, the sub-category of *topic interest* (24 times) was less common throughout all the cases whereas emphasis was given on the *interest in the careers* (8 times) in Case B (*"I liked the jobs, the architect and the civil engineer"*). *Practical activities* and particularly *experiments* (16 times) were also reported by the students in all the cases especially in Case C (7 times) (e.g. *"I liked it a lot because we did experiments, practical activities"*).

Maintained SI

All the students agreed that the scenario topic was quite important for the society and for learning at school though there was a negative trend in terms of the latter in Case C (mdn=2.00, mo=2). The statement 'I find this topic important for me personally' that denotes personal value was endorsed by all the students to the positive extreme (mdn≥3.00). Nevertheless, the statement 'The topic has something to do with me' that signifies personal relevance had a negative trend in Cases B and C (mdn=2.00, mo=2). According to the content analysis, the students' responses showed that *learning* and *relevance* were the common sources of sustaining SI with the former being more frequently reported (47 times) than the latter (35 times). *Learning* was mostly reported in Case B focusing on *career-related information* (13 times) gained from the career-related videos and the follow up discussion with the teacher (e.g. *"I liked best that we learned about jobs because we might choose one of these jobs in the future"*). Moreover, the most frequently reported code in all the cases was *learning in general* (21 times) probably indicating that the students valued learning and gaining information about the practical aspect of science in everyday life (e.g. *"Yeah I never considered the shading they put over the window and I haven't actually thought of why …*

and I never thought the angles of the sun and stuff like that. That was interesting", Case A). *Learning about social issues* was the least reported code (7 times). In terms of *relevance*, the most frequent source of SI reported by the students was *global value* (21 times) that was mostly endorsed by the students in Case A (15 times) (e.g. *"The subject of global warming is intriguing and a very important worldwide issue"*). On the other hand, the scenario topic was not perceived as having a *personal value* (14 times) for the students which contradicts the findings derived from Table 2 reflecting on Lesson 1 (e.g. *"It is important for people in general cause the architects are people which have the plan for you to make a house but for me personally it's not really relevant to me but it's important"*). The students who perceived the scenario topic as personally important they usually attributed this value to the career aspect because of its alignment with their aspirations (e.g. *"Yes because I like architecture and it is something I want to do in the future"*).

Intensity of SI

Table 4 shows that students' SI overall tended towards the positive extreme in all the cases (mdn>3). However, some fluctuations are identified in each case. In particular, in Case A students' SI was relatively decreased in Lesson 3 (mdn=3.25) from the previous lessons (Lesson 1: mdn=4.38, Lesson 2: mdn=4.25) whereas an increase can be seen in Lesson 4 (mdn=4). In Cases B and C there were slight differences indicating that the least interesting lessons were Lesson 3 and 1 correspondingly (mdn=4, mdn=3.50).

Table 4. Students' Situational Interest in each Intervention per Lesson

Cases	**Case A (N=14)**				**Case B (N=25)**			**Case C (N=25)**		
SI/Lesson	**L1**	**L2**	**L3**	**L4**	**L1**	**L2**	**L3**	**L1**	**L2**	**L3**
Median	4.38	4.25	3.25	4.00	4.13	4.50	4.00	3.50	4.00	4.00
Mode	4	5	3	4	4	5	4	4	4	5

Further insights from the interviews support these findings. In Case A, a student claimed that the expert's visit was not interesting due to the lecture-type presentation and that it could had been more engaging (*"Perhaps they could have done more hands-on things to get more involved, engaged"*). Nevertheless, the experimentation with the use of the computer as a novelty aspect promoted self-regulated learning and there are indications that it had succeeded in sustaining students' SI (e.g. *"I really liked it when we experimented on our own"*). Considering Case B, although the students showed interest in the introduction of the scenario, field notes and teacher's interview indicated that some students' attention was withdrawn during the career-related videos because of their length and sound problems. Two students also noted that *"the experts in the video were not talking clear"* and that *"the lesson was boring"*. Regarding Case C, students' SI was seen to gradually increase. More specifically, the teacher stated that *"students' engagement was enhanced once they got ownership during testing materials"*. Likewise, the majority of the interviewees expressed their excitement while doing the experiment (e.g. *"We understood better the topic, it was more creative and it triggers your interest more."*). According to the teacher, during the expert's visit the students were engaged *"once the architect managed to establish a connection with students"* and the climate became friendlier and personally relevant.

Career Awareness

Following the presentation of career-related information in Lesson 1, Table 5 below indicates that students' knowledge gained about job and opportunities and the understanding of skills necessary in the job of the architect tended toward the positive extreme in all the cases (mdn=3.00). Regarding the statement 'This career might be an option for me', students in Cases A and B responded negatively (mdn=2.00; mo=3 and mo=1 respectively) opposed to the students in Case C (mdn=3.00; mo=3).

Table 5. Descriptive Statistics with respect to Students' Career Awareness

Career awareness	Case A[a]		Case B[b]		Case C[c]	
Items[e]	Mdn	Mo	Mdn	Mo	Mdn	Mo
From this scenario, I gained new knowledge about jobs and career opportunities	3.00	3	3.00	3	3.00	3
This scenario enables me to understand the skills that are necessary in this profession	3.00	4	3.00	3	3.00	3
This job/career might be an option for me	2.00	2	2.00	1	3.00	3

a. N= 14, b. N= 25, c. N= 25
d. 1= totally disagree, 2= disagree=, 3= agree, 4= totally agree. The findings are discussed with respect to the two extremes.

Findings from qualitative data indicated that the students perceived knowing more about careers at the end of each intervention. In particular, the interviewees in Case A reported knowing the architect as a job title but not where architecture and engineering could branch out to. Reflecting on the career-related video and the follow-up discussion in Case B and the expert's visit in Case C respectively, the interviewees stated that the intervention enabled them to get an idea of the basic studies and sector-specific knowledge related to how the theoretical concepts in the teaching unit of heat transfers can be applied in architecture (e.g. *"I learnt that it's more complicated than just having to figure out what material is better to use, other factors come in place, from the temperature of the room, whether it's sunny, humidity also affects it"),* the opportunities to gain expertise and to understand the difference between the architect and civil engineer (e.g. *"I learned that the architect designs the building whereas the civil engineer is responsible for the foundations of the building to be stable and insulated"*). It was also seen that the informal interaction with the experts (Case C) was more engaging for the students instead of the lecture-type one (Case A) (e.g. *"It was interesting because we could ask anything and you don't usually have opportunities like that to talk to an expert"*). In addition, there were some references to the general responsibilities of the job, working conditions and specific skills (e.g. design & IT skills). A common finding was that the students considered learning about careers very useful (e.g. *"It's interesting because we don't learn about jobs. The teacher focuses on the lesson and many of us don't know what subjects to choose and the available jobs"*).

DISCUSSION AND CONCLUSIONS

The findings presented in this paper showed that the use of career-based scenarios as an introduction to science teaching units can serve as a mechanism to generate students' SI and raise their awareness about science-related careers under some conditions. What vividly stands out in sustaining students' interest throughout the scenario implementation and providing them with knowledge about careers relates to specific features of the scenario and how these are supported in the teaching sequence.

According to the findings from the three cases described above, focusing on students' SI, the students expressed positive feelings (e.g. enjoyment, excitement) towards the scenario and foremost the novelty aspect. More specifically, visual aids (i.e. video), 'setting the goal' tasks using PBL and interaction with experts were the most frequently reported sources of triggering SI. The mission assigned to the students and thereby the experimentation, as well as the interaction with the experts, seemed to have had facilitated students' active engagement in class. On the other hand, someone could share Rotgans and Schmidt's (2012) argument that the feeling of being curious about something that is new and unknown fades away at some point and then the students become less engaged and active. What it is worth mentioning here though, based on the reflection from our previous work (Drymiotou et al., 2018), is that the novelty aspect was repeatedly presented throughout the intervention to provide constant stimulations of SI and it presumably succeeded in 'holding' students' interest.

Moreover, considering the interaction with the experts, the measurement of the intensity of SI, indicated that interacting with experts is not always serving the purpose to trigger and/or sustain SI unless it occurs in an informal setting offering a fertile ground for the development of 'friendly' conversations. The lack of good planning and collaboration between the expert and the teacher which was looped by the researcher in Case A seemed to have failed developing an environment that could host fruitful discussions and promote students' engagement. Conversely, in Case C, the expert managed to establish a connection with the students which prompted them to ask more personal questions and get to know information about his out of work life and how this was affected by his work. In accordance with the findings presented by Kudenko, Simarro and Pintó (2017), the minimal contribution from industry representatives in initiatives to develop learning resources and support STEM curriculum often ignored personal and social attitudinal issues. The findings of this study perhaps highlight the significance of having a more personal interaction with the experts.

The results of this study also revealed that the students valued the fact that the scenario implementation provided them with general knowledge and information about careers and everyday social issues. Even though the majority of the students were not personally interested in the topic or the career, they perceived the scenario experience important and useful due to the transfer of science concepts to a real-life-personally-relevant context. This perhaps enabled them to establish connections between theory and practice. Similarly, findings from a study conducted by Palmer, Burke and Aubusson (2017) suggested that providing opportunities to create relevance to everyday life now and in the future would make the students understand its usefulness and probably increase their enjoyment in science and the possibilities for a relevant future study and career choice.

Although many of the students expressed positive feelings towards the scenario, only few chose the career of architect or civil engineer as a possible future option. This finding supports a previous study by Dorph, Bathgate, Schunn and Cannady (2017) in which fascination was found to be negatively correlated with having a career goal at all. However, in all the cases, it was revealed that the students gained information about the careers presented and were able to share what the experts' job entails emphasizing sector-specific knowledge and how this relates to their teaching unit. Perhaps even more noteworthy is that the students perceived learning about careers very useful for their future subject and career choices claiming that it is something missing from school lessons. Consisted with Archer, DeWitt and Dillon's (2014) findings, even though the intervention did not radically change students' career choices, it had a positive effect on broadening their understanding of the careers related to their teaching unit.

Overall, the scenario features that could possibly generate students' SI and raise career awareness pertain to primarily (a) promoting students' active engagement and self-regulated learning using PBL and novelty aspects, (b) establishing connections between theory and practice by transferring science concepts to a real-life-personally-relevant context and, (c) carefully integrating the career aspect by promoting a more personal interaction with experts and gain a more nuanced understanding of its practical aspect and the theory behind it. This study shares some interesting empirical evidence in terms of certain principles that may facilitate the design and implementation of career-oriented curricula in science classrooms with the potential to enhance students' interest in science and foster related career aspirations. These findings could be used to further theorize about the development of SI and career-oriented instruction adding to the existing body of literature.

ACKNOWLEDGEMENT

The research project is supported by the European Union through the Horizon 2020 program, Grant Agreement No. 665100.

REFERENCES

Archer, L., DeWitt, J & Dillon, J. (2014). 'It didn't really change my opinion': exploring what works, what doesn't and why in a school science, technology, engineering and mathematics careers intervention. *Research in Science & Technological Education*, 32(1), 35-55.

Bandura, A. (1986). Social foundations of thought and action: A social cognitive theory. Englewood Cliffs: Prentice Hall.

Blotnicky, K. A., Franz-Odendaal, T., French, F., & Joy, P. (2018). A study of the correlation between STEM career knowledge, mathematics self-efficacy, career interests, and career activities on the likelihood of pursuing a STEM career among middle school students. *International journal of STEM education*, 5(1), 22.

Brown, S. D. & Lent, R. W. (1996). A social cognitive framework for career choice counseling. *The career development quarterly*, *44*(4), 354-366.

Cleaves, A. (2005). The formation of science choices in secondary school. *International Journal of Science Education*, 27(4), 471–486.

Constantinou, C. P., Tsivitanidou, O. & Rybska, E. (2018). What Is Inquiry-Based Science Teaching and Learning? In: Tsivitanidou, O.E., Gray, P., Rybska, E., Louca, L. & Constantinou C. P. *Professional development for inquiry-based science teaching and learning*, pp. 1-23, Springer.

Dorph, R., Bathgate, M. E., Schunn, C. D., & Cannady, M. A. (2017). When I grow up: the relationship of science learning activation to STEM career preferences. *International Journal of Science Education*, 40(9), 1034-1057.

Drymiotou, I., Papadouris, N. & Constantinou, C. (2018). Using Scenarios to Enhance Students' Interest in Science and Promote Career Awareness. In Finlayson, O.E., McLoughlin, E., Erduran, S., & Childs, P. (Eds.), Electronic Proceedings of the ESERA 2017 Conference. Research, Practice and Collaboration in Science Education, Part 2: Learning Science: Cognitive, Affective, and Social Aspects (co-ed. Russell Tytler & Graça S. Carvalho), (pp. 304-315). Dublin, Ireland: Dublin City University. ISBN 978-1-873769-84-3.

Gottlieb, J. J. (2018). STEM career aspirations in Black, Hispanic, and White ninth-grade students. *Journal of Research in Science Teaching*, 55(10), 1365-1392.

Hidi, S. & Renninger, K. A. (2006). The four-phase model of interest development. *Educational Psychologist*, *41*(2), 111–127.

Holmegaard, H. T., Madsen, L. M., & Ulriksen, L. (2014). To choose or not to choose science: Constructions of desirable identities among young people considering a STEM higher education programme. *International Journal of Science Education*, 36(2), 186-215.

Kudenko, I., Simarro, C. & Pintó, R. (2017). Fostering European Students' STEM Vocational Choices. In Cognitive and Affective Aspects in Science Education Research (pp. 323-338). Springer, Cham.

Lykkegaard, E., & Ulriksen, L. (2019). In and out of the STEM pipeline–a longitudinal study of a misleading metaphor. *International Journal of Science Education*, 1-26.

OECD (2017). OECD Science, Technology and Industry Scoreboard 2017: The digital transformation, OECD Publishing, Paris, https://doi.org/10.1787/9789264268821-en.

Palmer, T. A., Burke, P. F., & Aubusson, P. (2017). Why school students choose and reject science: a study of the factors that students consider when selecting subjects. *International Journal of Science Education*, 39(6), 645-662.

Palmer, D., Dixon, J., & Archer, J. (2016). Using situational interest to enhance individual interest and science-related behaviours. *Research in Science Education*, 47(4), 731-753.

Papadouris, N. & Constantinou, C. P. (2017). Integrating the epistemic and ontological aspects of content knowledge in science teaching and learning. *International Journal of Science Education,* 39 (6), 663-682.

Papadouris, N. & Constantinou, C. P. (2014). Approaches employed by sixth-graders to compare rival solutions in socio-scientific decision-making tasks. *Learning and Instruction,* 20 (3), 225-238.

Potvin P. & Hasni A. (2014). Interest, motivation and attitude towards science and technology at K-12 levels: a systematic review of 12 years of educational research. *Studies in Science Education*, *50*(1), 85-129.

Rotgans, J. I., & Schmidt, H. G. (2012). Problem-based learning and student motivation: The role of interest in learning and achievement. In One-day, one-problem (pp. 85-101).

Stets, J. E., Brenner, P. S., Burke, P. J., & Serpe, R. T. (2017). The science identity and entering a science occupation. *Social Science Research*, 64, 1-14.

Taskinen, P.H, Schütte, K., & Prenzel, M. (2013). Adolescents' motivation to select an academic science-related career: the role of school factors, individual interest, and science self-concept, *Educational Research and Evaluation*, 19(8), 717-733, DOI:10.1080/13803611.2013.853620

Vincent-Ruz, P., & Schunn, C. D. (2018). The nature of science identity and its role as the driver of student choices. *International journal of STEM education*, 5(1), 48.

AIMING FOR AN INTEGRATED PERSPECTIVE ON MODELS OF LIGHT IN THE SECONDARY SCHOOL

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We discuss a teaching experiment on the introduction of elements of quantum physics already at the level of the fourth year of Italian high school (17-18 years old students) using Feynman's sum over paths approach. More precisely, the educational sequence is based on a continual dialectic juxtaposition between the wave and the Feynman's sum over paths models of light, and constitutes an attempt to provide a unifying perspective on different theories of light encountered by students in high school, and often perceived as disconnected: the ray model, the wave model, the quantum model. A focus of the work is on gradually introducing innovative elements in the traditional high school approach. The analysis of the experimentation data shows very rich and complex patterns, allowing to identify activities which may be more productive for students and to uncover weak points and student's difficulties.

Keywords: Light, sum over paths, optics

INTRODUCTION AND THEORETICAL FRAMEWORK

The teaching of light in the secondary school physics course can present itself to students as the progressive introduction of different theories (ray optics, wave optics, electromagnetic optics, the photon model) where very little time is devoted to explaining their relationship. Looking at the Italian textbooks, ray optics and wave optics are presented in very different parts of the course, corresponding to very different student ages: geometrical optics at grade 10, and wave optics at grade 12. Then, electromagnetic waves and a very basic (mainly phenomenological) photon model are introduced in grade 13, the last one in Italian high school. With the possible exception of the connection between wave optics and Maxwell's equation, very little or no space is devoted in textbooks to their compatibility or respective domains of validity. Such approach could possibly exacerbate student difficulties and confusions between the wave and ray model, which have been observed even at University level (Wosilait et al., 1999). Also, as more than a hundred years have elapsed from the initial formulations of the idea of a light quantum, many researchers and teachers have felt the need of going beyond the quasi-historical (Whitaker, 1979) approach offered by a majority of textbooks, and proposing to students a deeper conceptual reconstruction of quantum physics, emphasizing its structure as "a rational theory, with its own rules, its own language and first of all, its own facts" (Fabri, & Wheeler, 1996). Thus, the value of the theory as a breaking point with the classical conceptions should not (or not only) be simply stated within a meta-scientific, historical-like narrative, but should become apparent from the internal coherence of the non-classical model and its capability to explain physical facts.

In part in response to these needs, our group has proposed to introduce the photon model using Feynman's sum over paths approach already at the fourth year of secondary school, presenting it as the currently accepted synthesis of the secular debate between the corpuscular and wave models of light (Malgieri, Onorato, & De Ambrosis, 2015). Feynman's model allows to interpret all the traditional wave phenomena (interference, diffraction etc.) in terms of photons, and also provides a clear picture of how Fermat's principle, which is the foundation of ray optics, may arise from the rules of the sum over paths model, in the limit of small wavelengths with respect to relevant length scales of the problem. Thus, following this route, students can be led to juxtapose and compare models, and critically examine the relationship between them. The research question which has inspired the design of our teaching-learning sequence can be summarized as follows: can the sum over paths approach be used to help students acquire, early in their career, an integrated mental model of light, with a conceptual understanding of the connection between the photon model, wave theory, and ray optics?

The teaching-learning sequence (TLS) we developed constitutes a first attempt at transposing such idea in the educational practice. The main focus of the sequence is on the juxtaposition of the wave and photon models of light, and the need for a statistical interpretation of the results of wave optics, explained in terms of Feynman's model. In broad terms, the sequence comprises two main blocks of activities; the initial part is tightly connected to experimental evidence, as the phenomena of interference, diffraction and iridescence (thin film interference) are observed and analyzed in the laboratory, and explained in terms of the wave theory of light; in the second part, following rather closely the track of Feynman's book *QED* (Feynman, 1985), students are presented with novel, inescapable evidence demonstrating the existence of photons as a fundamental constituent of light, and the sum over paths model is introduced as a way of making sense and interpret the phenomena previously observed in terms of photons.

STRUCTURE OF THE TLS

The structure of the TLS is schematically reported in Table 1.

The first three lessons of the TLS consist of laboratory activities. The experimental phenomena observed, all of which involve light interference, starting from the iridescence of soap bubbles, are interpreted and modelized using a wave model which is directly derived from an analogy with sound and mechanical waves, as it is usual in the high school treatment at this level. In the fourth lesson, which is the heaviest in theory content, we pose the problem of the evidence for light quantization, and of the inconsistency of such evidence with both the classical wave and particle models. Feynman's model of the sum over all possible paths in its simplest form is introduced; and in the three final lessons the model allows to explain and re-interpret the experimental evidence of light interference phenomena. In the last lesson, which circularly closes the sequence, students work individually on a guided problem which returns on thin film interference (responsible for bubble iridescence) from the point of view of the Feynman model.

An important element in our sequence is the possibility of visualizing the mathematical model underlying quantum theory, a possibility provided to students mainly through GeoGebra simulations (Malgieri, Onorato, & De Ambrosis, 2014, 2018). The issue of providing a visual representation of quantum objects has long been debated in the research literature, with several authors arguing that such representation may favour the persistence of classical or hybrid quantum-classical conceptions. By design, the simulations we use, or guide students to produce, do not contain any direct visual representation of quantum objects, but only represent elements of the experimental setup (source, detectors, and physical constraint), and elements of the model such as paths and their associated tiny arrows or phasors. Even so, great attention to students' choice of words during their work is necessary to prevent overly concrete interpretations of elements of the model (e.g. the possible paths as alternative trajectories, or phasors representing amplitudes as vectors connected to some physical quantity) which have sometimes been reported for the educational use of Feynman's approach (Malgieri, Onorato, & De Ambrosis, 2017). It is also worth mentioning that in this experimentation we tried to have students take a more active role, involving them not only in the manipulation of existing simulations, but also in the creation of a new one representing the phenomenon, discussed several times within the sequence, of thin film interference.

Activity (location and time)	Experiments	Theory	Methods
1. Iridescence (Physics lab, 1 hour)	Observation of iridescence in soap bubbles	Wave model explanation of iridescence	Group work on the explanation of iridescence.
2. Interference (Physics lab, 1.5 hours)	Experiment on two slit interference	Wave model explanation of two slit interference	Laboratory group work
3. Diffraction (Physics lab, 1.5 hours)	Measurement of the width of a hair	Wave model explanation of light diffraction	Laboratory group work
4. Feynman's model (Classroom, 1.5 hours)		Evidence for the existence of photons and introduction to Feynman's model	Frontal lesson
5. Applications (Classroom, 2 hours)		Explanation of interference, diffraction and refraction using Feynman's model	Work in pairs on interference from multiple slits
6. Visualization of the model (Computer lab, 1 hour)		Explanation of thin film interference using Feynman's model	Group task on the construction of a GeoGebra simulation on thin film interference
7. Working with the model (Classroom, 2 hours)			Individual work on thin film interference using Feynman's model

Table 1. Structure of the TLS

The comparison between the wave and photon models of light runs as a common thread through the whole sequence. The central idea is that wave theory provides, in a statistical sense for a large number of photons, the same results which are given as probabilities for individual quantum objects by Feynman's approach. The connection with ray optics is developed essentially in lesson 5, when the explanation of light refraction using the sum over paths approach offers the possibility to show students how the results of geometrical optics are recovered in the limit of small photon wavelength.

Because of the age of students and the time available for the teaching sequence, only some essential ideas about quantum physics were discussed with students. We concentrated mainly on the way probabilities are computed in quantum physics for events (which in our case were always photon detections) which can happen through different, mutually exclusive routes, which is the cornerstone of Feynman's approach (Feynman, 1948, 1985). Most importantly, we attempted to begin building the language of quantum physics: the concept of a quantum object as a different entity from both a particle and a wave; the source-to-detector philosophy (Dobson, Lawrence, & Britton, 2000)); the general way of approaching a problem by considering all alternatives which lead to the same experimental outcome for the system as a whole.

METHODS AND CONTEXT

Aiming at a high level of students' participation and motivation in the activities, we choose to avoid traditional frontal lessons almost entirely; frontal teaching has been necessary only within the fourth lesson, for the introduction of the "rules of the game" of Feynman's approach. The privileged educational strategy was group or pair work, both in the physics laboratory, in the computer lab and in the classroom, using worksheets for guided inquiry experiments, guided problem solving, and activities involving the use or the construction of simulations. The worksheets filled in by the students allowed to collect a large amount of data with important indications on the critical points in the development of students' conceptual understanding.

The experimentation involved four classes (around 80 students) at grade 12 of science-intensive high school ("Liceo Scientifico") Taramelli in Pavia. The duration was about 10-11 hours in each class, in November and December 2017. The experimentation was conducted by a researcher, which was not the regular physics teacher in the classes. On a qualitative level, student's participation and interest during the experimentation was generally high, and they participated to the proposed activities with interest and positive attitude.

RESULTS AND CONCLUSIONS

Data collected during the teaching learning sequence includes laboratory sheets and reports, worksheets used by the students for exercises and problems, and teacher's notes on students' comments, questions and difficulties. Here we shortly report the main results from the analysis of such data.

1. The sequence was appropriate for the age of students, both in its formal and conceptual content. The analysis of the worksheets in most cases shows a majority of correct and complete answers to each one of the questions proposed in exercises and problems; this is especially true when students are required to work in pairs (for example, problem proposed in lesson 5, see Figure 1). When working individually, students may have difficulties with the details of Feynman rules (e.g. the phase shifts due to reflection) but they appear to master reasonably well the general conceptual meaning of the approach. For the final worksheet on thin film reflection, completed by the students individually in Lesson 7 (see Figure 2), the percentage of answers displaying a general understanding of the model was 73%, while answers completely correct in all details were 49% (sample N = 76 students).
2. Students were in general well disposed towards a probabilistic/statistic reading of natural phenomena, and the new language introduced by Feynman's approach. However, sporadic cases of strong epistemological resistance were observed. For example, a student objected that she did not consider it sufficient to learn how to compute probabilities, but she desired instead a deeper understanding of why Nature

behaves in such a way. Since the epistemological aspects of quantum theory were not a focus of the present work, students were not encouraged to entertain in philosophical debates for long times. Cases of tenacious opposition to the tenets of quantum physics by secondary school students were observed and discussed recently in the physics education community (Malgieri, Onorato, & De Ambrosis, 2017; Ravaioli, & Levrini, 2017).

3. The objective of providing a comprehensive, integrated perspective on the theories of light appears to have been partially met. Students understand and correctly describe the probabilistic-statistic relationship between the wave and photon theories. However, ray optics appears to be too far in the past in their school curriculum (they studied it two years earlier) to recall or apply correctly its rules, and to grasp the connection with Feynman's approach. This is due in part to the fact that in the Italian tradition geometrical optics is very rarely taught as stemming from Fermat's principle but more often as a phenomenological theory. Future experimentation will explore strategies for further reinforcing the student's understanding of the relationship between the sum over paths approach and ray optics.

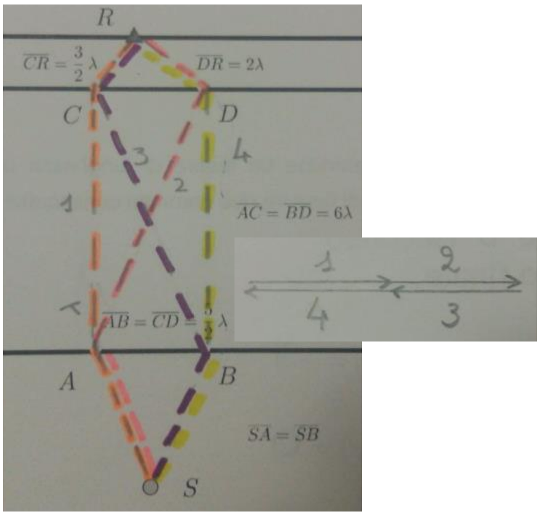

Figure 1. – Pictures produced by a student pair of the possible paths and (in the inset) phasors for computing the detection probability for a problem of photon interference from successive slits.

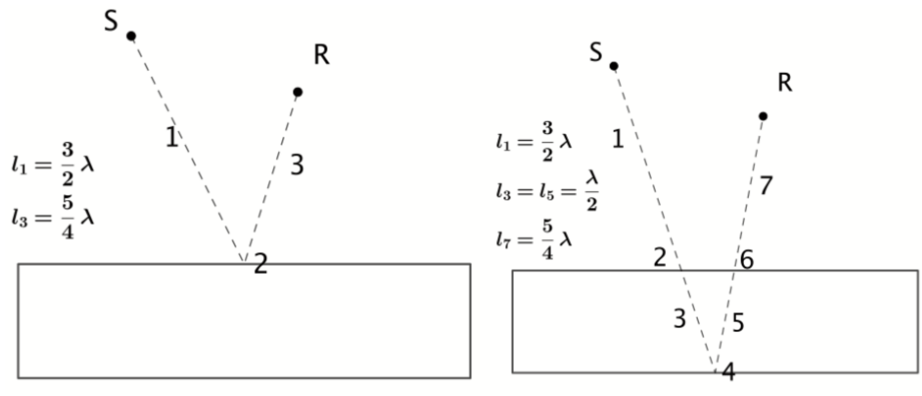

Figure 2. – Part of the worksheet on thin film reflection. Students are required to solve the problem of finding the reflection probability for two different wavelengths of light. The incidence of light is considered as approximately normal to the surface, and multiple internal reflections are ignored (but the issue is discussed with students).

The objective of providing a comprehensive, integrated perspective on the models of light appears to have been partially met. Students understand and correctly describe the probabilistic-statistic relationship between the wave and photon model. However, ray optics appears to be too far in the past in their school curriculum (they studied it two years earlier) to recall and apply correctly its rules, and to grasp the connection with Feynman's approach. This is due in part to the fact that in the Italian high school geometrical optics is very rarely taught as stemming from Fermat's principle, but more often as a phenomenological theory. Future experimentation will explore strategies for further reinforcing students' understanding of the relationship between Feynman's photon model and ray optics.

ACKNOWLEDGEMENT

The authors wish to thank Dr. Dario Codegoni Principal of the "Taramelli-Foscolo" High Scool, and the whole group of Math and Physics teachers of the same school for their collaboration and support to this work.

REFERENCES

Dobson, K., Lawrence, I., & Britton, P. (2000) The A to B of quantum physics. Phys. Ed., 35(6), 400

Fabri, E., & Wheeler, J. A. (1996). Come introdurre la fisica quantistica nella scuola secondaria superiore. La Fisica nella Scuola, XXIX, 63-80.

Feynman, R.P. (1948) Space-time approach to non-relativistic quantum mechanics, Rev. Mod. Phys. 20, 367.

Feynman, R. P. (1985). QED: The strange theory of light and matter. Princeton University Press.

Malgieri, M., Onorato, P., & De Ambrosis, A. (2014). Teaching quantum physics by the sum over paths approach and GeoGebra simulations. European Journal of Physics, 35(5), 055024.

Malgieri, M., Onorato, P., & De Ambrosis, A. (2015). What is light? From optics to quantum physics through the sum over paths approach. In Teaching/learning physics: integrating research into practice. Proceedings of the GIREP-MPTL 2014 International Conference. C. Fazio and RM Sperandeo Mineo (eds.) ISBN (pp. 978-88).

Malgieri, M., Onorato, P., & De Ambrosis, A. (2017). Test on the effectiveness of the sum over paths approach in favoring the construction of an integrated knowledge of quantum physics in high school. Physical Review Physics Education Research, 13(1), 019901.
Malgieri, M., Onorato, P., & De Ambrosis, A. (2018). GeoGebra simulations for Feynman's sum over paths approach. Nuovo Cimento C Geophysics Space Physics C, 41.
Ravaioli, G., & Levrini, O. (2017). Accepting quantum physics: analysis of secondary school students' cognitive needs. In Conference proceedings, ESERA Conference.
Whitaker, M. A. B. (1979). History and quasi-history in physics education. I. Physics education, 14(2), 108.
Wosilait, K., Heron, P. R., Shaffer, P. S., & McDermott, L. C. (1999). Addressing student difficulties in applying a wave model to the interference and diffraction of light. American Journal of Physics, 67(S1), S5-S15.

A TEACHING-LEARNING SEQUENCE TO BRIDGE THE GAP FROM MICRO TO MACRO IN THERMODYNAMICS

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In this paper we report about our progress in developing and testing a teaching-learning sequence (TLS) meant to lead high school students to an integrated perspective on the subject matter, to give them a taste of the computational side of the discipline, and have them reflect on its foundational aspects. In addition to aiming at traditional disciplinary learning goals, the TLS uses multiple strategies to activate and maintain students' engagement and interest. The sequence starts from a motivating activity on the irreversibility of processes and covers the first and second principle of thermodynamics and the concept of entropy. A central activity on thermal contact involves the use of a playable stochastic dice and coin toy model, which is meant to act as a mediator between the experimental results and theory, as well as to introduce elements of group game, with an expected increase in students' engagement. Another pivotal point in the sequence is an open discussion, stimulated by the reading of passages from Boltzmann, Loschmidt and Zermelo, on the compatibility between the reversible laws of Newton's mechanics and the irreversibility contained in the second principle of thermodynamics. The TLS was tested with a class of 23, grade 11 students of a science-oriented high school

Keywords: Thermodynamics, toy models, simulations

INTRODUCTION

The teaching of thermodynamics has been in past years among the most openly and widely debated areas of physics education. Poor educational results and a high incidence of alternate mental models of thermodynamics concepts have been consistently reported by many authors at the level of introductory college instruction (Loverude, 2015). Based on such data, proposals of curriculum renewal, innovative teaching learning sequences and educational reconstructions have been advanced. In relatively recent years, the idea of a "computational" approach to the teaching of thermodynamics, heavily based on computer simulations, has gained momentum (Moore & Schroeder, 1997). However, these proposals are usually centered on undergraduate education, and difficulties are perceived in promoting computational thinking at the level of secondary school. Also, several authors have argued that the traditional dichotomy between microscopic and macroscopic approaches to the subject matter needs to be downplayed, in favor of a more integrated approach in which the student can be led to think to a given problem under both perspectives (Reif, 1999; Levrini et al., 2010). Our group has been involved in research on the teaching of thermodynamics for a number of years, and has been part of the drive for innovation coming from the computational perspective, especially by proposing strategies for making computer simulations an effective bridge between theoretical models and experiment, and by investigating the outcome of the use of computer simulations in the teaching-learning process (Borghi et al., 2004). In recent times we have started developing an approach to different problems in physics which is based on activities where student groups compare the results of a real low-cost experiment with those of a) a playable dice/coin model and b) a numerical simulation extending the stochastic model to a number of elements not easily achieved by actually performing the game with physical dice or coins. In this perspective the design of simulations still plays a significant role, but such simulations do not take the lead from theoretical considerations but are motivated (and made easier to understand) as extensions of playable games of chance. The success of the toy model and simulation in emulating the behavior of real systems is then, only as a last step of the activity, explained in terms of a more complete microscopic theory. This idea has been tested with problems coming from different areas of physics: radioactivity, luminescence, and thermal contact (Onorato et al., 2017; Malgieri et al, 2018) and in the present work we used it as a central activity for a Teaching-Learning Sequence (TLS) on thermal phenomena, irreversibility and the second principle of thermodynamics for the secondary school. The TLS here presented and tested constituted a substantial revision and re-design of the one we discussed in Malgieri et al., 2016; our aim in particular was to increase the engagement of all students, proposing diverse activities capable of "activating" students with different skills and interests, improving the laboratory and game sessions, expanding the dimension related to the discussion of historical controversies.

THEORETICAL FRAMEWORK

Design of the TLS

The design of the teaching-learning sequence is based on a "three-dimensional approach" (Besson et al., 2010), involving a synergic integration of a critical analysis of the scientific content in view of its reconstruction for teaching, an overview of current teaching materials such as textbooks, and an analysis of educational research on the topic, with a particular focus on the literature on student difficulties. In particular, we considered research on student difficulties on the first principle of thermodynamics (Loverude et al., 2002); on the second principle and the concept of entropy (Loverude, 2015; Christensen et al., 2009; Leinonen et al., 2015); on general concepts of probability and statistics related to the teaching of thermal physics (Loverude, 2009). Fundamental choices, supported by much previous research, were to take a microscopic approach (Moore & Schroeder, 1997; Reif, 1999) and to abandon the order/disorder metaphor for introducing entropy (Leff, 1996; Wei et al., 2014). The analysis of foundational and historical-epistemological issues, with a focus on long standing historical debates (Steckline, 1983) played a significant role both in our initial design and in the following revision.

The construct of engagement

In the process of revision which led to the current version of the TLS, a central role was played by the construct of engagement (Mosher & McGowan, 1985; Fredricks et al., 2004). Engagement has a long history in the science education literature, but recent consensus has formed that it should be regarded as a multi-dimensional construct consisting of three interrelated dimensions: behavioral, emotional, and cognitive (Fredricks et al., 2016).

Behavioral engagement includes characteristics such as participation, effort, attention, positive conduct; emotional engagement primarily highlights positive and cooperative interactions with classmates, and self-identification with the current task or topic; cognitive engagement can be defined as the student's individual psychological investment in learning, which, if high, allows him/her to exert the necessary effort for comprehension of complex ideas. According to Newmann (1992) engagement is improved in learning environments in which the tasks students are confronted with (a) are authentic; (b) give students the opportunity to take responsibility for design, execution, and evaluation; (c) provide opportunities for collaboration; (d) require diverse forms of talents, maybe also those which are not often elicited in school; and (e) provide opportunities for fun. Yonezawa et al. (2009) also highlight the importance of allowing students practice and discuss critical thinking with respect to the accepted norms of the discipline in a favorable, democratic environment. Cavanagh et al. (2009) hypothesize that a necessary element for student's engagement, resides in the balance between their expectations for learning before the activity and their actual capability to learn during the activity. A main objective of the revision and re-design of our TLS was to improve as much as possible student's engagement, while preserving or improving the very good results on disciplinary learning of the sequence, reported in Malgieri et al. (2016), which shared its core disciplinary structure with the one discussed in this article.

Long term research questions concerning the development of our TLS can be described as follows. 1) Can playable toy models contribute to students' engagement and conceptual understanding in the learning of thermodynamics? 2) Is the task of building computer simulations which reproduce and extend the playable toy model bringing it closer to the real experiment meaningful and productive for students' learning? 3) Are 17 year old students mature enough for the debate on the foundations of thermodynamics to have a positive effect on their learning, and contribute to their understanding of the nature of science?

STRUCTURE AND DESCRIPTION OF THE TLS

The TLS has a total duration of about 22 hours and is structured according to the following steps: 1) Motivating activity on reversibility and irreversibility. 2) Microscopic time reversal and macroscopic irreversibility. 3) Kinetic theory of gases and the first principle of thermodynamics, concepts of microstates and macrostates. 4) The approach to thermal equilibrium. 5) Boltzmann's definition of entropy and the second principle of thermodynamics. 6) The historical debate on the second principle of thermodynamics. 7) Entropy and heat exchanges: a justification of Clausius' formula. In Figure 1, the TLS is represented in schematic form; the steps 3, 5 and 7, have a mainly theoretical content and are mostly delivered in the form of frontal lessons; elsewhere, such teaching strategy is kept to a minimum; group tasks, pair tasks, whole class discussions and gaming/coding activities are the prevailing instructional settings as will be discussed more in detail below.

Motivating activity on reversibility and irreversibility

In the initial activity students, divided in groups, are required to produce, videos for physical events which either look realistic also if the video is time-reversed, and videos which don't have such property, using similar equipment in both cases. The activity is not preceded by an explanation of its meaning (which is discussed later) and is meant to provide students with an intuitive understanding of the concept of irreversibility. Another aim was to activate students' engagement on the nontrivial (but within their reach) task of producing videos which look realistic when played backwards. Students worked on several different systems, including the well known cases of marble collisions (one-to-one and one-to-many collisions); cart collisions (elastic and inelastic) and special systems designed to provide a macroscopic analogy to the issue of energy dissipation, in which energy comes to be hidden in the microscopic world. Overall, a disciplinary goal was to provide students with the intuitive idea that irreversibility is connected to energy "spreading and sharing" (Leff, 1996) either in space, or over more degrees of freedom than those it was constrained to initially. However, no connection between the spreading and sharing of energy and the concept of entropy was made at this time.

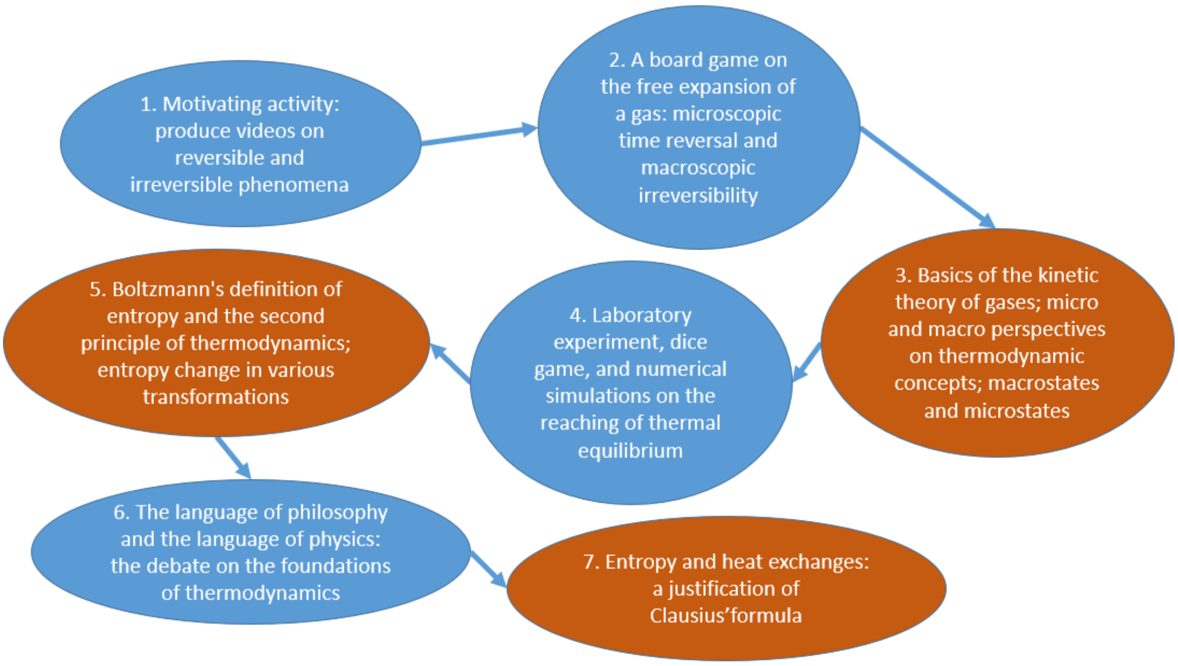

Figure 1. Schematic representation of the TLS. Steps colored in orange have a mainly theoretical content and are delivered mostly in the form of frontal lessons; on the contrary, steps colored in cyan involve significantly or entirely group tasks, laboratories, open discussions and other less conventional activities.

A board game on the free expansion of a gas.

In the context of a worksheet to be completed working in pairs, students play a board game meant to represent, in a stylized way, the free expansion of a gas. Four tokens move on a hexagonal grid cardboard according to deterministic rules (no randomness is involved) as can be seen in Figure 4. The rules are designed in such a way that movement of tokens is symmetric under time reversal in the same sense as Newton's laws. The game starts with all tokens on the left side. Students are led to reflect on the fact that, although the dynamics of the system is symmetric by time reversal, this does not mean that the two cases are equally likely that a) the tokens, starting from half the board, expand into the other half; or that b) being initially spread on the whole board, they spontaneously constrain themselves to half the board in a certain number of moves. In other words, the game stimulates students to reflect on the only apparent contradiction between microscopic laws that are symmetric under time reversal and the macroscopic concept of irreversibility. Proceeding on the worksheet after the game, students are led to reflect on the fact that, if the number of "tokens" approached 10^{23}, events such as the self-constraining of tokens on only one side of the box would become incredibly unlikely. Within students' worksheet, the game is also played using a random rule (with six sided dice) for token movement. In that case, considerations of time reversal symmetry do not hold, but the general probabilistic treatment of the chance of tokens constraining themselves to half the board remains, exactly, the same. The game can be seen as an introduction to the Loschmidt paradox, which will be later discussed with students.

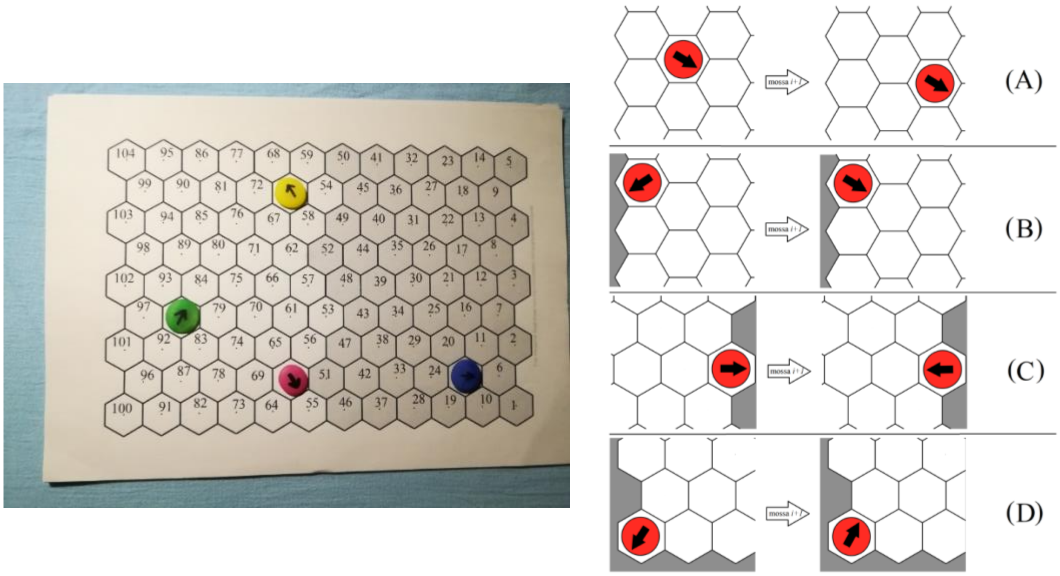

Figure 2 – Board game on the free expansion of a gas. (Left) the board and tokens (Right) the special moves representing wall collisions. Token collisions are not considered in the game.

Laboratory activity on thermal equilibrium

After a theoretical interlude in which, building on the intuitive understanding gained from the initial activities, students are introduced to 1) a microscopic perspective on the ideal gas law, 2) the first principle of thermodynamics, 3) the concepts of macrostates and microstates, a new group activity is performed in the physics laboratory. There, students start with simple experiments on heat transfer, namely between water in a container and the environment, and between two water samples at different temperatures. After the experiment, students are explained a simple toy model representing thermal contact. A cardboard has two rows of squares, with different numbers of squares, which can be either filled with a coin or empty. According to the roll of two dice, coins are exchanged between the rows. The model also allows to define a "toy-temperature" (Onorato et al., 2017) inspired by the kinetic definition of temperature, which is proportional to the ratio between the number of occupied squares of row, and the total number of squares of the same row.

The number of squares on each row corresponds to the number of faces of two dice each group has available (for example, a 12 sided and a 20 sided dice). A certain quantity of coins is initially distributed on the squares of the two rows so that one is almost filled, one almost empty. The experiment proceeds with students throwing the two dice, and moving the coin from one row to the other if the roll of the two dice corresponds to one filled and one empty square. Students repeat the process of throwing dice many times exchanging each time the positions of coins until they declare that the system is essentially “at equilibrium” (30-35 times are typically sufficient).

In the next lesson, students are taken to the computer lab (the activity spans 4 hours in total, of which 2 in the physics lab and 2 in the computer lab) where each of the groups is given the task of writing down the abstract pseudo-code for a computer program simulating the toy model for an arbitrary number of squares on the two rows, and initial coins. Subsequently the teacher helps students to write the actual code in Matlab/Octave (no more than 20 lines of code), and perform simulations with a larger number of rows and coins observing a progressive reduction of fluctuations away from equilibrium. Finally, the teacher analyses the toy model as a game of probability along the lines described in Onorato et al. (2017) drawing an analogy between the board game and the actual process of heat transfer. The most significant result of tihis comparison is the derivation from probabilistic consideration of the exponential behavior of the approach to equilibrium, observed in the real experiment. Thus, the toy model is justified as a simplification of the underlying microscopic dynamics of the real problem of heat transfer. Also, the toy model connects to the game of the free expansion of a gas, in the sense that allows to represent the equilibrium macrostate as the one with the highest multiplicity in microstates. The toy model is also coherent with the intuitive idea of spreading and sharing of energy, in that irreversibility is tied to an increase in the number of energy microstates available to the system (considering first the two objects as isolated, then in thermal contact). The activity in the computer laboratory proved to be quite engaging for students, activating in particular those with an interest in informatics.

Classroom debate on the foundations of thermodynamics

The activity developed in three steps: first (1), in a joint lecture with the philosophy teacher, students are introduced to the language of paradoxes, starting from the paradoxes devised by ancient Greek philosophers. The goal of the lecture is to introduce students to the idea that while the scientific method signs a discontinuity between the language of physics and the one of philosophy, there is also a line of continuity, consisting in the use in physics of elements of language such as paradoxes and mental experiments. Then (2), students are given an individual worksheet containing original texts of physicists of the XIX century, debating Loschmidt’s paradox, the paradox of Maxwell’s demon, and the meaning of the second principle. Finally (3), the texts are openly debated in the classroom.

The discussion was very participated and, according to some of the interviewed students, contributed greatly to increase students’ self-confidence. The activity was an occasion for students to practice critical thinking with respect to the accepted dogmas of the physical discipline, by taking opposite sides in historical debates. As previously discussed, this may be a key element in promoting students' engagement. The effect of activation and increased engagement was particularly evident in the case of students with a personal interest in philosophical questions and issues.

CONTEXT AND DATA COLLECTION

The TLS had a total duration of 26 hours and was tested with a class of 23, grade 11 students (12 male and 11 female) of a science-oriented high school ("Liceo Scientifico"). Lessons and activities were conducted conjunctly by the teacher of the class, who had participated in the process of revision of the TLS, and a researcher of our group.

Data for the experimentation is very rich and includes pre and post-tests, an initial psychometric test (Raven matrices) evaluating each students' potential, individual notebooks, group lab reports, worksheets, the recording of all lessons, final productions of each group in the form of a PowerPoint presentation, a final online anonymous satisfaction questionnaire, and individual interviews to four students who were selected either because, according to the teacher, had displayed highly unusual engagement in the sequence with respect to other physics lessons, or, in one case, because the student had already a pre-existing strong interest in the discipline. In this article we discuss pre- and post-test data, and some general threads which can be detected in students' satisfaction questionnaire and interviews.

DATA ANALYSIS

Pre-test data

The pre-test was composed mainly by standard items from research-validated assessments on thermal phenomena, most of which taken from the literature discussed in the Theoretical Framework section. Students displayed several incorrect ideas well documented in the literature: for example, 18 students out of 23 defined temperature as a "measure of heat", despite having encountered the ideas of heat and temperature previously in the high school curriculum. The confusion between heat and temperatures also caused many students to refer to thermal contact as the "transfer of temperature" between bodies. Students showed difficulty also with probability and combinatorics: only 6 students out of 23 correctly determined how many numbers of 3 digits can be obtained using 4 basic digits. Also, students performed very poorly (17 out of 23 incorrect answers) with an item concerning the magnitude of fluctuations in samples of different dimensions, generally displaying the belief that the probability of a fluctuation from the mean of given magnitude is independent of the size of the sample and confirming a difficulty already noticed in the literature in the context of the teaching of thermodynamics. As reported in Loverude (2009) this kind of question may be very difficult even for advanced undergraduates. The very low result for this item further highlighted the importance of conducting numerical simulations of our model systems with increasing number of elements, in order to observe directly fluctuations fade away with the growing magnitude of the considered sample.

Post-test data

Data from the disciplinary post-test generally provided encouraging indications, as it did in the version of 2016: although both samples were small, the disciplinary results can be considered similar. For questions which can be compared with the literature (microscopic interpretation of the compression of an ideal gas, variation of the number of accessible microstates for two systems in thermal contact, variation of entropy in the same situation) results are comparable with or better than those reported in the literature for University students. A majority of students seemed to have gained a reasonably good understanding of the concept of entropy, and about half the students could analyze in detail, including correct and complete conceptual explanations, the situation in which the entropy of the universe is increased due to irreversible heat exchange between a initially hot body and the environment. Difficulties persisted in the definition of temperature (7/21 students) and heat (4/21). However, to our disappointment, the misconception that the magnitude of fluctuations from the mean is independent from the size of the sample seemed to be quite robust: notwithstanding our efforts, only 6/21 of students provided the correct answer in the post-test, in a question similar, although not identical to the one of the pre-test.

A general thread in the post-test was that for items requiring an explanation, students generally were extremely prolific in writing, producing long and detailed explanations and analyses for the proposed physical situations. According to the teacher, such result was very unusual for the class. Even when those explanations were not, from a disciplinary point of view, completely correct, the willingness of students of elaborating and reporting them can be considered a sign of increased self-confidence and engagement.

The satisfaction questionnaires

Satisfaction questionnaires were given to students at the end of the sequence in anonymous form. The questionnaire was presented as an online survey which students could complete at home. Question concerned the relation with teachers and fellow classmates, the perceived role of group work, pair work, and a general evaluation of their experience with the TLS. Raw approval rates were very high, with 60% of students providing a fully positive evaluation, and 40% stating that the experience was more on the positive side. Group and interdisciplinary activities were particularly appreciated. However, students were not necessarily, and not all, convinced that their understanding had been improved with respect to traditional teaching: while almost all students report of having been more engaged with the TLS than during the usual lessons, and a majority reports an increased interest for the discipline, only about half of them think that the structure of the TLS was overall beneficial for their understanding. Overall, students' results and questionnaire confirm the prevailing view that the reflexes of student's engagement on cognitive outcomes are not trivial or immediate, although the former may well be a factor influencing the quality of students' learning.

Some general results from students' interviews

It is possible to detect in the interviews some recurring themes: A common students' observation concerns the satisfactory experience in building the knowledge of the subject starting first from group work on games or laboratory activities. Students report that in the first stages of the sequence they could not get the general picture of what they were doing and thus concentrated on the activities with greater personal engagement and without prejudices on what the intended results should have been. However, in the end they were able to connect all what they had done in a coherent picture. One student says "[...] *If one had begun with theoretical lessons, probably there would not have been so much attention, or would have felt so much involved, instead in this way, when theory was presented, it connected to things we had seen already in practice, and all became simpler, so for me it was useful*". Another student observes that this approach allows to understand concepts in a deeper, and probably more long-lasting way. He also remarks that working in this way, theory and disciplinary norms appear to come in response to a necessity of explanation and formalization student themselves perceive, while with the usual approach they come from authority, and are somewhat imposed to them.

Students appreciated the effort of establishing a connection between different areas of physics by adopting a microscopic perspective, and often coming back to the picture provided by mechanics. All students seem aware of the nature of physics as a connected and consistent whole, but also remark that, in the usual teaching and in textbooks, subjects and theories often appear disconnected and unrelated one with another.

One of the interviews which was particularly important for us was to a female student who had generally mediocre results in physics, but was extremely active and engaged in the TLS, and had good results in the final test. She reported the satisfaction she experienced in arriving in some case, to an explanation on her own, and highlighted the importance of the debate on historical controversies in increasing her self-confidence to tell what she thought without fearing that it could be wrong. This student reports having had previously a difficult relationship with physics, which she perceived as something which, she says, "*did not correspond to me*" ; but states that this project gave her again confidence in her possibilities, and the desire to re-approach the subject: "*this project has made flourish a passion which was hidden and so… it was very useful, it brought me the desire to try again*".

Some partly critical observations came from the student with a long-standing personal interest in physics. Although he also appreciated the teaching-learning sequence and most of its activities, he reported that at certain times the approach had confused him, because he was well adjusted to the usual method of having a complete and self-consistent formal presentation of the subject, which he could then understand more in depth using the textbook or other sources.

CONCLUSIONS

Students enjoyed the TLS. This is confirmed by worksheets, interviews, and the online approval questionnaire given to students after the experimentation, in which students' approval rates were very high. Part of the success of the TLS may be due to its capability to "activate", through different activities, students with different personal interests (coding, taking and reversing videos, giving a presentation, philosophical discussion…). Disciplinary results were good but, considering the smallness of both samples, they were not significantly better or worse than in the previous version of the sequence.

The effort of expanding the moments of active learning, group work, and multi-dimensional activity had positive effects in the self-confidence of students, their engagement in the sequence, and the general quality of their argumentation. The quality and complexity of the final productions of each student group (PowerPoint presentations) is also an element confirming such tentative conclusion.

The classroom discussion on historical controversies was also very participated and engaging for students. This was not entirely expected, but we can now confirm that 17 year old students can understand, and become interested in, the historical debate between Boltzmann, Loschmidt, Zermelo, on the meaning of the second principle, and other long-standing issues in the foundations of thermodynamics.

REFERENCES

Besson, U., Borghi, L., De Ambrosis, A., and Mascheretti, P. (2010) Three-Dimensional Approach and Open Source Structure for the Design and Experimentation of Teaching-Learning Sequences: The case of friction. International Journal of Science Education 32 1289.

Borghi, L., De Ambrosis, A., & Mascheretti, P. (2004). From university courses to teaching practice in schools: an example. In Quality Development in Teacher Education and Training, GIREP Book of Selected Contributions of the Second International Seminar (pp. 420-424).

Cavanagh, R., Kennish, P., & Sturgess, K. (2008). Develpment of a theoretical framework to inform measurement of secondary school student engagement with learning. In Changing Climates: Education for Sustainable Futures, 2008 Annual Conference of the Australian Association for Research in Education. AARE.

Christensen, W. M., Meltzer, D. E., & Ogilvie, C. A. (2009). Student ideas regarding entropy and the second law of thermodynamics in an introductory physics course. American Journal of Physics, 77(10), 907-917.

Fredricks, J. A., Blumenfeld, P. C., & Paris, A. H. (2004). School engagement: Potential of the concept, state of the evidence. Review of educational research, 74(1), 59-109.

Fredricks, J. A., Filsecker M., and Lawson M. (2016). Student engagement, context, and adjustment: Addressing definitional, measurement, and methodological issues. Learning and Instruction, 43, 1-4.

Leff, H. S. (1996). Thermodynamic entropy: The spreading and sharing of energy. American Journal of Physics, 64(10), 1261-1271.

Levrini, O., Fantini, P., Pecori, B., Gagliardi, M., Scarongella, M., & Tasquier, G. (2010, June). A longitudinal approach to appropriation of science ideas: a study of students' trajectories in thermodynamics. In Proceedings of the 9th International Conference of the Learning Sciences-Volume 1 (pp. 572-579). International Society of the Learning Sciences.

Leinonen, R., Asikainen, M. A., & Hirvonen, P. E. (2015). Grasping the second law of thermodynamics at university: the consistency of macroscopic and microscopic explanations. Physical Review Special Topics-Physics Education Research, 11(2), 020122.

Loverude, M. (2009) Student Understanding of Basic Probability Concepts in an Upper-Division Thermal Physics Course. AIP Conference Proceedings. Vol. 1179. No. 1.

Loverude, M. (2015). Identifying student resources in reasoning about entropy and the approach to thermal equilibrium. Physical Review Special Topics-Physics Education Research, 11(2), 020118.

Loverude M., Kautz C. and Heron P. (2002). Student understanding of the first law of thermodynamics: relating work to the adiabatic compression of an ideal gas Am. J. Phys. 70 137–48

Malgieri, M., Onorato, P., Valentini, A. and De Ambrosis, A. (2016). Improving the connection between the microscopic and macroscopic approaches to thermodynamics in high school. Physics Education, 51(6), 065010

Malgieri, M., Rosi, T., Onorato, P., & Oss, S. (2018). Looking at phosphorescence with a smartphone, explaining phosphorescence with a dice toy model. Physics Education, 53(6), 065016.

Moore, T. A., & Schroeder, D. V. (1997). A different approach to introducing statistical mechanics. American Journal of Physics, 65(1), 26-36.

Mosher, R., & McGowan, B. (1985). Assessing student engagement in secondary schools: Alternative conceptions, strategies of assessing, and instruments. University of Wisconsin, Research and Development Center.

Newmann, F. M. (1992). Student engagement and achievement in American secondary schools. Teachers College Press, 1234 Amsterdam Avenue, New York, NY 10027.

Onorato, P., Malgieri, M., Moggio, L., & Oss, S. (2017). Microscopic and probabilistic approach to thermal steady state based on a dice and coin toy model. European Journal of Physics, 38(4), 045102.

Reif, F. (1999). Thermal physics in the introductory physics course: Why and how to teach it from a unified atomic perspective. American Journal of Physics, 67(12), 1051-1062.

Steckline, V. S. (1983). Zermelo, Boltzmann, and the recurrence paradox. American Journal of Physics, 51(10), 894-897.

Wei, R., Reed, W., Hu, J., & Xu, C. (2014). Energy spreading or disorder? Understanding entropy from the perspective of energy. In Teaching and learning of energy in K–12 education (pp. 317-335). Springer, Cham.

Yonezawa, S., Jones, M., & Joselowsky, F. (2009). Youth engagement in high schools: Developing a multidimensional, critical approach to improving engagement for all students. Journal of Educational Change, 10(2-3), 191-209.

AN INTERVENTION STUDY ON STUDENTS' DECISION-MAKING USING TRADE-OFFS TO RESOLVE SOCIO-SCIENTIFIC ISSUES

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This study aims to examine the effects of an intervention enhancing students' socio-scientific decision-making. Socio-scientific decision-making necessitates reasoning from multiple perspectives and the use of trade-offs. We developed a socio-scientific issue-based unit for non-science undergraduate students focusing on students' decision-making for resolving conflict around the issue. In this unit, students considered the trade-offs of science and technology and engaged in a decision-making intervention focused on proposing solutions to resolve conflict. The participants were forty-nine non-science undergraduate students. In pre- and post-tests, students were asked to construct arguments on the focal issue. Their arguments were explored mainly in terms of the quality of their decisions. A comparison of pre- and post-tests revealed a general shift to higher-level responses after the intervention. Students' arguments on socio-scientific issues changed from justificatory arguments to proposals for solutions. This demonstrated that the instruction promoted students' socio-scientific decision-making, particularly in generating solutions to resolve issues.

Keywords: socio-scientific issues, decision-making, multiple perspectives

THEORETICAL FRAMEWORK

Socio-scientific issues (SSI) represent complex social dilemmas related to the application of scientific principles and practices. In the last decade, science education researchers and practitioners have made significant advances in the use of SSIs as a context for transforming science learning (Romine, Sadler, & Kinslow, 2017; Sadler & Dawson, 2012). Current literature regarding the effects of SSI interventions reported the beneficial results on interest and motivation, content knowledge, nature of science, and community of practice (e.g., Sadler, 2009). SSI approaches can be an effective means of supporting learning that are aligned with Vision II science literacy, which focuses on the ways in which students conceptualise and use science content and practices through explorations of complex issues (e.g., Zeidler, 2014).

Friedrichsen, Sadler, Graham, and Brown (2016) presented a model for SSI instruction that highlights: (a) a focal issue, (b) the interaction of science ideas and practices, (c) social connections, (d) the use of information and communications technologies (ICT), and (e) a culminating experience that encourages students to synthesise their ideas. In their instructional model, SSI-based instruction should start with the presentation of a compelling issue. Their model posits three interacting elements as the primary substance of students' learning experiences: social connections, science ideas and practices, and ICT. Students ought to substantively apply science ideas and practices as they negotiate the focal issue. They should also have opportunities to consider the social complexities of the focal issue, which often interact with the ways in which the underlying science is interpreted or applied. As they make sense of the focal issue, students should interact with ICT in order to access and analyse new ideas as well as share their ideas with classmates or broader audiences. The culminating experience is designed as an activity for students to synthesise their experiences with the focal issue and apply their learning throughout the unit. In a culminating experience, students return to the focal issue and apply their scientific understandings to grapple with the social aspects of the issue.

Wu and Tsai (2007, 2011) proposed an integrated analytical framework for learners' informal reasoning on SSIs, using three indicators: decision-making modes, reasoning modes, and reasoning level or quality. Decision-making is intuitive when it is spontaneous and immediate, and it is evidence-based when it takes into account information of a factual nature. Reasoning modes are characterized by their social, ecologic, economical, or scientific/technological orientations. The total number of reasoning modes would also be obtained as quantitative measures. The greater the total number of reasoning modes an individual learner utilises, the more he/she is orientated to reasoning from multiple perspectives. Reasoning quality describes the learner's ability to generate arguments using three components: supportive argument, counterargument, and rebuttal.

SSI cannot be solved on the basis of 'simple cause and effect reasoning'. Because of the multidimensionality of SSIs, socio-scientific decision-making necessitates reasoning from multiple perspectives, including scientific, environmental, and social (Lee & Grace, 2012). To examine students' reasoning from multiple perspectives, Lee and Grace (2012) categorised the justifications students provided in support of their decisions into six types, each representing a distinct perspective, and counted the number of perspectives invoked by each student. Some research (Liu, Lin, & Tsai, 2011; Wu & Tsai, 2007) generated the total number of reasoning modes, which was an equivalent indicator to Lee and Grace's (2012) perspectives.

In socio-scientific decision-making, students first need to understand and describe SSIs in its complexity; second, they need to be able to generate solutions that account for multiple perspectives on the issue, and third they have to be able to critically evaluate solutions (Eggert, Ostermeyer, Hasselhorn, & Bögeholz, 2013). Several studies developed various instructional interventions to improve students' socioscientific decision-making performance. Some studies provided a decision-making framework, or provided decision-making strategy training, or provided prompts to reflect on the choice of decision-making strategy (Fang, Hsu, & Lin, 2018). One such structured decision-making framework is as follows: define the problem, options, criteria, information, survey, choice, and review (Sutter et al., 2018). As for an appropriate decision-making strategy, Eggert and Bögeholz (2010) identified the ability to use trade-offs as one crucial aspect of socio-scientific decision-making, and described the use of tradeoffs as a *compensatory decision-making strategy*. In contrast, a non-compensatory strategy means the use of a cut-off. Various instructional interventions have been developed to support students' use of appropriate decision-making strategies, such as introducing the optimization strategy (e.g. Papadouris, 2012), and using additional meta-cognitive approaches (Eggert et al, 2013; Gresch & Bögeholz, 2013; Gresch, Hasselhorn, & Bögeholz, 2013).

These intervention studies focused mainly on choosing the best option or selecting among possible solutions rather than developing new, alternative solutions. Although Eggert et al.'s (2013) socio-scientific decision-making questionnaire consisted of items that represented the development of sustainable solutions to SSIs, they dealt with the summed score of the scale on ‘developing and evaluating solutions’. Kim, Ko, and Lee (2019) designed and implemented the community-based socioscientific issues program (SSI-COMM). This program included the phase of action-taking, where students look for and implement the best solutions to the issue. However, Kim et al. (2019) did not analyze the students' solutions. Furthering these studies, therefore, this study examines students’ socio-scientific decision-making focusing on the ability to generate solutions that account for multiple perspectives, while also considering trade-offs or conflicts around the issue.

AIM AND RESEARCH QUESTIONS

We designed a socio-scientific issues-based curriculum unit for non-science undergraduate students focusing on students’ decision-making for resolving conflict around SSIs. The study used a pre - post intervention approach to investigate the quality of students’ decisions and was guided by two research questions:

1. When students engage in a decision-making intervention and consider the trade-offs of science and technology, is their socio-scientific decision-making orientated towards evidence-based decision-making and reasoning from multiple perspectives?

2. How do the students’ arguments around SSIs change during the intervention? Do their arguments progress from being one-sided to two-sided, and do they transform into proposed solutions to the issue, while accounting for multiple perspectives and considering trade-offs?

METHODS

Participants

Forty-nine non-science undergraduate students (13 male, 36 female).

Curriculum Unit

The goal of the curriculum unit was for the students to generate compromise-based solutions to resolve the conflicts around SSIs, rather than choosing the best option. The theoretical framework of the design of the unit was a model of SSI instruction presented in Friedrichsen et al. (2016). The development of a genetically modified organism, that is, Japanese cedar pollinosis alleviation rice was selected as the focal issue. First students learn the scientific background of the process and treatments of allergies and GMOs [scientific ideas]. In collaborative sessions, students then explored opinions favouring or opposing the focal issue, examining the benefits and drawbacks of the genetic modification technology [social connections]. Collaboratively, they clarified the complex relationships among the opinions and identified six competing perspectives, or trade-offs: financial gain, medical expenses, treatment, side effects, development of genetic modification technology, and environmental impact [scientific practice]. Finally, they constructed a compensatory solution to resolve the conflicts of some of the trade-offs [culminating experience]. Table 1 shows an overview of the instructional unit.

Task

Students were asked to construct arguments as if they were making a public decision on the development of transgenic rice as medicine for pollen allergies. We conducted the pre-test with the whole class at the beginning of the unit. The post-test was implemented as individual homework after the unit.

Analysis

For the first research question, we analysed students' justifications in supportive arguments or counterarguments in terms of the perspectives used, following the methods of Lee and Grace (2012). Six categories were defined to classify perspectives, which were identified during instruction.

This study explored students' decision-making mainly in terms of the level or quality of the decision, focusing on dealing with trade-offs (for the second research question). The quality of students' decisions was analysed utilising three components: supportive arguments, counterarguments, and proposal of solutions. The evaluative rubric is displayed in Table 2. The rubric was composed of six levels, the lowest of which included only an unsubstantiated claim. Successive levels progressed to include justifications, counterarguments, and proposals. Following the rubric of Eggert et al. (2013), students' solution proposals were categorised as 'higher-level' if they were detailed and intended to resolve the conflicts of multiple trade-offs. We regarded such proposals as the result of reasoning from multiple perspectives.

Table 1. Overview of the curriculum unit.

Lesson	Learning activity
1	Introduction of Socio-scientific issues
2	Science ideas: Learn about the scientific aspects of allergies and genetic modification
3	Social connections: Explore opinions of multiple stakeholders.
4	Socio-scientific decision-making task: Pre-test
5	Science practices: Clarify the relationships among the opinions and identify competing perspectives.
6	Generate solutions to resolve conflicts.
Homework	Socio-scientific decision-making task: Post-test

Table 2. Rubric for assessing the quality of the students' decisions and examples from this survey.

Level	Description	Examples
0	Made only simple claims, without justification.	I agree.
1	Made claims justified by supportive arguments, but no counter-arguments (justificatory arguments: One-sided).	I would like to formulate an opinion from the standpoint of opposing the development of Japanese cedar pollinosis alleviation rice. (skip) I do so because according to the opinion of an opposing doctor, drugs currently in use are highly effective and their side effects are known *[supportive arguments]*.
2	Generated supportive arguments and counter-arguments (justificatory arguments: Two-sided).	I would like to formulate an opinion in favour of the development of Japanese cedar pollinosis alleviation rice. (skip) Opponents are concerned about unknown allergies and side effects that the consumption of genetically modified crops may bring *[counter-arguments]*, but all drugs of any sort inevitably come with side effects.
3	Generated two-sided arguments and suggested a need for the proposal to resolve conflict on one trade-offs.	I would like to formulate an opinion in favour of the development of Japanese cedar pollinosis alleviation rice. (skip) Certainly some farmers are opposed to this considering the risk of cross-contamination of ordinary rice *[counter-arguments]*. (skip) Also, when it comes to the stage of actually cultivating the rice in question, it would be vital to prevent the opposing farmers' worry of rice contamination from becoming reality. It will be essential to provide farmers wishing for the development of alleviation rice with a thorough explanation of all such an endeavour would entail,

		and to rigorously manage and cultivate the fields with alleviation rice *[suggest a need for solutions]* .
4	Generated two-sided arguments and constructed a proposal to resolve conflict on one trade-off.	I would like to formulate an opinion in favour of the development of Japanese cedar pollinosis alleviation rice. One reason to oppose it is the dangers associated with it. Unknown side effects are one such danger. (skip) Naturally, with unknown side effects, it is not immediately clear how to deal with them, and thus the number of hospital visits may actually increase rather than decrease *[counter-arguments]*. To prevent such outcomes, long-term experimentation is necessary, but the budget for such is limited. What if we invited individuals, well-informed about the dangers involved, to participate in clinical experimentation and provided them with alleviation rice free of charge or at low cost? *[solutions to resolve conflicts]*. This would reduce the need for developers to spend large amounts of money on long-term experimentation, as well as provide those agreeing to clinical testing of pollinosis alleviation rice with extremely low-cost treatment. After all, it is essential to prove its safety in order for it to be fully accepted by society *[conflicts of side effects]*.
5	Generated two-sided arguments and constructed a proposal to resolve conflict on multiple trade-offs.	I would like to formulate an opinion from the standpoint of opposing the development of Japanese cedar pollinosis alleviation rice. (skip) Advances in genetic modification technology will contribute to the future development of various other types of functional rice and will also benefit developing countries and rural areas *[counter-arguments]*. If we could just reliably eliminate side effects and other risks to health as well as the environmental destruction caused by the spread of modified genes, the value this advancement could provide seems very much worthy. For example, what if at first only a small number of farms were to cooperate with development companies in genetic modifications, in a limited area, isolated from other farms, with rice grown only indoors, as well as distribution limited to take place directly between development companies and farms? *[first solution to resolve conflicts: Environment]* This would prevent contact with other plants and contamination of conventional rice, and thus prevent spread. Furthermore, by delaying practical use of alleviation rice treatment until its safety has been confirmed by repeated clinical experiments, and allowing it only in cases where conventional treatments have failed and the person in question applies for and consents to its use, I believe a minimum level of safety can be guaranteed. *[second solution to resolve conflicts: Side effects]*

RESULTS

First, the students' justifications in supportive arguments or counterarguments were analysed in terms of the perspectives used. Figure 1 displays the frequency data of each perspective used in pre- and post-test. The perspective of treatment was used most; eighty percent or more of the participants used this aspect of information or evidence to make their arguments. Figure 2 illustrates the average number of perspectives the students used. The number of perspectives embedded in the supportive arguments remained the same, while the number of perspectives in the counterarguments increased significantly after intervention ($t(48)=1.359$, *n.s.*; $t(48)=5.322$, $p<.001$). At the post-test, students cited on average two categories of counterargument. Therefore, students became more capable of reasoning from multiple perspectives on the SSIs.

Next, the quality of the students' decisions was rated. Figure 3 presents the distributions of these levels in the pre- and post-tests. More than 80% of the arguments generated in the pre-test were justificatory arguments without proposals to resolve the conflict, and about half of their arguments were one-sided. Most students were able to make evidence-based decisions before the intervention, however inadequately. About 10% of the arguments were rated level 3, as they did not provide a detailed solution themselves. In the post-test, more than half of the students were able to propose a solution for one or more of the trade-offs. The students' decision levels increased significantly from pre-test to post-test (*T=841.50, p<.001*), with a notable increase in the number of arguments at levels 4 and 5. That means students' arguments transformed into proposals of solutions to resolve the conflicts of the one or more trade-offs. Table 3 shows the utilisation rate of each trade-off in solutions students proposed in the post test. Trade-offs of financial gains, environmental impact, and side effects were treated most in students' solutions.

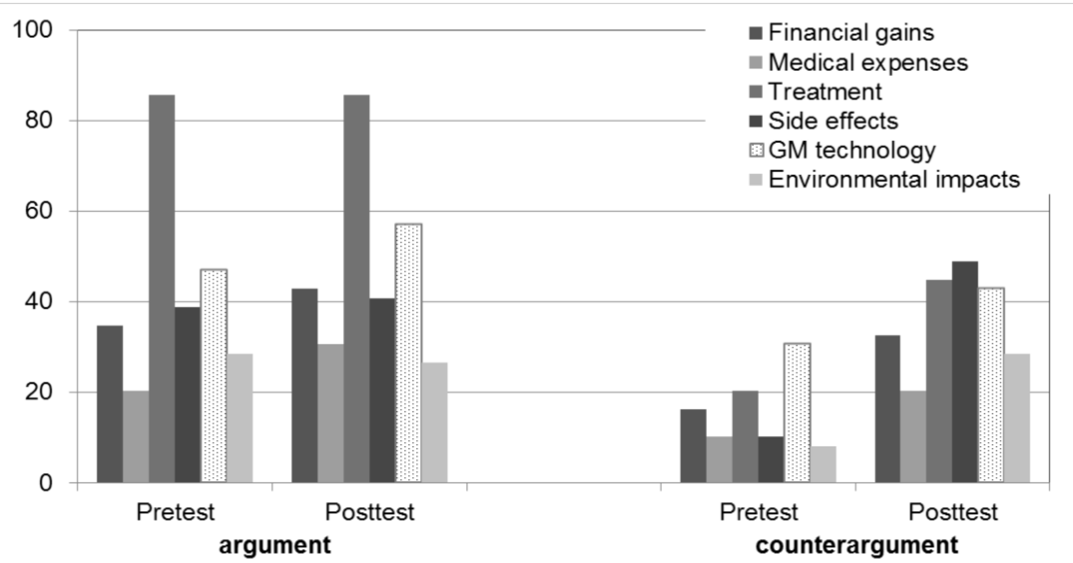

Figure 1. Utilisation rate of each perspectives in students' justification in pre- and post-test (%).

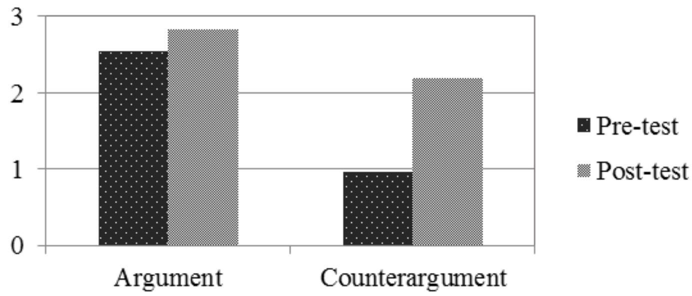

Figure 2. Average number of perspectives invoked among students' justification in the pre- and post-test.

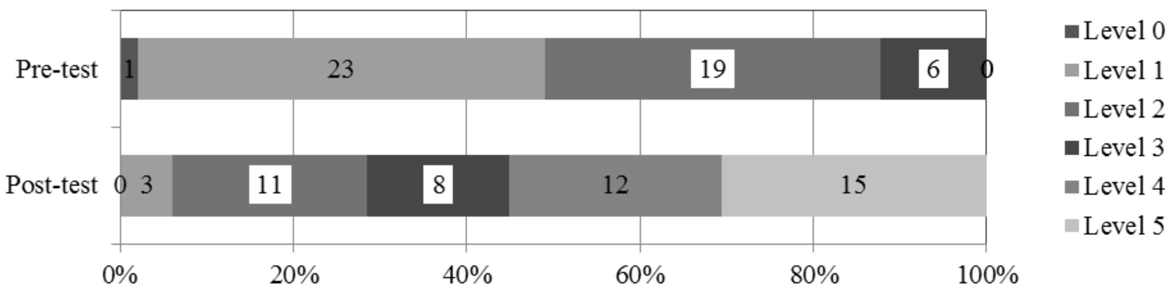

Figure 3. Distribution of the quality of the students' decisions in the pre- and post-test.

Table 3. Utilisation rate of each trade-off in students' solutions.

Tradeoff	Financial gains	Environmental impacts	Side effects	GM technology	Treatments	Medical expenses
(%)	51.85	51.85	44.44	22.22	14.81	7.41

DISCUSSION

We developed a socio-scientific issue-based curriculum unit for non-science undergraduate students focusing on students' decision-making for resolving conflict around the issues. In our SSI-based unit of instruction, the students considered the trade-offs of a specific scientific technology (the development of transgenic rice as a hay fever remedy) and engaged in a decision-making intervention focused on proposing solutions to resolve conflicts. A significant increase of perspectives embedded in students' counterarguments in the post-test demonstrated that students became more capable of multi-perspective reasoning on the SSIs. A comparison of the pre- and post-test scores revealed a general shift to higher-level responses after the intervention; the students' arguments on the SSIs changed from justificatory arguments into proposals for solutions. In the post-test, one-sided arguments diminished, and the number of perspectives embedded in their counterarguments increased. Moreover, solutions on multiple perspectives of the issue as well as those on one perspective were developed. Our hypothesis is supported by the transition of students' written arguments.

These findings demonstrated that our instruction promoted the students' socio-scientific decision-making, both in reasoning from multiple perspectives and in their compensatory decision-making dealing with trade-offs. However, we should pay attention to the fact that some of trade-offs were less-utilised in proposing solutions. Providing the framework for students to analyse and develop solutions on such trade-offs would may bring more proposals to resolve conflict on multiple trade-offs, that is, level 5 decisions. Based on these results, we should improve the details of our instruction in order to further improve students' decision-making.

ACKNOWLEDGEMENT

This work was supported by JSPS KAKENHI Grant Number JP17H01979 and JP18K18646.

REFERENCES

Eggert, S. & Bögeholz, S. (2010). Students' use of decision making strategies with regard to socioscientific issues-an application of the Rasch partial credit model. *Science Education, 94,* 230–258.

Eggert, S., Ostermeyer, F., Hasselhorn, M., & Bögeholz, S. (2013). Socioscientific decision making in the science classroom: the effect of embedded metacognitive instructions on students' learning outcomes. *Education Research International, 2013,* 1-12.

Friedrichsen, P. J., Sadler, T. D., Graham, K., & Brown, P. (2016). Design of a socio-scientific issue curriculum unit: Antibiotic resistance, natural selection, and modeling. *International Journal of Design for Learning, 7,* 1-18.

Gresch, H., & Bögeholz, S. (2013). Identifying non-sustainable courses of action: A prerequisite for decision-making in education for sustainable development. *Research in Science Education, 43(2),* 733–754.

Gresch, H., Hasselhorn, M., & Bogeholz, S. (2013). Training in decision-making strategies: An approach to enhance students' competence to deal with socio-scientific issues. *International Journal of Science Education, 35,* 2587–2607.

Kim, G., Ko, Y. & Lee, H. (2019). The effects of community-based socioscientific issues program (SSI-COMM) on promoting students' sense of place and character as citizens. *International Journal of Science and Mathematics Education*, https://doi.org/10.1007/s10763-019-09976-1.

Lee, Y.C. & Grace, M. (2012). Students' reasoning and decision making about a socioscientific issue: A cross-context comparison. *Science Education, 96,* 787-807.

Liu, S.-Y., Lin C.-S., & Tsai, C.-C. (2010). College students' scientific epistemological views and thinking patterns in socioscientific decision making. *Science Education, 94,* 497-517

Romine, W. L., Sadler, T. D., & Kinslow, A. T. (2017). Assessment of Scientific literacy: development and validation of the quantitative assessment of socio-scientific reasoning (QuASSR). *Journal of Research in Science Teaching. 54*, 274–295.

Sadler, T. D. & Dawson, V. (2012). Socio-scientific issues in science education: contexts for the promotion of key learning outcomes. In B.J. Fraser, K. Tobin, & C. J. McRobbie (eds.), *Second international handbook of science education* (pp. 799-809). Dordrecht, Netherlands: Springer.

Sutter, A.M., Dauer J.M., & Forbes, C.T. (2018) Application of construal level and value-belief norm theories to undergraduate decision-making on a wildlife socio-scientific issue, *International Journal of Science Education, 40,* 1058-1075.

Wu, Y. T. & Tsai, C.-C. (2007). High school students' informal reasoning on a socio-scientific issue: Qualitative and quantitative analyses. *International Journal of Science Education, 29,* 1163-1187.

Wu, Y. T., & Tsai, C.-C. (2012). The effects of university students' argumentation on socio-scientific issues via on-line discussion in their informal reasoning regarding this issue. In M. S. Khine (Ed.) *Perspectives on Scientific Argumentation. Theory, Practice and Research.* (pp. 221-234). Dordrecht, Netherlands: Springer.

Zeidler, D. L. (2014). Socioscientific issues as a curriculum emphasis: Theory, research and practice. In S. K. Abell, & N. G. Lederman (Eds.), Handbook of research on science education (pp. 697–726). Mahwah, NY: Routledge.

AN INQUIRY APPROACH TO THE INCLINED PLANE EXPERIMENT

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This work is the result of an ongoing research whose objective is to verify the efficiency, in terms of learning and comprehension, of an inquiry approach script applied to students in classes of Physics laboratory in relation to the traditional scripts. To this end, we have applied each kind of script for an inclined plane experiment to two first year classes of public high school and to one class of Physics course in a public university, which was divided in two small groups. Both schools are in the state of Minas Gerais, Brazil. From the comparison of the results from the three classes it was possible to perceive that the inquiry approach script was not only more efficient, but also provided greater involvement of the students in developing the activity. Also, there was a clear change in the posture of the students in terms of the autonomy required for each group work. To evaluate the students' learning, in addition to participation during class, each group produced a report with a discussion of the results and the respective conclusions.

Keywords: inquiry learning, Physics laboratory, inclined plane experiment.

INTRODUCTION

Experimental activity is a significant didactic resource for Science Education, allowing, from choices, different approaches. According to Andrade-Neto and Leyva-Cruz (2015), theoretically, experimental activities usually performed within the laboratory stimulate an active participation of students, as well as generate reflective situations about phenomena and physical concepts. However, we have perceived that the "filling tables" model, usually applied in several schools, has not provided an effective learning, nor developed the student's thinking. For this to be possible, it would be necessary a changing in the experimental classes and a reformulation of the curriculum of higher education courses, which would not only prioritize the conceptual content, but also the procedural and attitudinal contents of the student. One possibility would be to modify the teaching methodology, using the investigative model. According to Goya (2014), despite its simplicity, the inclined plane experiment has enormous didactic potential. Due to Galileo Galilei's discoveries using it and its importance to the History of Science, the inclined plane experiment appears in the list of the ten most beautiful experiments of all time, according to the journal Physics World in 2002. The inclined plane experiment can be consisted of a very simple apparatus which can easily be found in physics labs. Also, it is concept is easily found in mechanical physics textbooks. Despite the apparent simplicity, errors considered basic, related to conceptual failures and data collection, happen very often in the classes. Ueno-

Guimaraes and Muramatsu (2017) observed in their studies on laboratory classes of a university that students were having difficulties in basic and fundamental concepts often used in a laboratory, such as order of magnitude, units of physical magnitude and standard deviation. This observation led Ueno-Guimaraes and Simões (2015) to question the validity of maintaining didactic laboratory of Physics in the curriculum, without a reformulation of its methodological strategies. Our proposal idea for the inclined plan experiment is to induce the students to determine the static friction coefficient of a body by considering two practical approaches. The first is the traditional approach, where students should follow a pre-established script. This practical model does not provide any moment of reflection for the students on what is being done and does not require much preparation for its realization. The second approach is the investigative experimentation model, which stems from a problem initially proposed by the teacher or the students themselves. This model has the characteristic of allowing greater autonomy of the students in the decision of the procedures to be performed in the laboratory. Autonomy enables students to take an active position in knowledge building and provides a greater understanding of what is being done in the experiment. The general objective of this work is to discuss on how investigative scripts can be implement in classes of physics didactic laboratories, aiming to enable changes in the experiments and generate improvements in the consolidation of knowledge related to it. We are proposing a specific objective of measuring the effectiveness of this experimental model in the learning of physics contents, in comparison to the traditional model.

THEORETICAL FRAMEWORK

The activities called "investigative" are seen as starting point, where the student can develop the understanding of scientific concepts, leaving a passive posture and acting on the object of study. According to Azevedo (2012), the process and the attitudes to which the student is submitted, within the investigative process, are as important as the final results and the learning of the concepts itself. Azevedo (2012) indicates that for an activity to be considered investigative, the student must go beyond the field of superficial manipulation and observation of the experiment in the class. The method requires reflection, discussion and explanation about the phenomena under study. As this model gains prominence, it should be emphasized, according to Munford and Lima (2007) and Azevedo (2012), that an investigative activity does not necessarily need to occur within or even be an activity of a laboratory. Actually, for an activity to be considered "investigative" it should have five moments: a question or the introduction of a problem situation; a moment of investigation, where the students will discuss the problem and devising a way to solve it; a moment when the hypothesis will be constructed; moment of discussion involving the group members and, finally, a moment of reflection, where different views on the problem from the several groups are debated in the class. An important feature of investigative activity is its versatility. Wellington (2000) denotes it as degrees of openness and orientation, which can vary according to the objectives and the structure of investigative activity. Some activities, because of these degrees of openness, may be seeing as ordinary to students, or sometimes, the opposite, and it may be a whole new situation, where a more active participation of the students will be necessary. Considering the notion of degrees of freedom and the idea of moments necessary for an activity to be qualified as investigative, Ueno-Guimaraes and Muramatsu (2017) introduced in their work a table based on the original idea of Pella (1969), described in the works of Carvalho (2010). In the original table there was five degree of freedom, where higher degree corresponds to a higher level of participation of the student in the experiment. Ueno-Guimaraes and Muramatsu (2017) added in their work another degree of freedom named degree zero. This results in a restructuration of the degree of freedom chart, shown in the Table below, where the symbol T represents the teacher participation and S represents the participation of the student.

Table 1. Degrees of freedom in investigative activity and the corresponding participation of teachers and students.

	Degree 0	Degree I	Degree II	Degree III	Degree IV	Degree V
Problem	-	T	T	T	T	S
Hypotheses	-	T	T/S	T/S	T/S	S
Work plan	T	T	T/S	S/T	S	S
Data	S	S	S/T	S	S	S
Conclusion	T	T	S/T/class	S/T/class	S/T/class	S/T/society

The degree zero means the student has zero degree of freedom in terms of acting on their own or thinking about what is going on in the experiment. The effective participation of the student is almost none. The theory of the experiment is present and the students have to achieve the objective by filling table and perform some pre-established calculations. Sometimes, the final objective is to prove a known scientific concept or get a specific known physical quantity. Adding the fact that the script is also very restrict, the student knows what should be the final result and, sometimes, they manipulate the data to get it. At degree one, students have some freedom to choose how to perform the data collection. The students still have to follow a script which resembles a kind of “cake recipe”. The script of the experiment is established from the proposal of the problem to the conclusion of the experiment, and only activity left for the students is to fill the tables. At degree two it is given to the students the opportunity to formulate their own conclusions from the collected data, but these should be presented and discussed with the teacher and the rest of the class. In this level of participation some new problems may appears during the execution of the experiment. At degree three the students should develop their own script or working plan to solve the problem presented by the teacher. Also, they should discuss among them how the data will be collected. The conclusions are discussed in group and with the classroom, with teacher guidance. At degree four the students are responsible for all the steps of the development of the experiment and on how to get the results from a proposed problem by the teacher. Finally, at degree five, the students should be able to propose and solve the problem. This degree of freedom is usual in more advanced academic levels, such as Masters and Doctorates.

METHODOLOGICAL PROCEDURES

The research being present here is basically of qualitative nature. However, some data were taken and they consisted of descriptions of the situations experienced by the authors in the laboratory classroom and part of the text from reports produced by their students. The physical structure of school's city was taken into consideration in the activities carried out in the classroom. Both high school and the university, where the activities were applied, are public school of a historic city of Ouro Preto. This city is a mining area of central part of Brazil and it was grown from the colonial times without any major plan. It was possible to use it as a contextualization of the activity since it has several streets consisted of steep slopes. The present work was carried out with two classes of the first year of public high school in the state of Minas Gerais, named A and B, and with a group of students in the undergraduate physics course of a Federal University of the same state. In both high school classes, the Newton's Laws would still be worked out, giving for a fair comparison between them on the performance and results obtained in the inclined plane experiment. An introductory text and pictures of the cities was used to contextualize the problem and generate a discussion. The discussion was mostly guided by the questions raised by the students. It was expected that the important characteristics of the problem would be identified in the situation contextualized such as when a car could not go up in a steep slope street due to a lack of friction between a car tire and the ground. It was important that the students could make the correlation of this situation with the experimentation to be performed. The necessary trigonometric formulas and correlations were presented for the development of discussion and activity as demand arose. Groups of four or five students were formed at the end of the discussion, so that the structuring of experimentation would be performed by them as a group, offering the possibility of autonomy in their decisions and allowing an improvement in argumentative capability, in defense of the proposed model. Doubts have appeared during the discussion and they were accentuated during the execution of the practice. Working with trigonometric properties, students could not relate concepts to application in the experiment. Some of them could identify the opposite and adjacent side of the right-angled triangle in the drawings on the board, during the explanation, but could not identify them in the experimental apparatus they had assembled. As an evaluative method, both in the traditional and investigative approach, it was necessary that the students had a discussion about the results obtained and that they wrote a short report about the procedures performed in the laboratory, as well as about the obtained results. The classes of the first years A and B from high school were composed of 19 students and 12 students, respectively. These students had several serious conceptual flaws. Many of them had even not seen several subjects, which were included in the school curriculum but not addressing to them. This generated some difficulties during the classes preventing the activities to be, satisfactorily, performed. The third class consisted of freshman of Physics course. They had already worked on the fundamental concepts, during their high school, necessary for the realization of the activity. The assumption was that these students would perform the laboratory activities much better as compared to high school students who were still addressing these fundamental concepts.

PRESENTATION AND ANALYSIS OF RESULTS

The data were taken in the following way: for high school class A we used only the traditional script and for class B only the investigative scripts. For the freshman of the university we applied the traditional script for half of the class and investigative script for the other half. In terms of participation level of the students the traditional script can be classified as degree one while the investigative script can be classified as level three. The traditional script was applied to the high school class A, which its students are considered as exemplary by the school, since they used to have “good conduct” in the classroom and have grades considered reasonable by the school. The class B is the opposite and it is considered “lost cases” by the school. Thus, we would expect in an overall terms that students from class A would perform better compared to students class B. Based on this assumption, we decided to apply only the traditional script for class A, which in theory would not need as much help as class B, and only the investigative script to class B. The proposal of the script was to find the value of the static friction coefficient of two surfaces, glass and wood. It was required in the script a comparison between values obtained for the static coefficients from the angle obtained from the opposite and adjacent side (Table 3 of the script) of the slope and from force equations which requires the measurements of the angle (Table 5 of the script). In principle, the students should find equal values or close values for the coefficients. In addition, it was necessary, at the time of the assessment, to answer whether these values coincided and to explain these results. The results found by the students using the traditional scrips are arranged in the tables, as it was required in the script. Below we present only the tables with the results of for the frictional coefficients using the traditional script applied to class A. All groups in class A were able to perform the experiment satisfactorily, at the predetermined time but with the help of the teacher.

Group 1

Table 3

Surface	Wood	Glass
μ_s	0,375	0,5

Surface	Wood	Glass
μ_s	0,05	0,45

Table 5

Check: Do the data obtained for the static friction coefficients calculated in table 5 match the values of the last row of table 3? Yes (   ) No (x)

Answer: *The value of the wood was similar.*

Group 2

Table 3

Surface	Wood	Glass
μ_s	0,46	0,46

Table 5

Surface	Wood	Glass
μ_s	0,03	0,6

Check: Do the data obtained for the static friction coefficients calculated in table 5 match the values of the last row of table 3? Yes ( ) No (x)

Group 3

Table 3

μ_s	0,35	0,452

Table 5

Surface	Wood	Glass

Surface	Wood	Glass
μ_s	1,663	0,012

Check: Do the data obtained for the static friction coefficients calculated in table 5 match the values of the last row of table 3? Yes ( ) No (x)

Answer: No answer.

Group 4

Table 3

Surface	Wood	Glass
μ_s	0,427	0,432

Table 5

Surface	Wood	Glass
μ_s	0,570	0,565

Check: Do the data obtained for the static friction coefficients calculated in table 5 match the values of the last row of table 3? Yes ( ) No (x)

Answer: *The values were different because there was some wrong data.*

By observing the calculated values for the static friction coefficient of tables 3 and 5 of each group and comparing them, it is possible to draw some conclusions. In some cases, students were able to find very small values, up to about ten times lower than expected, as seen in table 5 of groups 1, 2, and 3. When looking for the source of errors, we came across parallax in obtained the angle and unit conversion. Similar errors were also found in the reports of the students in the work of Ueno-Guimaraes and Muramatsu (2017). Group 3, besides the previous errors, they also found a value for the static friction coefficient greater than one, which is physically impossible. Looking for the source of the error, once again, we come across unit conversion errors. For instance, the hypotenuse value found by them was in km. Only group 4 was able to reach similar values in both methods. Even so, we had the use of generic phrases, denying this proximity in explaining the comparison of values. Make us wonder if they understood what they actually did. The freshman of the university presented a better performance, managing to follow the pre-established script without major procedural and interpretation problems. Problems arose largely from data collection and data processing. Below we present the tables with the results obtained by the groups from the university Physics course, using the traditional script.

Group 1

Table 3

Surface	Wood	Glass

μ_s	0,38/0,42	0,42/0,47

Table 5

Surface	Wood	Glass
μ_s	0,26	0,34

Check: Do the data obtained for the static friction coefficients calculated in table 5 match the values of the last row of table 3? Yes (   )   No (x)

Answer: *The differences between the calculated coefficients in the two tables may have been caused by measurement errors.*

Group 2

Table 3

Surface	Wood	Glass
μ_s	0,36	0,26

Table 5

Surface	Wood	Glass
μ_s	0,29	0,26

Check: Do the data obtained for the static friction coefficients calculated in table 5 match the values of the last row of table 3? Yes (   )   No (x)

Answer: *The values attributed in the predicted measures agglutinated a series of numerical failures that resulted in divergent results.*

Group 3

Table 3

Surface	Wood	Glass
μ_s	0,398	0,349

Table 5

Surface	Wood	Glass
μ_s	25	27,7

Check: Do the data obtained for the static friction coefficients calculated in table 5 match the values of the last row of table 3? Yes (   )   No (x)

Answer: *There were errors in weight convertion*.

The students were able to perform the experiment with very little intervention of the teacher. They managed to complete the experiment in a shorter time than the reserved time, 1h30min. They could even perform the experiment independently. However, they did some mistakes in the collecting data. Group 1 collected obtained wrong values from the opposite and adjacent side of the inclined plane necessary to calculate the tangent of the angle. This let them with different values of the static friction coefficient from table 3 and 5. Another group found identical values for the opposite and adjacent side, even though there was a significant variation of angles. Some parallax problems were also recurring. Non-integer values were noted and used throughout the experiment, but the protractor which the smallest measure was one degree, makes this type of reading incorrect. All students were requested to write a short sentence about the practice performed and all answers were too generic. In 60% of the cases, there were divergences in the values found in tables 3 and 5. Their justifications vary between collection and propagation of erroneous data, even in groups that reached values close to each other. For the students in class B we applied the investigative script. It was took to students a longer time to perform the proposed activities, as compared to the time taken by the high school class A. The investigative script applied can be classified as degree three, and, it is reasonable that a longer time was needed. The need for such autonomy by the students ended up hindering the development of the activity. The discussions took place superficially, requiring many interventions by the teacher, until some consensus and understanding of the objectives and procedures could be achieved. The absence of a didactic laboratory in the Elementary and / or high School created some extra difficulties since the students could not identify the equipment being mentioned and did not know how to use the apparatus. Another difference between class B compared to class A was level of disorganization of the obtained data for the class B to a point of making analysis difficult. The lack of tables to be filled (as in the traditional script) was a decisive factor for this disorganization. During the experiment, students wrote down the collected values in the margins and footers of the pages, and used the back of the sheet, even though they were handed with a blank craft sheet with a template function. The data collected by the students were not organized according to any logic and there were few data with their proper units. As the students were lost in their own data, neither group could reach the objective of calculating the value of the static friction coefficient in both cases, and only one group could correlate the angle of the plane with the value of the force in the block. As shown in the group's next answer: "The force we put on the straight plane is stronger than on the inclined plane because of its angle." As mentioned, the class of freshman of the university Physics course, was divided in two and half of them developed the investigative script. The half of the class was further divided in groups. The first group decided to try to solve the principles of kinematics by calculating the block's descent time and the acceleration to which it was subjected but failed to develop the experiment in this way. After a few minutes of discussion among them and mediated by the teacher, they approached the concept of friction and by recalling the formula that enunciates the phenomenon, they were able to calculate it and come up with some results for the value of static friction coefficient between the studied surfaces. The second group tried to develop by force diagram correctly but the obtained values for the friction coefficients were in the order of 10^{-2}. This was because students did not make the correct conversion of unit, indicating that students have some difficult with units. After the group discussions, they could understand the experiment even thou they got wrong values for the friction coefficient. Similar problem was also observed for the freshmen of laboratory of Engineering courses, presented in the work of Ueno-Guimaraes and Simões (2015). In addition, the second group did not write the text of the evaluation, giving only one sheet, where they performed the calculations. The third group was able to carry out the experiment without major difficulties, because among the members, there was a senior student, who had already performed the experiment in a didactic laboratory, while attending the first period of the previous course. The experiment was performed by them correctly and quickly, not having to use the time 1h30min to practice. The reports written as a form of evaluation by students of investigative experimentation were more descriptive than the reports from the students of the traditional script. The report of the third group, there are deductions and free-body diagrams in an attempt to argue about the validity of the obtained results. In one of the reports, the students pointed out their mistake and how they managed to solve it, showing attention in what was being done by them in the laboratory and corroborating with Borges (2002), when he says that the student takes a new position, from passive to active, allowing a reflection on what was developed and accomplished by him.

FINAL CONSIDERATION

The idea of investigative teaching has been reported in the Literature, but, in practice, it has not been largely applied by the teachers. We still reproduce the teaching model of the last century, in which the teacher is the active agent and the students are passive. By applying the investigative methodology, the improvement and effectiveness of the student's learning is clear. In the degree I of the experiments, all groups were able to reach the proposed objective, which was to calculate the value of the static friction coefficient on two surfaces. When comparing the data obtained by them, we see that only high school group 4 and freshman group 2 were able to obtain values close to each other. This equates to 25% and 33% success, respectively, using the traditional script. In addition to the small number of groups that have managed to come up with expected results, other problems can be considered serious. In all the reports analyzed, there were problems of unit conversion and text interpretation. Students, especially from the early years, did not understand what the script required, concepts such as mass and weight were still not clear to them and they did not know some trigonometric properties. The same mistakes were present in the reports of the investigative script, however, the hit rate was higher, still with some help from the teacher. Anyway, all groups in the investigative managed to reach the objective of the experiment, which the final results were closer to the expected values. The fact that freshman of the university came out with three different approaches shows that there was not only one correct way to conduct the experiment, and allows for further development with respect to student autonomy in the face of a challenge. Unfortunately, students from high school B were unable to deal with the degree of freedom of the investigative script used, possibly due to the fact they were still to immerse in a model of traditional teaching where they are not protagonists. We believe that these results could still be enhanced if there were more meetings such as these, or even if it was possible to apply an Investigative Teaching Sequence in several experiments. There is also the possibility of achieving a gradual opening of degrees of freedom, starting with scripts of degree one and advancing as far as possible. Such procedures will still be put into practice in future research. Another interesting and relevant aspect on this subject, which could be applied in laboratory classes, was addressed by the idea of SCALE-UP (Beichner, 2007). This methodology is strongly related to peer instruction. The idea is to foster a corporate learning environment that would encourage students to collaborate with their peers, questioning and teaching each other. The activity of teachers in this case would be to encourage and assist students to reach their own answers and conclusions about certain problems of physics and let them present their conclusions to the other students. The learning would take place when opposing ideas and having a discussion with the answers and works presented by all the groups. We can conclude by saying that there is an urge for change and an alternative teaching practices which have to be developed and applied. However, as the initial and continued formation of science teachers does not yet favor this kind of approach (Galiazzi, 2011), the use of new methodologies is not widely spread either in theoretical or experimental classes.

REFERENCES

Andrade-Neto, A. V. & Leyva-Cruz, J. A. (2015). Análise teórica e proposta para determinação experimental do coeficiente de atrito de rolamento em um plano inclinado. *Revista Brasileira de Ensino de Física v37*, Brasil. Disponível em: www.sbfisica.org.br. Acesso em: 11 jun. 2019.

Azevedo, M. C. S. de. (2012). Ensino por Investigação: Problematizando as atividades em sala de Aula. In *Ensino de Ciências: Unindo a Pesquisa e a Prática*. Organizado por Anna Maria Pessoa de Carvalho. São Paulo: Pioneira Thomson Learning, 19-33 p.

Beichner, R. *et al*. (2007). SCALE-UP. Research-Based Reform on University Physics. Available in: http://www.per-central.org/items/detail.cfm?ID=4517.

Borges, A. T. (2002). Novos rumos para o laboratório escolar de Ciências. *Caderno brasileiro de Ensino de Física*, v. 19, n. 3: p. 291-313, dez.

Carvalho, A. M. P. de. (2010). *Ensino de Física*. São Paulo: Cengage Learning – Coleção ideias em ação.

Carvalho, A. M. P. de. (1999). *Termodinâmica*: Um ensino por investigação. São Paulo: FEUSP.

Galiazzi, M. do C. (2011). *Educar pela pesquisa*. Ijuí: Editora da UNIJUÍ.

Goya, A.; Laburú, C. E. & Filho, P. S. de C. (2014). Estudo comparativo de rolamento e a determinação do início de deslizamento de uma esfera num plano inclinado. *Revista Brasileira de Ensino de Física v36*, 2502.

Munford, D. & Lima, M. E. C. de C. (2007). Ensinar ciências por investigação: em que estamos de acordo? *Revista Ensaio*, Belo Horizonte, v.9, n.1. Disponível em: <http://www.portal.fae.ufmg.br/seer/index.php/ensaio/article/view/122/172>. Acesso em: 23 jul. 2019.

Ueno-Guimaraes, M. H. & Simões, B. dos S. (2015). Uma abordagem investigativa para o experimento do plano inclinado. *Revista Internacional de Aprendizaje en Ciencia, Matematicas y Tecnologia* 2 (2): 77-89. doi:10.18848/2386-8791/CGP/v02i02/77-89.

Ueno-Guimaraes, M. H. & Muramatsu, M. (2017). Um enfoque investigativo para o resultado de uma medida física. *Revista Didasc@lia: Didáctica y Educación. Vol.8. n 6.* ISSN 2224-2643.

Wellington, J. (2000). *Teaching and learning secondary science:* contemporary issues and practical approaches. London and New York: Routledge.

PART 6: STRAND 6

Nature of Science: History, Philosophy and Sociology of Science

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CONTENTS

STRAND 6: INTRODUCTION

NATURE OF SCIENCE: HISTORY, PHILOSOPHY AND SOCIOLOGY OF SCIENCE

Understanding of nature of science (NOS) is now seen as an integral part of scientific literacy. In a world struggling with global crises, such as the climate change and the COVID-19 pandemic, understanding of central scientific concepts is usually not enough for engaging with these socio-scientific issues. Discussing and taking action towards a more sustainable world demands scientific competence for citizenship, which includes understanding of uncertainty and tentative nature of scientific knowledge as well as the ethical aspects of science. Thus, maybe now more than ever, there is a need to discuss how history, philosophy and sociology of science could and should inform science education.

Altogether 7 of the studies presented in Strand 6 (Nature of science: history, philosophy and sociology of science) were accepted to be published in the ESERA 2019 conference proceedings. Most of them focus on charting or developing students or teachers understanding of NOS.

Two of the papers focus on secondary school level. The first is written by Anne Caroline de Freitas, Michele d. Facioli Medeiros and Marcelo Tadeu Motokane. The study describes how students experiences during an inquiry-based learning project informed the way they perceive scientists and what scientists do. The second one by Pascal Pollmeier and Sabine Fechner focuses on scientific creativity in the context of data analysis. In this study, the students were confronted with two experiments which contradicted each other with regard to the underlying theory. The authors found that most students did not take anomalous data into account in their modelling processes and the students working on their theory scored higher in the post-questionnaire. In conclusions they propose that creativity should be taught in school science in order to make students aware of their own creative potential.

Two papers focused on pre-service teacher education. Stefan Müller and Christiane S. Reiners present a study examining pre-service science teachers´ conceptions about the tentative and sociocultural nature of scientific knowledge. As public discussions about socio-scientific issues requires understanding of limitations of science, these two aspects of NOS are an important component of scientific competence for citizenship. The results of the study show that the conceptions about these aspects of NOS are also rather resistant to change. The paper by Cristina Cobo Huesa, Ana María Abril Gallego and Marta Romero Ariza reports a study on evaluating the impact of an intervention intended to improve pre-service teachers' understanding of epistemological and sociological aspects of NOS. This design-based study integrates inquiry-based teaching and the history of science through an explicit and reflective instruction, embedded in the scientific controversy of the spontaneous generation theory. The authors conclude that the combination of inquiry and the history of science, along with explicit reflections about NOS, can improve pre-service teachers' understanding of epistemological and sociological aspects of science.

Two of studies carried out in Greece focused on in-service teachers. Dimitrios Schizas and Dimitris Psillos investigated how in-service physics teachers understand the unique features of school physics and biology. They used a theoretical framework on the notion of worldview and important differences that exist between the Newtonian and the neo-Darwinian worldviews. In the other study, Anna Koumara and Katerina Plakitsi designed a development program for science teachers. Using the cultural historical activity theory as a guiding framework, the program combined history of science, scientific inquiry and socio-scientific issues to meet the needs of the teachers and their students.

The last paper by Daniele Trajano Raupp, Tania Renata Prochnow and José Cláudio Del Pino presents a brief analysis of how historical aspects related to stereochemistry are addressed in Brazilian high school textbooks. The results indicate that there is a deficiency in the historical approach, possibly due to the textbook authors' lack of formal education in the history of science. They also point out that chemistry teachers' heavy reliance on textbooks when selecting the historical content to be included in their classes, can contribute to a poor understanding of historicity by their students.

Ebru Kaya & Veli-Matti Vesterinen

STUDENTS VIEWS ABOUT SCIENCE AND SCIENTIST

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Science education should enable students to use instruments of science, to comprehend ways of producing, to legitimate and to disseminate knowledge. However, science teaching has been historically characterized by valorization, reproduction and memorization of contents. Consequently, science is pointed out as unquestionable, neutral and dissociated from socio-political aspects. Thus, this study aims to analyze students' views about science and scientists. The students who participated in this study, attended in a project along four years which their science classes were planned and executed considering the Inquiry Based Learning. In this study were evaluated textual productions from the questioning: "Who is the scientist?" and "What do the scientists do?". A lexical analysis by ALCEST software was done. The four lexical classes made by this software were later analyzed qualitatively in association with the visions about nature of science established in literature. Our data show that the students identified science as: composed of different areas; its relationship to society and the usage of different tools and procedures that involve various inquiry methodological steps. As discussed here, these results could be associated with the students' teaching context.

Keywords: Nature of science; Inquiry-based Teaching; Quantitative methods

INTRODUCTION

Science is characterized as a knowledge corpus composed of its own particular norms, values and principles that lead actions and procedures involved in the construction and dissemination of scientific productions (Sasseron, 2015). It involves the development of technical skills such as using specifics equipments; researching skills as: raising hypotheses, making predictions, organizing information, planning experiments, creating models; and also communication skills (Driver, Newton & Osborne, 2000; Carvalho et al., 2013; Dushl, 2016).

Considering this, scientific education should allow students to associate different ways of knowledge construction and how scientists do their studies (Abd-El-Khalic, Bell, & Lederman, 1997; Lederman et al., 2019). However, science teaching has historically been characterized by contents valorization, reproduction and memorization. Consequently, science has been pointed out as unquestionable, neutral and dissociated from socio-political aspects (Fernández, Gil, Carrascosa, Cachapuz & Praia, 2000). Thus, the school context often reproduces stereotypes published in media, reproducing a naive view of scientific production (Morais & Andrade, 2009). These naive views may distance students from scientific culture; interfere on understanding specific issues about nature of science; create a barrier in learning (leading to demotivation in science classes) and consequently this student will face barriers to participate in decision making in their social surroundings (Cachapuz et al., 2011; Kominsky & Giordan, 2002; Fernandéz et al., 2001).

Considering this, is important to identify students conceptions about nature of science in order to elucidate their proximity to scientific culture. So, studies in this perspective contribute to reasoning about current didactics approaches in science teaching and how its reflects on teaching-learning process.

Despite studies highlighted the relevance of analyzing students conceptions about science and scientist, there is a lack of studies which investigate relations between didactic approaches and students views.

In this perspective, this study aims to analyze students' views about science and scientists.

METHODOLOGY

The participants of this research are students from the first year of high school (15-16 years old). They were from a public school and attended along four years in a project which their science classes were planned and executed with the assumption of Inquiry Based Learning (Munford & Lima, 2007; Motokane, 2015). For the National Science Education Standards (NSES, 1996), the Inquiry Based Learning has some essential elements in science classes such as engaging students in solving scientific problems, enable them to prioritize evidences to solve this problems, construct explanations with scientific knowledge, and finally, communicate and justify their explanations. According Bybee in the book Scientific Inquiry and Nature of Science, edited by Flick e Lederman (2006), science doing is composed by some fundamental suposings as data collecting, logical reasoning, substantiate explanations with reliable evidences. So, for this author, this didactic approach may promotes a wide comprehension of nature of science and science inquiry. Therefore, as students experience these essential aspects of Inquiry Based Learning, they become even more aware of scientists' practices and ways scientific knowledge is constructed and structured; getting close to scientific culture through creation of an investigative context (Sasseron, 2015).

Besides that, throughout the four years which the students participated in the project, classes were planned and applied in collaboration with the same teacher, who is also a member of our research group.

In this study we characterized 67 written texts produced from the questions: "Who is the scientist?" and "What do the scientists do?". We analyzed the transcriptions of the texts by using the ALCEST software 4,5 (Analyse Lexicale par Contexte d'un Ensemble de Segments de Texte). This tool provides a lexical quantitative analysis regarding word repetition and succession, creating thematic groups (classes). These lexical classes are formed by Units of elementary context (UECs) (Kronberger & Wagner, 2013), which are segments of texts. Thus, each class is composed by different UECs, from classification and distribution of words. It is produced by the frequency and by the $\chi 2$ distribution of the vocabularies.

Besides that, the software produces a plot that illustrates the descending hierarchical classification (DHC), representing the fragmentation of the textual corpus and the relationships between the different classes. Other stages of analysis were done qualitatively with the intention of identifying the meanings presented on the lexical classes in association with the visions about nature of science established in literature. These data constructed by the authors were discussed and validated by experts.

FINDINGS

From qualitative analysis, we named the classes generated by the software considering the content words and context words (UEC's). The following examples represent the classes, with the categorization made by the authors and representatives UECs for each one:

Table1. Categorization made by the authors according to ALCEST data: content words (in bold) and UECs for each class.

Class	Content words	UECs	Category
1	**chemistry, area, science, fact, biology, evolution**	"The scientist **studies theories of science**. There are several **areas** to be **studied** in **science**, **for example, chemistry, biology, historian, humanities**, astrology, among **others**. **Theory** is what **has already been** confirmed into a certain point." " **Physic** and **science** norms that conduct to a **nature** phenomena, how they are susceptible to be represented by experimental observation, and put them in logical schemes"	Areas of scientific studies
2	**discover, thing, machine, medice, laboratory, do, day, experiment the, for**	"The scientist proves **very important things for** our **day** by **day**. Also, scientists **do very interesting things like** studying **their** students **to be** their **future** substitutes, bringing **future to** their country." "Scientist is the one who studies science, he **discovers and invents** things like objects, robotic **machines and experiments**."	Results of scientific studies
3	**criate, hypothese, universe, society, subject, prove**	"**His work** is exercised doing research, studies, collected **information**, analysis of samples, **creation** of theories, etc. to **try to prove** their theories **create hypotheses and proving** their theories take **information to society** " "**His work begins**, **but** his ideas, **research**, and testing **will work out** or not and **they** ask for **help** from other scientists to **improve** their **experiment**"	Methodologies of scientific studies

The data analysis indicated that students' speech about science and scientist is based on three aspects characterized by the categories created: (i) Scientist’s acting areas; (ii) Results of scientific studies and (iii) Methodologies of scientific studies.

It is important to highlight that views presented here are not isolated or independent, it associates and complements each other, setting up a global panoramic of science perception (Fernandéz et. al 2000). Thus, when analyzing representations about scientific doing and associate them to views about nature of science is important to consider that their relations made up a conceptual framework (Driver & Oldham, 1986; Fernandéz et. al 2000).

The assignments made by the students point out a wide comprehension of the scientific community composed by different areas (noted in classes 1 and 2 – see Table 1). This is mainly featured from roots of words as **chemistry, biology, physic, area**; which describe class 1. It is worth to mention the indication of “human sciences” and the “historian” as a scientist, that represent a broad understanding of the scientific culture; relating science to its social and human areas. Also, this perspective reveal a refusal of the unproblematic and ahistorical view.

Besides that, students were able of recognize the limitations of science knowledge and the perspectives that open up to the present society (Fernandéz et al., 2000) as noticed in class 1 ("**Theory** is what **has already been** confirmed into a certain point."- Table 1) and class 3 ("and testing **will work out** or not - Table 1). In these classes students approached the non-linear conception of scientific doing, that is represented by a continuous search for revisions of results (Fernandéz et al., 2000). These beliefs contrast with an "experimentalist reductionism", which corresponds to a simplistic view of scientific work (Fernandéz et al., 2000).

In this sense, by highlighting society as belonging to the process of scientific production ("**and proving** their theories take **information to society"** - Table 1), the student portrayed the social character of the construction of knowledge, distancing itself from a neutral image of science. This conception approached the collective, social and historical understanding of scientific studies and disconnecting itself from the view of the scientist as a genius who holds the absolute truth, living in a "kingdom apart from society" (Bizzo, 2009).

We can see from UECs and content words from class 2 that it represents “Results of scientific studies”. This class has peculiarities as a broader appe of scientific production and applications as noted in "Also, scientists **do very interesting things like** studying **their** students **to be** their **future** substitutes, bringing **future to** their country. (Table 1)" In this UEC, students understood even educational researches as a scientific practice and how it relates to society.

Furthermore, these textual productions presented an apprehending of the construction and dissemination of scientific knowledge, proper to the investigative process of nature of science such as the work with data ("studies, information collected"); the survey of possible solutions to the problem ("hypotheses"); tests ("analysis of samples"); conclusions ("creation of theories") and scientific dissemination (“take information to society”) (Carvalho et al., 2013).

Understanding these moments belonging to the investigative context, their science classes have approximated the student to aspects about scientific doing (Sasseron, 2015). In this sense, the student have not shared a cumulative, linear and rigid visions about the structuring of scientific knowledge.

Getting in touch with such fundamental steps of investigative process by Inquiry Based Learning, students are able to resignify stereotyped views about scientific work. In this way, this didactic approach may be related to distance students from views massively reproduced in media. Thus, this overview comprehension leads students to argumentation and consequently act in their society considering scientific knowledge (Sasseron, 2015).

In this context, it is noticed that these students have contacted and accessed to lexical and epistemological repertoire of scientific knowledge that can be use to make explanations of natural and social phenomena more accurately (Castro, 2017).
Therefore, learning concepts and scientific theories get more significance since concepts and theories are then situated in its own production context (Gil Pérez & Martínez-Torregrosa,1987; Mundord & Lima, 2007).

FINALS CONSIDERATIONS

Results found in this study could be related to the teaching context in which the student were attended, since the Inquiry Based Learning has the purpose of create an investigative context, specific to the science community (Motokane, 2015). By getting in touch with such fundamental situations of the investigative process, they are able to contrast the scientific knowledge with views that are known by society, resignifying stereotyped and naive views about science and scientific work.

Thus, this didactic approach promotes the comprehension regarding science and technology, society and the environment (Sasseron, 2015). Therefore, contributes to student's citizenship education, whereas they may be able to reason and consciously participate in situations that involve decision making and positioning about scientific issues.

So, studies approaching views about nature of science is extremely important to analyze the students' proximity to scientific culture. In this field, these data also lead to possible gaps on the current didactic approaches used in science teaching and how it relates to the teaching-learning process and student's decision- making in their society.

ACKNOWLEDGEMENT

This research was supported by the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior - Brasil (CAPES) - Finance Code 0001.

REFERENCES

Abd-El-Khalick, F., Bell, R. L., & Lederman, N. G. (1998). The nature of science and instructional practice: Making the unnatural natural. *Science education*, 82(4), 417-436.

Bizzo, N. (2009). *Mais Ciência no Ensino Fundamental: metodologia de ensino em foco*. Editora do Brasil S/A.

Cachapuz, A., Gil-Perez, D., Carvalho, A. D., Praia, J., & Vilches, A. (2005). *A necessária renovação do ensino das ciências*. 2 ed. São Paulo: Cortez.

Carvalho, A. M. P. D. , Oliveira, C. M. A., Scarpa, D.L., Sasseron, L. H., Sedano, L., Silva, M. B., Briccia, V. (2013). *Ensino de ciências por investigação: condições para implementação em sala de aula*. São Paulo: Cengage Learning, 1-20.

Castro, R. G. (2017) *A construção de argumentos no processo de recontextualização do conceito de biodiversidade*. Instituto de Física, Instituto de Química e Instituto de Biociências da Universidade de São Paulo.

Coll, C., Pozo, J. I., Sarabia, B., & Valls, E. (2000). Os conteúdos na reforma: ensino e aprendizagem de conceitos, procedimentos e atitudes. In *Os conteúdos na reforma: ensino e aprendizagem de conceitos, procedimentos e atitudes.*

Duschl, R. (2008). Science education in three-part harmony: Balancing conceptual, epistemic, and social learning goals. *Review of research in education*, 32(1), 268-291.

Driver, R., Newton, P., & Osborne, J. (2000). Establishing the norms of scientific argumentation in classrooms. *Science education*, 84(3), 287-312.

Driver, R., & Oldham, V. (1986). A constructivist approach to curriculum development in science. *Studies in science education,* 13, 105-122.

Fernández, I., Gil, D., Carrascosa, J., Cachapuz, A., & Praia, J. (2002). Visiones deformadas de la ciencia transmitidas por la enseñanza. *Enseñanza de las Ciencias*, 20(3), 477-488.

Flick, L., & Lederman, N. G. (2004). Scientific inquiry and nature of science. *Contemporary Trends and Issues in Science Education*, 67.

Gil Pérez, D., & Martínez-Torregrosa, J. (1987). *La resolución de problemas de física: una didáctica alternativa (Capítulo IV)*. España. Ministerio de Educación y Ciencia.

Kosminsky, L., & Giordan, M. (2002). Visões de ciências e sobre cientista entre estudantes do ensino médio. *Química nova na escola*, *15*(1), 11-18.

Kronberger, N., & Wagner, W. (2002). Palavras-chave em contexto: análise estatística de textos. *Pesquisa qualitativa com texto, imagem e som*, 416-441.

Morais, M. B., & Andrade, M. D. P. (2009). Ciências–ensinar e aprender. Belo Horizonte: *Dimensão*.

Motokane, M. T. (2015). Sequências didáticas investigativas e argumentação no ensino de ecologia. *Ensaio Pesquisa em Educação em Ciências* (Belo Horizonte), 17(spe), 115-138.

Munford, D., & Lima, M. E. C. D. C. (2007). Ensinar ciências por investigação: em quê estamos de acordo?. *Ensaio Pesquisa em Educação em Ciências (Belo Horizonte)*, 9(1), 89-111.

National Research Council (1996), National Science Education Standards: Washington, DC, *National Academy of Sciences Press*, 262 p.

Sasseron, L. H. (2015). Alfabetização científica, ensino por investigação e argumentação: relações entre ciências da natureza e escola. *Ensaio Pesquisa em Educação em Ciências* (Belo Horizonte), 17(spe), 49-67.

CREATIVITY IN DATA ANALYSIS THROUGH CONFRONTATION WITH ANOMALOUS DATA

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Creativity is perceived to be one of the core competences to succeed in the modern world. It is connected to art, music, dancing, etc., but there is just little insight into the role of creativity in science. As data analysis plays a major role in science, creative thinking has to be used to form theories out of observations. This study uses models-of-data to represent the mental model of the students. Within models-of-data different observations and previous knowledge are linked through different types of links, e.g. causal links. The goal of this study was to examine the creative aspect of data evaluation in presence of anomalous data. The students were confronted with two experiments which contradicted each other with regard to the underlying theory. Afterwards the students were asked to decide about their favored theory and reasoning about their choice in their lab reports. The model-of-data, which was reconstructed from the lab reports of the students, was used to extract creative aspects in the mental modelling process.

Furthermore, a pre-post-questionnaire on epistemological beliefs of the students was conducted. Students mostly acquired an unscientific view on epistemology in school. The question was whether the confrontation with anomalous data and the triggering of creative modelling processes have any influence on this.

The results show that most students did not take anomalous data into account in their modelling processes. They did either not recognise or just ignore the data. Just a few students worked on their theory because of the new, contradictory data. The students working on their theory scored higher in the post-questionnaire, so a positive effect of creativity on scientific epistemology can be assumed. Thus, creativity obviously gets a part of science and should be taught in school science in order to make students aware of their own creative potential.

Keywords: epistemology, conceptual change, anomalous data

BACKGROUND AND RATIONALE

Data analysis is a crucial process within science education. Students have to deal with data to construct evidence and enlarge their theory. Even if this process seems to be much straight forward, creativity is needed to do so (Ertl, 2010; Kind & Kind, 2007). Like Kind and Kind (2007) mention, creativity is “the ability to produce novel and appropriate work” (p. 1). In the field of philosophy of science one can find many theories about how knowledge is constructed (Kuhn, 1996; Lakatos, 1978; Popper, 2005). Every theory of knowledge acquisition or the structure/nature of knowledge includes elements of creativity, but often it is not directly referred to. Because of this flawed classification of creativity in the scientific process, students do not perceive their own creativity in a scientific context (Braun, 2011). Even in modern, kind of scholastic versions of knowledge acquisition theories like “conceptual change theory”, creativity is not mentioned directly (diSessa, 2002; Limón, 2001; Posner, Strike, Hewson, &

Gertzog, 1982). This favors the connection of creativity to arts, but more heavily the separation from science. However, theories of NOS (nature-of-science) define creativity as a crucial part of epistemology (Lederman et al., 2002).

Furthermore, the modelling process is full of creative tasks that can be made visible through the generation of models-of-data (Chinn & Brewer, 2001). Models-of-data enable us to see the linking between different knowledge aspects, which differ in their creative level. Besides the creative level of links, model-of-data can give information regarding the epistemology of the students. Creativity and epistemology are directly linked to the question whether creativity is needed to generate knowledge. In the next section I will give an overview of the linking and nature of this to conceptual understanding.

THEORETICAL FRAMEWORK

Creativity has its roots in the 1950s and the presidency of Joy P. Guilford of the American Psychological Association (APA) (Plucker, 2001). After his presidential address, creativity reached more attention and many different researchers worked in this field. Creativity was first assumed to consist of convergent and divergent thinking (Simonton, 2012). Divergent thinking seems to be the "more creative" task, wherein students have to think about a problem in various ways, or from different perspectives. By doing so, they may find more possible solutions. This simple definition of creativity seems to be too narrow, so more research was conducted regarding influencing factors of creativity. Attention was given to environmental influences like socio-cultural influences (Funke, 2000), multiculturalism (Simonton, 2012), social embeddedness (Massoudi, 2003) and much more. A conclusive definition of creativity would include the personality, intelligence and identity of a person (Simonton, 2012) as well as different environmental factors, most importantly freedom, space for thinking and the process itself (Funke, 2000).

As Kind and Kind (2007) assume, creativity has a clear connection to scientific modelling processes. Anomalous data is well known to trigger cognitive conflicts which can be seen as starting points for theory processing. In *conceptual change theory*, there is a long tradition of research focusing on this field (Limón, 2001; Posner et al., 1982). However, most of this research does not include creativity. The integration of anomalous data in the existing mental, theoretical network can be visualized in so-called *model-of-data* (Fig. 1). *Model-of-data* are visual representations of the cognitive system of observations with explanatory approaches in an inquiry setting (Chinn & Brewer, 2001). These models contain observations and previous knowledge, set in relation by different types of links (e.g. causal link, inductive link, etc.). The different links between the aspects reveal different degrees of creativity. As can be seen in Figure 1, some of the links, e.g. 6 → 7 are simple causal links. But there are more creative links too, e.g. the analogical link of aspect 6-9 with aspects 10-13. Causal links sometimes are obvious, but this analogical link must be explored through cognitive processes. Once explored, it is not self-evident, that the link or aspect gets part of the theory. Before integrating the aspect, there will be a plausibility-check for the whole theory (Chinn & Brewer, 2001). With the help of models-of-data the creative modelling process can be examined in a relatively direct way. It is important to reflect the role of epistemology in connection to creativity. It is assumed, that a higher creativity level leads to a more informed epistemological insight.

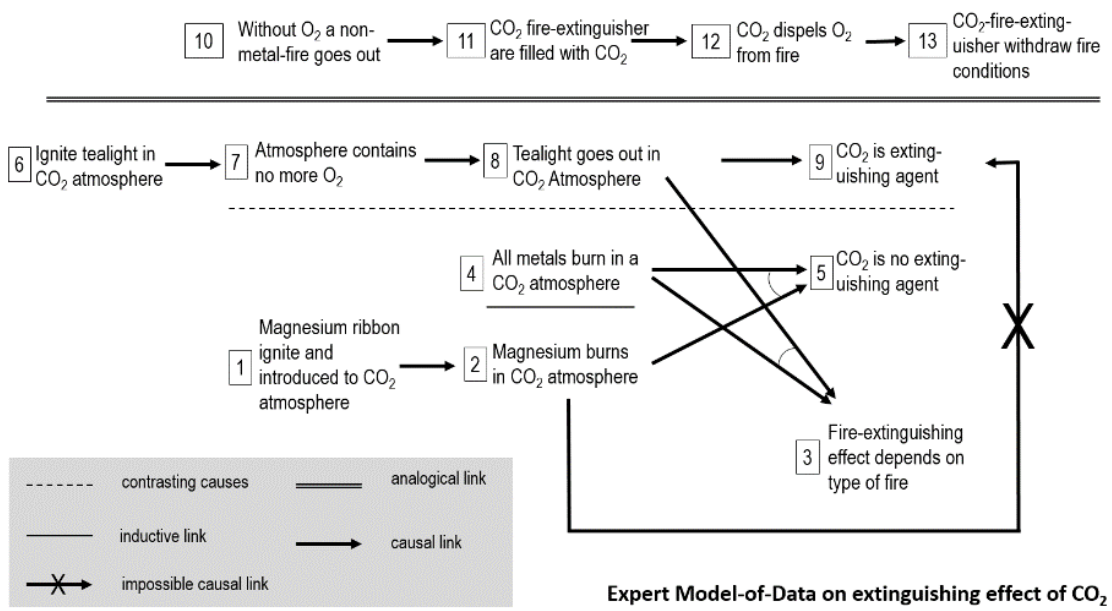

Figure 1. Example model-of-data for burning conditions of selected substances and the extinguishing effect of CO_2.

To create a model-of-data and reflect about epistemology it is necessary to create information which could be processed. Therefore, anomalous data can be used, as they are a crucial component of the conceptual change process (Posner et al., 1982). Chinn and Brewer (1993) postulate seven different ways of reaction to anomalous data. Most ways (5 out of 7) deal with ignoring anomalous data because of different reasons (e.g. "holding anomalous data in abeyance" (Chinn & Brewer, 1993, p. 8)). There are two ways of theory transformation which differ in their degree of change. There can be minor changes in the peripheral region of the theory or major changes on the core beliefs of the students.

RESEARCH AIM

The main aim of this study is to identify creative aspects in the data evaluation task in presence of anomalous data in a lower secondary school science course. In addition, the induction of a conceptual change through anomalous data can be evaluated.

RESEARCH DESIGN AND METHODS

In this study, grade-7 students (N=30) were confronted with anomalous data regarding the extinguishing effect of carbon dioxide. At first the students observed the attempt to extinguish burning fat with water as opposed to carbon dioxide. Before this observation the students were encouraged to form their own hypotheses. In a second experiment the students had to form hypotheses and observe burning magnesium in a carbon dioxide atmosphere. This experiment served as confrontation with anomalous data because the ongoing redox reaction can be observed. Afterwards the students had to decide, if carbon dioxide is an extinguishing agent or not. To force the students to a distinct statement, they had to formulate a mnemonic. In view of epistemology the students were encouraged to ask for further information they need to formulate the mnemonic.

To collect data, the students had to fill up a lab report for the whole intervention. The lab report was structured by the author to keep the students' focus on the experiments and hypotheses instead of creating a lab report. The data generated through this report served for setting up the model-of-data of the students by the author and the categorization into the categorical system of Chinn and Brewer (1993). Additionally, a pre-/post-questionnaire with closed and open items was conducted. The open items generate a qualitative access and were adapted from existing nature-of-science questionnaires (Lederman & O'Malley, 1990; Schwartz, Lederman, & Lederman, 2008). Similarly, the quantitative part of the questionnaire was adapted from established nature-of-science questionnaires (Lederman, Abd-El-Khalick, Bell, & Schwartz, 2002; Meichtry, 1992). Table 1 shows some of the items and the categorical system.

Table 2. Scales, items and sources of the pre- & post-test.

Scale	Number of items	Sources	Example item
Creativity	5	Lederman et al., 2002; Schwartz et al., 2008; Meichtry, 1992	Scientists are creative.
Scientific process	4	Lederman et al., 2002	Does the development of scientific knowledge require experiments?
Data as preliminary source of knowledge	3	Lederman et al., 2002; Schwartz et al., 2008	When you use the word 'prove', what do you mean?

In addition to the items presented above, some items were added by the author which could be rated on a four-point Likert scale. With this self-generated items, it is possible to draw attention on various aspects.

The combination of the qualitative and quantitative approach within the questionnaire and the in-depth information out of the lab reports enables to have a closer look on the creative modelling processes.

RESULTS

At first, a reliability analysis was conducted to evaluate the compiled questionnaire. This analysis resulted in poor values, so a factor analysis was conducted. Table 1 shows the scales after re-categorization through factor analysis. In a previous attempt, the category 'data as preliminary source of knowledge' was divided into the categories 'data' and 'tentativeness of scientific knowledge'. Also some items were sorted in different categories

Table 2. Cronbachs-Alpha values for the recategorized scales.

	Pre-test	Post-test
Creativity	.477	- .067
Scientific process	.688	.289
Data as preliminary source of knowledge	.169	.683

regarding to the new categorization. Table 2 shows the reliability values for the re-categorized scales.

As one can see, the reliability values after the factor analysis are not very well at all, but in case of the few items and a small sample some concessions can be made.

In a pre-post comparison, a significant effect can only be found for the perception of creativity (t=1,976, p=.03, N=23, d=0,40). All other categories do not reach a level of significance (p > .05). With a view on the open items no big differences can be observed. A few answers are a bit more advanced, so the students were more precise e.g. in mentioning important steps of the scientific process. Furthermore, the communicative nature of science got clearer for the students in the post-questionnaire. They mentioned that scientist have to talk about their findings, to generate new evidence.

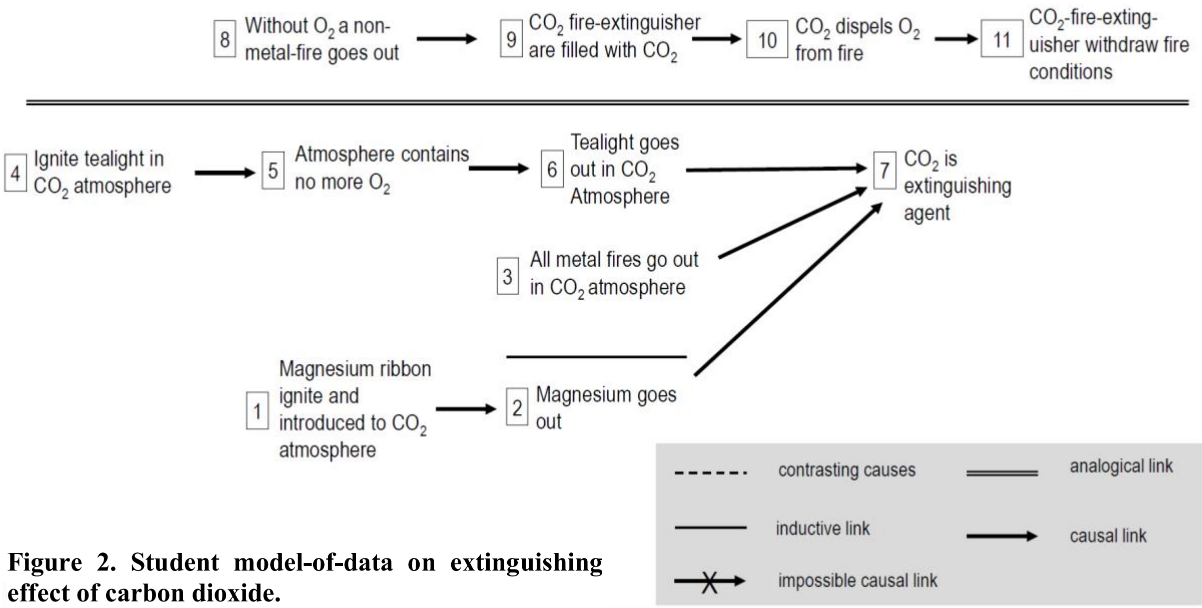

Figure 2. Student model-of-data on extinguishing effect of carbon dioxide.

Furthermore, the students had to compare the work of scientists with their own work and they saw many similarities in that. Especially the process of scientists and students seems to be similar, whereas the state of knowing differs. The students said, that they know what should be the outcome of an experiment, because some scientists conducted the experiment earlier (BA12). When these scientists conducted the experiment, they do not know what would happen, so this is a big difference between students and scientists.

Next to the questionnaire, the lab report can provide information regarding the modelling process. Figure 2 shows the reconstructed model-of-data for the students' view on the extinguishing effect of carbon dioxide. As can be seen, the students used very few different types of links between the events. Causal links are overrepresented, whereas some links do not exist (e.g. contrasting link & impossible causal link). The whole model-of-data is conclusive for the students, there are no contradictions. With regard to the demonstrated experiments, some of the events are incorrect, which leads to a model-of-data which differs from an expert view in Figure 1.

The most important difference of the students' model-of-data and the expert ones can be seen in event 2. While the experts observe the ongoing reaction of magnesium in carbon dioxide, the students observe a fire in the process of being extinguished. The observations differ, which can also be explained by the students' reaction to anomalous data. Figure 3 shows the distribution of responses to the anomalous data of the students: Most students ignore the anomalous data, which means they recognize the contradictory character of their observation, but do not deal with it. This distinction is important because there is a second group which not dealing with the anomalous data, but also not noticing them as contradictory. Furthermore, there is a small group of students which worked on their initial theory. Some changed their core beliefs (theory change), some changed peripheral aspects of their theory (peripheral theory change). Regarding the group "Theory change" it must be stated that the students of this group did not reach the expert theory. Their initial theory was about the missing extinguishing effect of carbon dioxide, so they changed their theory to "carbon dioxide is an extinguishing agent" after they take the observations shown in Figure 2. Students in the group "peripheral theory change" just changed aspects of their theory. For example, some students thought about the amount of carbon dioxide which is needed and the correlation of it to the speed of the extinguishing process. This group processed a change on the "protective belt" (Lakatos, 1978, p. 48) of their theory, without affecting their core beliefs. The students of these two groups who worked on their theory even scored higher in the post-questionnaire.

DISCUSSION AND CONCLUSION

All in all, the study shows that the students use creative mechanisms while modelling, but in a very limited scope. With a look on the student's model-of-data in comparison to the expert one's, two aspects could be emphasized: First, the students use less creative links. Like mentioned above, students mostly use causal links. Causal links belong to less creative links in comparison to the other possible links. While contrasting causes and impossible causal links require divergent thinking, causal argumentation has a more convergent character. By including convergent thinking, a certain level of creativity is reached. A more advanced level needs more types of thinking and a degree of freedom, which can be achieved by divergent thinking. Second, the students use less links at all. While experts build a strong network of their events, the students build up less connections and reach a lower level of interconnectedness. A possible explanation of these big differences between students and experts could be seen in the previous knowledge. Experts have a huge amount of knowledge and profession in their field, while students are novices. Additionally, students are not as experienced in theory construction as experts, so that it is a big challenge for them to construct a theory, even if it is not that complex.

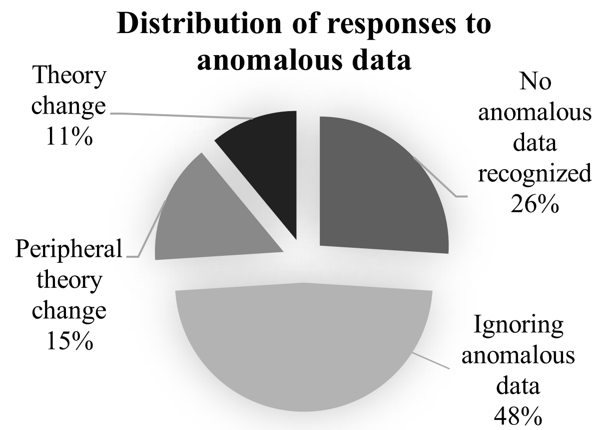

Figure 3. Distribution of responses to anomalous data.

Furthermore, the knowledge in the field of epistemology and overall meta-conceptual awareness can have an influence, which leads directly to the content of the questionnaire. As described earlier a significant effect was just found for the category “creativity”. One can say, the modelling task and confrontation with anomalous data seems to influence the understanding of creativity. The students worked creatively in the lesson and learned on a meta-level, too. The implicit confrontation with creative activities can help to reach a better understanding, but just in a limited amount. The effect size is not large (d=0,40), but it was not expected to be large without an explicit theming of creativity. With a look on the other categories one can see the stability of epistemological beliefs. For example, the average of category “data as preliminary source of knowledge” in pre-post-comparison differs about ΔM=0.2 (M_{pre}=2.93; M_{post}=2.73), for category “scientific process” the mean difference is even smaller with ΔM=0.014. It gets clear that core assumptions about epistemology are such entrenched, that they will not change through a 60-minute intervention. More time and repetitions are needed to consolidate an informed epistemology. However, although this intervention has potential for optimization, the “creativity”-category showed up a positive connection between creativity and epistemology. If there would be more work like this in school, the students can be assumed to expand their epistemological beliefs.

What remains unclear with regard to the model-of-data is the ignorance of many students to the anomalous data. First it is questionable why some students do not recognize the anomalous data. It might be possible, that these students have very entrenched initial theories, so that they sort anomalous data out just because it does not fit their theory. This process then takes place before any observation is documented, therefore no anomalous data can be seen in their lab reports. A possibility to prevent such processes would be to give precise observation tasks. A clear structure might help the students to document every observation and thus a separation of observation from analysis is possible. Second, it must be asked, why such a huge amount of students ignore the anomalous data even though they observed them. Besides the entrenchment of initial theory, what might play a role here too, the reason may lie in the anomalous data itself. Like Posner et al. (1982) state, there are some presuppositions for accommodation what mainly means to build up a new theoretical background for upcoming information. One presupposition is comprehensibility of the new concept. The students have to imagine a new concept to explain the anomalous data. Maybe there is a lack in theory building, respectively previous knowledge, which seems to be crucial for theory construction. When the students cannot imagine a new theory to explain new data, they may stick to their initial theory. This adoption can be underpinned by Kuhn’s (1996) theory of scientific revolutions. If there is no alternative to the existing theory – with which the students are dissatisfied – they will stick to the ‘old’ theory. The expert theory, which is taught in 8-9 grade in Germany, seems to be too complex and ‘out-of-reach’ of the students. Also the quality of the anomalous data can be reanalyzed. The anomalous data must be meaningful, otherwise they might rebound on the protective belt of the initial theory. Quality can be discredited in many ways. Besides the meaningfulness there can be problems with the source of data (Is the source believable?), the methodology of generating the data (How was the data generated?), etc.

In the model-of-data it gets obvious, that students use creative thinking. For example, the inductive and analogical links in Figure 2 show aspects of divergent thinking. Even causal links have a creative portion, which seems to weigh more for the students than the experts. Experts have a huge amount of knowledge, so it might be more easy to draw causal links. Students lack of previous knowledge in most scientific areas, accordingly causal linking is difficult.

To sum up, the intervention is suitable to make students aware of creativity in science. Because of the higher scoring of students who worked on their theory in the post-questionnaire, a connection of creativity and epistemology can be assumed. However, an overall effect on epistemological beliefs cannot be observed. This may due to the fact, that beliefs are very stable and students do not change their whole epistemology or entities just because of an irritation resulting from anomalous data. To reach higher effect sizes, the quality of the anomalous data should be reviewed. The main goal of this study was to influence epistemology through creativity, not to enlighten the thematic focus. This does not mean that the thematic focus is irrelevant, but even if the students do not reach the expert theory, the intervention can be successful. When students work creatively, they have the best opportunities to work like real scientists (Chinn & Malhotra, 2002) and enhance their epistemological beliefs.

REFERENCES

Braun, D. (2011). *Kreativität in Theorie und Praxis: Bildungsförderung in Kita und Kindergarten. Fachwissen Kita [Creativity in theory and practice – Educational research in Kindergarten and day care centers].* Freiburg, Br.: Herder. Retrieved from http://www.socialnet.de/rezensionen/isbn.php?isbn=978-3-451-32455-0

Chinn, C. A., & Brewer, W. F. (1993). The role of anomalous data in knowledge acquisition: A theoretical framework and implications for science instruction. *Review of Educational Research*, *63*(1), 1–49.

Chinn, C. A., & Brewer, W. F. (2001). Models of data: A theory of how people evaluate data. *Cognition and Instruction*, *19*(3), 323–393.

Chinn, C. A., & Malhotra, B. A. (2002). Epistemologically authentic inquiry in schools: A theoretical framework for evaluating inquiry tasks. *Science Education*, *86*(2), 175–218.

DiSessa, A. A. (2002). Why “conceptual ecology” is a good idea. In M. Limón & L. Mason (Eds.), *Reconsidering conceptual change: Issues in theory and practice* (pp. 28–60). New York, Boston, Dordrecht, London, Moscow: Kluwer Academic Publishers.

Ertl, D. (2010). The Nature of Science - Das Wesen/die Natur der Naturwissenschaften (The nature of science). *PLUS LUCIS*. (1-2), 5–7.

Funke, J. (2000). Psychologie der Kreativität [Psychology of creativity]. Retrieved from https://www.psychologie.uni-heidelberg.de/ae/allg/mitarb/jf/Funke_2000_Kreativitaet.pdf

Kind, P. M., & Kind, V. (2007). Creativity in science education: Perspectives and challenges for developing school science. *Studies in science education*, *43*(1), 1–37.

Kuhn, T. S. (1996). *The structure of scientific revolutions* (3. ed.). Chicago, Ill.: University of Chicago Press. Retrieved from http://www.loc.gov/catdir/description/uchi051/96013195.html

Lakatos, I. (1978). The methodology of scientific research programs. In J. Warrall & G. Currie (Eds.), *Philosophical Papers* (Vol. 1, pp. 1–250). Cambridge, New York, Port Chester, Melbourne, Sydney: Cambridge University Press.

Lederman, N. G., Abd-El-Khalick, F., Bell, R. L., & Schwartz, R. S. (2002). Views of nature of science questionnaire: Toward valid and meaningful assessment of learners' conceptions of nature of science. *Journal of Research in Science Teaching*, *39*(6), 479–521.

Lederman, N. G., & O'Malley, M. (1990). Students' perception of tentativeness in science: Development, use, and sources of change. *Science Education*, *74*(2), 225–239.

Limón, M. (2001). On the cognitive conflict as an instructional strategy for conceptual change: A critical appraisal. *Learning and Instruction*, *11*(4-5), 357.

Massoudi, M. (2003). Can scientific writing be creative? *Journal of Science Education and Technology*, *12*(2), 115–128.

Meichtry, Y. J. (1992). Influencing student understanding of the nature of science: Data from a case of curriculum development. *Journal of Research in Science Teaching*, *29*(4), 389–407.

Plucker, J. A. (2001). Introduction to the special issue: Commemorating Guilford's 1950 presidential address. *Creativity Research Journal*, *13*(3-4), 247.

Popper, K. R. (2005). *Logik der Forschung [Logic of research]*. (11. Ed.). *Gesammelte Werke: in deutscher Sprache (Collected works: in german language); 3*. Tübingen: Mohr Siebeck.

Posner, G. J., Strike, K. A., Hewson, P. W., & Gertzog, W. A. (1982). Accommodation of a scientific conception: Toward a theory of conceptual change. *Science Education*, *66*(2), 211–227.

Schwartz, R. S., Lederman, N. G. & Lederman, J. S. (2008). An instrument to assess views of scientific inquiry: The VOSI questionnaire. Retrieved from https://www.researchgate.net/publication/251538349_An_Instrument_To_Assess_Views_Of_Scientific_Inquiry_The_VOSI_Questionnaire/link/0deec52b9d9a9a2092000000/download

Simonton, D. K. (2012). Teaching creativity. *Teaching of Psychology*, *39*(3), 217–222.

TENTATIVENESS AND SOCIOCULTURAL EMBEDDEDNESS – RESISTANT MYTHS ABOUT NATURE OF SCIENCE?

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An adequate understanding of Nature of Science is a necessary condition for social participation. With regard to current controversial public discussions about socio-scientific issues, it seems particular important that students have adequate ideas about the supposed limitations of science. However, recent studies have shown that many preservice science teachers believe in myths regarding the tentativeness and sociocultural embeddedness of scientific knowledge and that their conceptions about both aspects have been resistant to change.

The purpose of our research project is to investigate preservice science teachers´ conceptions about the tentative and sociocultural nature of scientific knowledge, the origins of this conceptions and their resistance to change as well as possibilities of altering them in teacher education. In a first study, forty-one preservice chemistry teachers participated in a curriculum-oriented Nature of Science course, designed in the sense of the Conceptual Change Theory. Data were collected by using questionnaires, interviews, classroom artefacts and participatory observation. Results indicate that while the preservice chemistry teachers mostly held only partially informed or inconsistent views about both aspects at the beginning, the intervention mostly leads to much more informed views regarding the sociocultural embeddedness. However, the intervention also led to a certain degree of uncertainty for some participants with regard to the tentativeness of scientific knowledge. In addition, it turned out that the origins of the preservice teachers´ conceptions are very diverse.

Keywords: Nature of Science, Conceptual Change, Initial Teacher Education (Pre-service)

INTRODUCTION

With regard to current debates on “fake science”, “alternative facts” and controversial public discussions on socio-scientific issues, it seems particularly important that students become empowered to evaluate scientific processes and publications adequately. Therefore, adequate ideas about not only the strengths, but also the limitations of scientific knowledge are necessary (McComas, 1998). Students should be particularly aware of both the tentative nature of scientific knowledge and its social and cultural embeddedness (Osborne et al., 2003). Thus, in cases of public resistance to science “it seems that the main problem is not only the lack of understanding of the relevant science, but also—and perhaps most crucially — the lack of understanding of the uncertainty inherent in science.” (Kampourakis, 2018, p. 830)

The importance of an understanding of the tentativeness and the socio-cultural embeddedness of scientific knowledge is indicated in national science education standards documents (Olson, 2018). Nevertheless, little research in science education has focused on either or both of these two aspects of Nature of Science (NOS) in particular. A necessary condition for a thorough understanding of NOS on the student side is a teachers´ adequate understanding of NOS (Lederman, 1992). However, studies show that many preservice science teachers tend to have naïve views on both aspects (Abd-El-Khalick, 2006). Further, some recent studies indicate that misconceptions to some aspects of NOS are less likely to change then to other aspects, including views about the tentativeness and social cultural embeddedness of science. Both aspects seem to be especially resistant to change (Cofré et al., 2019). Mesci and Schwartz (2017) argue that one reason for this resistance to change is that the tentative nature of scientific knowledge contradicts the worldview of many future teachers. This is in line with Snow (1964), who criticized a large gap between the sciences and the humanities. Accordingly, for our study we derived the hypothesis that preservice science teachers´ conceptions about the tentative and socio-cultural nature of scientific knowledge are inadequate and resistant to change, because both aspects are more likely assigned to the humanities.

While most of the mentioned studies investigate conceptions of science teachers or preservice science teachers in general, there are no studies dealing specifically with views of preservice chemistry teachers about the tentative and sociocultural nature of science. Such an investigation seems necessary, because chemical knowledge plays a crucial role to understand contemporary challenges such as climate change or the expansion of regenerative energy sources. Therefore, adequate ideas of the strengths and limitations of this knowledge are essential for students to participate in public debates. Based on these considerations, the following research questions arise:

- Which conceptions about the tentativeness of scientific knowledge and its socio-cultural embeddedness do preservice chemistry teachers possess?
- Are these conceptions resistant to change?
- What are the origins of these conceptions and their resistance?
- How far are school-related contexts and NOS-activities suited to promote a more adequate and more functional understanding of both aspects among future chemistry teachers?

To answer the research questions different qualitative studies were conducted. Design and main results of an initial study, which mainly aims at answering the first three questions, are presented in the following sections. However, to assess views about NOS aspects, a clarification of the terms “tentativeness” and “sociocultural embeddedness” is necessary, and this dealt with in the following chapter.

THE TENTATIVE NATURE OF SCIENCE

The conducted studies are based on the following definition of tentativeness of scientific knowledge, which is also visualized in a diagram (see Figure 1):

From a philosophy of science perspective, scientific knowledge becomes reliable more and more over time, because it is empirically tested, valid for a long time and therefore very robust to changes (Osborne et al., 2003). Accordingly, scientific knowledge is widely accepted within the scientific community. In addition, most scientific theories have a high explanatory value and are almost free of inconsistencies. In this regard, scientific knowledge is durable (Abd-El-Khalick et al., 2008). However, all categories of scientific knowledge (theories, laws, constants, …) cannot be proven absolutely. Therefore, they are tentative as they are principally all subject to change (Popper, 1959). These changes can be slow and continuously or revolutionary (McComas & Olson, 1998). Scientific knowledge can change when new evidence and knowledge arise by conceptual or technological progress. Changes might also be due to reinterpretation of existing evidence and knowledge in light of new theoretical ideas or to changes in the cultural and social spheres (Lederman et al., 2002). It depends on the scientific community whether scientific knowledge is rejected, changed or partly changed (Kuhn, 1962). The principal tentativeness of scientific knowledge thus does not imply arbitrariness or unreliability of science. Far from it, the ongoing critical review and discussions by scientists, as well as the rejection of obsolete findings underline the durability and reliability of accepted knowledge. In this way, scientists are able to gain reliable knowledge approximately (Bell, 2009).

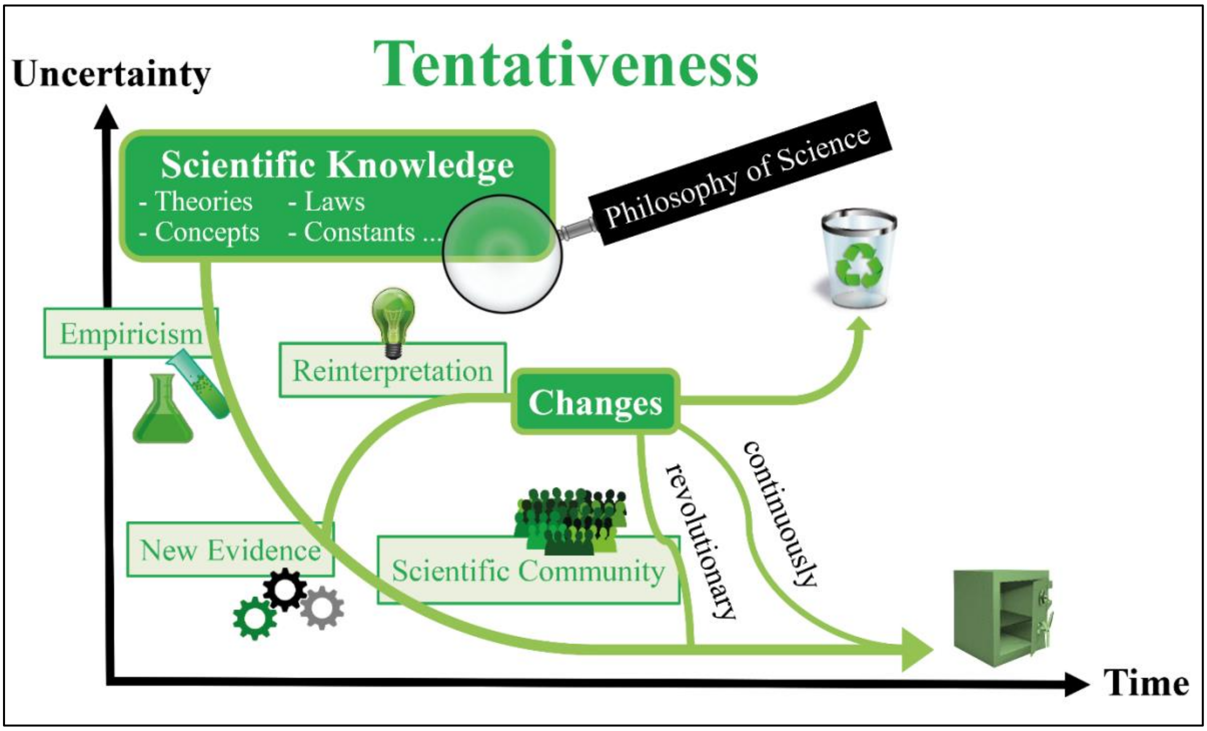

Figure 1. A scheme visualising the tentative nature of scientific knowledge.

The definition above (as well as the following definition of sociocultural embeddedness) is not intended to be passed on to students as declarative knowledge. But, it is rather a proposal and guiding framework for teachers to design competence-oriented learning environments (Allchin, 2013). In this way, learners should be able to participate actively in discussions about the certainty and trustworthiness of scientific knowledge.

THE SOCIAL AND CULTURAL EMBEDDEDNESS OF SCIENCE

Since science is a human enterprise, scientific knowledge is embedded in a wider social and cultural context (see Figure 2): On the one hand, scientific knowledge affects many elements and spheres of society and culture, for instance when new technologies are developed based on new scientific knowledge. On the other hand, scientific research is affected by numerous factors, including social fabric, worldviews, power structures, philosophy, religion as well as political and economic factors. These factors may influence the choice of research subjects, the way research is conducted (e.g. public funding for scientific research) and/or the final acceptance and dissemination of scientific findings by the scientific community or the society (Abd-El-Khalick et al., 2008; Kaya & Erduran, 2016). When analysing the sociocultural embeddedness of scientific knowledge, the historical context and the milieu of the time of the respective knowledge, should also be taken into account (Niaz, 2016).

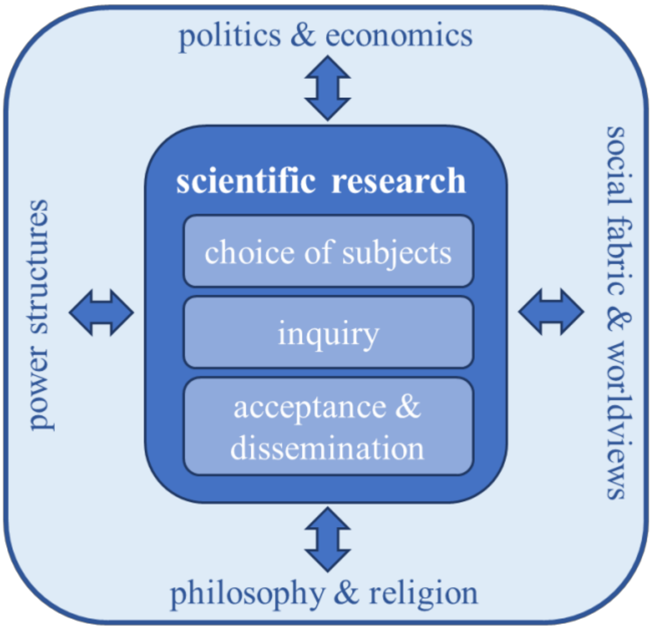

Figure 2. A scheme visualising the sociocultural embeddedness of science.

RESEARCH DESIGN AND METHODOLOGY

In two parallel chemistry education courses forty-one preservice chemistry teachers took part in a case study in 2018. To determine the participants´ conceptions about the two aspects "tentativeness" and "socio-cultural embeddedness" as well as their origins, a semi-standardized open-ended questionnaire was used as a pre-test, partly based on the VNOS-C questionnaire (Lederman et al., 2002). Additionally, semi-structured interviews were used for validation and for generation of more profound insights. During the following intervention classroom artefacts, portfolios and participatory observation were collected to validate the participants´ views in the sense of data and methodological triangulation (Flick, 2018). The participants finally completed the same questionnaire as a post-test, to determine conceptual changes.

Accordingly, the intervention itself was designed in the sense of the Conceptual Change Theory by Posner, Strike et al. (1982). Due to the conditions Posner, Strike et al. marked out, it was divided into three stages: During the first stage, the participants were encouraged to reflect on their own preconceptions. Therefore, they investigated characteristics of science. In the second stage, they had the opportunity to rearrange their views or build up new ideas about the social and cultural embeddedness of science and the tentative nature of various types of knowledge. For this purpose, the preservice teachers analysed and reflected historical and current case studies from chemistry, which are also relevant to the curriculum (for example the replacement of phlogiston theory, the discovery of quasicrystals or the current political influences on climate research). In addition, they carried out non-contextualized black-box activities, designed to illustrate both aspects. The last stage of the intervention aimed at applying their new ideas to chemistry teaching. Accordingly, the students analysed classroom situations and textbooks in which the aspects play a major role.

In order to answer the research questions, the pre- and post-test data from each participant were analysed using the qualitative content analysis according to Mayring (2015). Based on comparable studies (Miller et al., 2010; Mesci & Schwartz, 2017) the preservice teachers' views about both NOS aspects were assigned to a continuum of categories from naïve and inconsistent to increasing levels of "informed" (+, + +, + + +). A participant´s view about an aspect was assigned as naïve when it is contrary to the definitions above. For example, one preservice chemistry teacher regards scientific knowledge or at least a category of scientific knowledge as unchangeable:

> "Not scientific laws. They cannot be revoked, because other theories are based on them." [All German quotations in this article were translated by the authors.]

If the participant´s conception partially correspond to the definition, but partially also contradict it, it was encoded as inconsistent. The level of "informed" depends on the way of explanation: it is possible, that the participant argues only with the help of examples (+) or is explaining his/her view using a single argument (+ +) or provides a multidimensional and differentiated explanation (+ + +).

The Inter-Coder Reliability between the two coders is $p_0 = 0.9$ for views about both aspects, while the coefficient κ (Brennan & Prediger, 1981) is 0.83 concerning views about the tentative nature of science and 0.86 related to views of the sociocultural embeddedness.

RESULTS

The results of the assignment are presented in Table 1.

Table 1. Preservice teachers´ views about the sociocultural and tentative nature of scientific knowledge.

	Not classifiable	Naïve	Inconsistent	Informed +	Informed + +	Informed + + +
Views about the embeddedness of scientific knowledge in sociocultural contexts						
Pre-test	4	3	11	16	7	0
Post-test	0	0	4	12	14	11
Views about the tentativeness of scientific knowledge						
Pre-test	1	4	10	13	12	1
Post-test	0	5	5	21	10	0

Views about the sociocultural embeddedness of scientific knowledge

Related to the sociocultural embeddedness the preservice teachers´ views are relatively heterogeneous, but mostly inconsistent or only partially informed prior to the intervention. In fact, there is not a single participant with views on the highest level of "informed" in the pre-test. After the intervention, almost all of the participants possess informed views about sociocultural embeddedness with 11 future teachers having ideas on the highest level, such as:

> "Politics, particularly, influences science, whether by conditions of education and research or by research funding. […] Some research subjects also promise a high reputation, expressed in scientific mainstream. Furthermore, scientists are naturally human beings and as such social beings. […] Consequently, ethics also plays a major role. Finally, the fact that people often hold on to familiar concepts and therefore do not want to accept opinions contrary to their own ideas could affect the dissemination of scientific findings (see Daniel Shechtman and the discovery of quasicrystals)."

Overall, almost two third of the participants are more informed in the post-test.

In order to explain this significant conceptual growth and to identify the origins of their views, the participants were also asked to share experiences that shaped their views of scientific knowledge. Those inductively formed categories (Mayring, 2015) indicate that the embeddedness of science is not a common topic, especially not in school education (see Table 2). Many participants could not even name any experience related to this NOS element. Based on these results, the following conclusion arises: Conceptions about the sociocultural embeddedness are not resistant to change, but they barely exist due to a lack of discussion.

Table 2. Influences named by preservice chemistry teachers shaping their views of NOS aspects.

Influences on the participants´ views about sociocultural embeddedness	Entries	Influences on the participants´ views about tentativeness	Entries
University	13	University	26
Literature	8	School	17
TV shows & movies	7	TV shows & movies	12
School	4	Literature	8
Internet	2	Persons	4
Persons	2	No entry	8
Other	2		
No entry	15		

Views about the tentativeness of scientific knowledge

Tentativeness is discussed more often in science education (see Table 2), both at university and at school level. Therefore, a few more preservice chemistry teachers held informed views before the intervention compared to the sociocultural embeddedness (26 versus 23). For example, many participants mention the development and changes of different atomic models as examples of tentativeness. However, the majority has only partially informed or inconsistent conceptions (see Table 1). For instance, one participant believes that scientific knowledge can change and confirms this statement with an example:

> "Yes, the atomic model has changed again and again."

However, when asked about the differences between the sciences and the humanities, the same person also states:

> "In science, it is possible to prove hypotheses."

A context analysis was used to show that the term "prove" in this statement is not used in the sense of everyday language, but is to be understood as a distinction to the humanities and thus in an absolute sense. Accordingly, the participant was coded as inconsistent.

After the intervention, in total more preservice teachers have informed views than before (31 versus 26). In addition, the examples mentioned by the participants to explain tentativeness indicate that they associate their ideas more often with chemical content. However, the post-test results also show that some preservice teachers remain on the same level of understanding or even have less informed views about the tentative nature of science than in the pre-test. In summary, with regard to tentativeness two problems emerged from the study: First, preservice chemistry teachers are not able to explain their views and therefore mainly remain on the first level of information and second the intervention seems to unsettle some of the participants:

> "Now I think: Everything could be wrong, everything could be right. No one knows."

That means the intervention is suitable to initiate the cognitive conflict necessary for a conceptual change, but it is not suitable to solve it. For this purpose, the movies, TV shows and books, mentioned by the preservice teachers as influences on their conceptions about science (see Table 2) might be useful in further studies, to create cognitive conflicts and initiate further conceptual changes.

Another finding is that before the intervention, the participants´ conceptions about tentativeness are often restricted to models and theories, but less to other types of scientific knowledge (see Table 3). During the intervention, there is an improvement concerning other categories of changeable knowledge. For example, laws, constants or conceptions are mentioned more often as subject to change in the post-test. Nevertheless, theories and models remain the most frequently mentioned examples.

Table 3. Categories of changeable scientific knowledge mentioned by preservice chemistry teachers.

Categories of scientific knowledge mentioned	Pre-test	Post-test
Theories/Models	37	57
Data	6	19
Laws	5	10
Classification systems	4	3
Definitions/Concepts	3	25
Hypotheses	2	1
Universal constants	0	11
No entry	1	0

The two cultures

Some statements of the participants, who made great progress in regard of both aspects, show that after the course they see more similarities between science and humanities. As an example, we look at the participant GK59: He is a male preservice teacher and studies chemistry and biology in the 4th semester at the University of Cologne. His views about tentativeness and sociocultural embeddedness during the pre-test were assigned as inconsistent. When asked, which ways of thinking and working he considers characteristic of science or the humanities, he reveals views that correspond mainly to scientism:

> "In addition, scientific methods are objective and reproducible. [...] In the natural sciences, facts and the research path are what matter. In the humanities, this is not the case."

However, the post-test questionnaire and post-interview reveal that GK59 holds informed (+) views after the intervention. Additionally, he sees more similarities between the sciences and the humanities:

> "I don´t remember what I had written, but I was more of an idealist than a realist. Scientists are not perfect. They are always influenced. A lot of things have changed for me."

Consequently, there seems to be a connection between adequate ideas about science on the one hand and bridging the gap between the two cultures on the other. This connection has to be fostered in the future. At the same time, it should be noted that some perils arise from epistemic relativism (Romero-Maltrana et al., 2019).

CONCLUSIONS AND DISCUSSION

The initial question was: Are conceptions of the two NOS aspects - tentativeness and sociocultural embeddedness - resistant to change? Based on the presented results and related to preservice chemistry teachers, the answer has to be: to some extent. The intervention led to a significant higher level of information about the sociocultural embeddedness of scientific knowledge. Accordingly, views about the embeddedness appear to be not that resistant. It seems that this NOS-tenet is simply neither often reflected nor in detail, neither within science education nor in public. Consequently, it should be taught in a more multidimensional way within science education, addressing the different dimensions of embeddedness (see Figure 2). For example, using different contexts, non-contextualized activities and structural aids turned out to be most helpful for a conceptual growth.

On the other hand, the resistance of misconceptions about tentativeness of scientific knowledge could be confirmed, because the participants are not able to explain their views. Furthermore, those views are often restricted to theories and models and less to other types of scientific knowledge. Last but not least, the intervention unsettles some students.

Consequently, a more differentiated discussion of tentativeness of all types of scientific knowledge is necessary to achieve a more adequate understanding. And to make it less likely that preservice teachers will be unsettled by such a discussion of tentativeness, the focus should also be on the certainty and durability of scientific knowledge. That's underlined by Clough (2007, p.2), who says:

> "Students who claim that science is tentative without acknowledging the durability of well-supported science knowledge can hardly be said to understand the nature of science."

First results of a subsequent study indicate that an approach, which takes into account the above considerations, is potentially suitable to promote a more adequate understanding of tentativeness. Accordingly, it is justified to describe the resistance to change of preservice chemistry teachers´ views about tentativeness as only "partly resistant".

REFERENCES

Abd-El-Khalick, F. (2006). Over and over and over again: College students' views of nature of science. In L.B. Flick & N.G. Lederman (Eds.), *Scientific inquiry and nature of science: Implications for teaching, learning, and teacher education* (pp. 389-425). Dordrecht: Springer.

Abd-El-Khalick, F., Waters, M. & Le, A.-P. (2008). Representations of nature of science in high school chemistry textbooks over the past four decades. *Journal of Research on Science Teaching, 45*(7), 835-855.

Allchin, D. (2013). *Teaching the nature of science: Perspectives & resources*. Saint Paul, Minn: SHiPS Education Press.

Bell, R.L. (2009). Teaching the nature of science: Three critical questions. *National Geographic Learning*. Retrieved from http://ngl.cengage.com/assets/downloads/ngsci_pro0000000028/am_bell_teach_nat_sci_scl22-0449a_pdf

Brennan, R.L. & Prediger, D.J. (1981). Coefficient κ: Some uses, misuses, and alternatives. *Educational and Psychological Measurement, 41*, 687-699.

Clough, M.P. (2007). Teaching the nature of science to secondary and post-secondary students: Questions rather than tenets, *The Pantaneto Forum*, *25*. Retrieved from: http://www.pantaneto.co.uk/issue25/front25.htm. Republished (2008) in the *California Journal of Science Education*, *8*(2), 31-40.

Cofré, H., Núnez, P., Santibánez, D., Pavez, J.M., Valencia, M., Vergara, C. (2019). A Critical Review of Students´ and Teachers´ Understandings of Nature of Science. *Science & Education, 28*(3-5), 205-248.

Flick, U. (2018). Triangulation. In N.K. Denzin & Y.S. Lincoln (Eds.), *The SAGE handbook of qualitative research* (5th ed.) (pp. 444-461). Los Angeles: SAGE.

Kampourakis, K. (2018). Science and uncertainty. *Science & Education*, *27*, 829-830.

Kaya, E., Erduran, S. (2016). From FRA to RFN, or how the family resemblance approach can be transformed for science curriculum analysis on nature of science. *Science & Education, 25*(9), 1115-1133.

Kuhn, T. (1962). *The structure of scientific revolutions*. Chicago: University of Chicago Press.

Lederman, N.G. (1992). Students' and teachers' conceptions of the nature of science: A review of the research. *Journal of Research in Science Teaching*, *29*(4), 331-359.

Lederman, N. G., Abd-El-Khalick, F., Bell, R. L. & Schwartz, R. S. (2002). Views of Nature of Science Questionnaire: Toward Valid and Meaningful Assessment of Learners´ Conceptions of the Nature of Science. *Journal of Research on Science Teaching, 39*(6), 497-521.

Mayring, P. (2015). Qualitative Content Analysis. Theoretical background and procedures. In A. Bikner-Ahsbahs, C. Knipping & N. Presmeg (Eds.), *Approaches to qualitative research in mathematics education. Examples of methodology and methods* (pp. 365-380). New York: Springer.

McComas, W. F. (1998). The principal elements of the nature of science: Dispelling the myths. In W.F. McComas (Ed.), *The nature of science in science education: Rationales and strategies* (pp. 53-70). Dordrecht: Kluwer.

McComas, W. F. & Olson, J. K. (1998). The nature of Science in international science education standard documents. In W.F. McComas, (Ed.), *The nature of science in science education: Rationales and strategies* (pp. 41-52). Dordrecht: Kluwer.

Mesci, G. & Schwartz, R.S. (2017). Changing preservice science teachers´ views of nature of science: Why some conceptions may be more easily altered than others. *Research in Science Education*, *47*, 329-351.

Miller, M.C.D., Montplaisir, L.M., Offerdahl, E.G., Cheng, F.-C. & Ketterling, G.L. (2010). Comparison of views of the nature of science between natural science and nonscience majors. *CBE Life Sciences Education, 9*(1), 45-54.

Niaz, M. (2016). *Chemistry education and contributions from history and philosophy of science.* Heidelberg, New York, Dordrecht, London: Springer.

Olson, J.K. (2018). The inclusion of the nature of science in nine recent international science education standards documents. *Science & Education*, *27*(7-8), 637-660.

Osborne, J., Collins, S., Ratcliffe, M., Millar, R. & Duschl, R. (2003). What "Ideas-about-Science" should be taught in school science? A delphi study of the expert community. *Journal of Research in Science Teaching*, *40*, 692-720.

Popper, K. (1959). *The logic of scientific discovery*. London and New York: Routledge.

Posner, G.J., Strike, K.A., Hewson, P.H. & Gertzog, W.A. (1982). Accommodation of a scientific conception: Toward a theory of conceptual change. *Science Education*, *66*(2), 211-227.

Romero-Maltrana, D., Benitez, F., Vera, F. & Rivera, R. (2019). The "Nature of Science" and the perils of epistemic relativism. *Research in Science Education, 49*, 1735-1757.

Snow, C.P. (1964). *The two cultures*. London: Cambridge University Press.

INTEGRATING INQUIRY, HISTORY AND REFLECTIVE LEARNING TO IMPROVE VIEWS OF SCIENCE: DESIGN AND EVALUATION OF AN INTERVENTION

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Scientifically literate citizens require an appropriate knowledge about science in order to acquire a good understanding of how science works and affects their daily life. This knowledge about science, which is known as Nature of Science (NOS), is considered a crucial aim of worldwide science education standards. For this reason, preservice teacher development adopts an essential role in this science educational scene, due to teachers' responsibility for promoting meaningful context to learn about science. Therefore, the purpose of this study consists in evaluating the impact of an intervention intended to improve preservice teachers' understanding of epistemological and sociological aspects of NOS. The intervention was developed using a design based research methodology. It integrates inquiry-based teaching (IBT) and the history of science through an explicit and reflective instruction, embedded in the scientific controversy of the spontaneous generation theory. Pretest-posttest differences between the experimental and the control group scores and the effect size are used to discuss improvements in the understanding of NOS after the intervention. Overall, the results show that the experimental group obtained a moderate progress and scored higher than the control one, with significant scores in three items applied in the evaluation. These results support the potential of combining inquiry and the history of science, along with explicit reflections about NOS, to improve preservice teachers' understanding of both key epistemological and sociological aspects of science.

Keywords: history of science, inquiry-based teaching, nature of science.

INTRODUCTION

An appropriate understanding of the Nature of Science (NOS) is one of the main aims of scientific literacy since it provides citizens a holistic view about how the scientific enterprise works and influences their life, to participate in socio-scientific issues democratically (Hodson, 2014; Next Generation Science Standards, 2013; OECD, 2019).

A consensus view has prevailed in the instructions focused on improving people's beliefs of NOS (Abd-El-Khalick & Lederman, 2000; Akerson, Abd-El- Khalick & Lederman, 2000; Lederman, 2007). This consensus view integrates a list of seven tenets, mainly referred to epistemological aspects of science. Nevertheless, despite of the fact this general view can be useful to start teaching NOS (Kampourakis, 2016), we consider not to reduce science to some simplifying aspects, but give a real image of its multiple relations with our contemporary social system, highly required in preservice and prospective teacher development courses. In that sense, in the last few years, many authors (Acevedo-Díaz & García-Carmona, 2016; Allchin, 2011; Dagher & Erduran, 2016) have reconceptualized NOS in their attempt to stand out the social system of NOS and to take into account multiple aspects of scientific practice, from the experimental to the social dimension, in a higher level of organization.

Regarding this broader sense about science, teaching NOS integrates an understanding about epistemological aspects, such as the nature of scientific knowledge (scientific theories, laws and hypothesis, the tentative nature of scientific knowledge) and the role and nature of scientific practices (observation, inference, modeling, classification, logical reasoning). Moreover, sociological aspects play an important role in this framework, highlighting the complex relationships between science-technology-society and those within the scientific community (personal scientific beliefs, motivations, professional scientific competence, acceptance of new scientific theories) (Manassero, Vázquez & Acevedo, 2001).

Besides the social need of NOS to take part into socio-scientific decision-making in our closest, regional or local, and global environment, the comprehension of NOS also fosters the human side of science, effective teaching-learning processes of scientific ideas and critical thinking (Driver, Learch, Millar & Scott, 1996; McDonald & McRobbie, 2012).

Despite these justified reasons, there are some obstacles in the effective instruction of NOS. On the one side, teachers' beliefs about NOS reveals they have an idealistic, empiric and positivistic view of science, which considers science as an absolute and static body of knowledge (Akerson, Erumit & Kaynak, 2019; García-Carmona, Vázquez-Alonso & Manassero-Mas, 2011; Lederman, 2007). On the other side, some experts sustain NOS is not relevant for real societal life and too demanding for students (Kötter & Hammann, 2017). Actually, the integration of NOS in curriculum increases the potential of instructions in fostering the understanding of science facts, theories and laws, as well as to humanize sciences (Acevedo-Díaz, García-Carmona & Aragón, 2017, McComas, 2011; Nelson, Scharmann, Beard y Flammer, 2019; Yacoubian & BouJaoude, 2010). As consequence, the improvement of preservice teachers' view of NOS is justified by the fact they cannot teach contents they do not know about or they do not find useful, suggesting the need to support them in developing a better understanding of this issue and showing them its utilitarian nature, through contextualized, noteworthy and effective teaching-learning sequences (TLS).

Researchers in the area claim that a higher effort should be placed on the design and evaluation of effective interventions to improve conceptions of NOS (Clough, 2018). In this sense, inquiry-based teaching (IBT) and the history of science provide powerful opportunities to recognize and understand key features of NOS (Abd-El-Khalick, 2013). An IBT approach mainly fosters the understanding of epistemological aspects of scientific knowledge and practices, whereas the history of science shows the social construction and validation of scientific knowledge in its real context. In addition, the integration of both methodologies within the critical analysis of scientific issues in an explicit and reflective way, offers interesting opportunities to address these two dimensions of NOS consistently, to promote the dialogue and to challenge students to change their naïve conceptions of NOS to informed ones (Acevedo-Díaz et al., 2017; McComas, 2011, Yacoubian & BouJaoude, 2010).

Considering the above arguments, this work presents the design and evaluation of an innovative intervention integrating inquiry, history of science and reflective learning to improve pre-service teachers' understanding of NOS.

THE INTERVENTION: INQUIRING ABOUT THE ORIGIN OF LIVING BEINGS

The intervention consisted in the implementation of a TLS, entitled "Inquiring about the origin of living beings", contextualized in the scientific controversy of spontaneous generation theory (Cobo-Huesa, Abril & Ariza, 2019).

This TLS introduces Aristotle's thoughts about the spontaneous generation of life under particular circumstances and engages pre-service teachers in discussions about the origin of mold in rotten oranges, challenging them to design their own experiments to refute Aristotle and to evince the biogenesis theory. At this point, pre-service teachers are not only involved in a hand-on activity based on the IBT, but they have also to reflect about their bias observations and explanations about the appearance of mold guided by their prior experiences and thoughts and about the role of their mistakes in the scientific theory refutation. Afterwards, they are invited to learn about the events in the history of science that fostered the evolution of scientific ideas towards the biogenesis theory. Likewise, they have to discuss, under a critical and a reasoning stance, about epistemological and sociological aspects of NOS through several historical episodes, which show some experiments and explanations made by the most relevant scientists involved in the spontaneous generation theory (Cobo-Huesa et al., 2019). Therefore, this intervention addresses the dialectical processes involved in the development of scientific knowledge, through an explicit reflection about the characteristics and the role of evidences, explanations, motivations of scientists and the standards and values of scientific enterprise. Finally, participants have to value the didactical benefits of IBT and the history of science in science education.

In short, this TLS emphasizes the structure of "construct the knowledge before discover it". That is, participants have to design and conduct their own experiments and struggle in the constructing evidence-based knowledge, before knowing about the huge and creative effort made by scientists to overcome the overwhelming acceptance of spontaneous generation theory. In addition, this intervention becomes useful to provide scenarios where students make connections between their prior knowledge and ancient theories.

METHOD

Research design and samples

A pretest-posttest-control group design was used to evaluate the impact of the intervention on pre-service teachers.

The sample consists of an experimental and a control natural group enrolled in the third course of a university degree to become primary school teachers. The experimental group consists of 51 students (30 female, average age 21), while the control group included 23 students in the pretest sample (13 female, average age 22) and 19 students in the posttest sample (10 female-two missing data, average age 21) due to limitations in the sample collection in this group.

The intervention was developed in the context of Didactics of Natural Science subject practices in the experimental group and it took six hours (three sessions). By contrast, the control group received a traditional instruction of science, instead of the intervention previously described and, as consequence, without an explicit and reflective instruction about NOS. The pretest and posttest were administered in the control and experimental group, a month and a half before and after the intervention, respectively.

Instrument

The assessment tool used to measure the impact of the intervention on preservice teachers' understanding of NOS was the Spanish version of the 'Views on Science-Technology-Society' (VOSTS) questionnaire, which consists in a pool of one hundred empirically developed multiple-choice items about several issues about NOS (Manassero et al., 2001). Each item consists of several statements that show appropriate, plausible or naïve views of the issue addressed in the item, classifying by a panel of expert judges. The participants valued each statements in a Likert type scale rating in 1 to 9. Afterwards, these direct scores were standardized through a quantitative metric rating in a scale [-1 to 1], so scores closest to -1 reveals a naïve view of NOS, while a score closest to 1 reveals an appropriate view of NOS.

For the purpose of this study, we selected 10 items from this questionnaire, dealing with epistemological and sociological dimensions of science. The items used in the pretest and posttest are shown in Table 1.

Table 1. Items of Spanish version of VOSTS used in the pretest and the posttest to evaluate the effectiveness of the TLS.

Dimension	Item	Issue
Epistemology	10113	Science procedure: the general science procedure involves observation, formulate and test a hypothesis.
	90111	Theory-laden: Scientific observations are rarely neutral. Instead, they are guided by scientists' theoretical beliefs, prior knowledge and expectations.
	90411	Tentative: although scientific knowledge (facts, theories, laws) is reliable and durable, it is always subjected to change.
	90651	Mistakes: they are intrinsic to scientific practice and, sometimes, they involve new discoveries or advances.
Sociology	20821	Social embeddedness of science: the social and historical context influences the construction of scientific knowledge.
	60111	Motivation: the main reason to do science depends on scientist's personal background.
	60211	Standards and values: scientist must not be only objectives, open-minded and fair-minded, but also imaginative and creative.
	70211	Disagreements: Disagreements in science are due to scientific (e.g. lack of facts), moral and personal reasons (e.g. personal benefits).
	70221	Decision-making: the logical structure, coherence, as well as scientists' interests and motivations, influence the acceptance of a scientific theory.
	70411	Competition: scientists compete for financial aids that fund their research. This competitive situation can cause conflicts of interests and scientific corruption.

The effectiveness of the intervention was assessed by comparing the pretest and posttest average scores of each item, in the experimental and the control group, and through the effect size statistic. This statistic measures the magnitude of the difference between two scores in standard deviation units (Morris, 2008). A positive value of effect size shows an improvement in the understanding of NOS after the intervention, and an effect size is considered relevant if it is larger than 0.30, although below this value, differences could still be statistically significant ($p < 0.01$) (Vázquez-Alonso, Aponte, Manassero-Mas y Montesano, 2016).

RESULTS

The objective of this study is to assess the improvement in pre-service teachers' views of NOS by comparing the variation in the average scores of the ten items applied in the pretest-posttest assessment, as well as by determining the magnitude of this variation through the effect size statistic. Therefore, the analysis of results is focused on detecting an improvement in key aspects related to epistemological and sociological dimensions of science to reflect about the learning potential of the TLS to provide a proper global view of NOS.

On the one hand, if we attend to the descriptive statistics of the experimental group (which receive the NOS education treatment) in Figure 1, participants' beliefs of NOS before the implementation of the TLS (pretest line) reveal a negative score in one item (60111_Motivation) and an overall homogeneous pattern in the rest of them, with slight positive scores. After the implementation (posttest line), in general, the profile is characterized by an improvement in nine of the ten items evaluated, but in different achievement degrees. If we attend to effect size line, four of that items show relevant scores after the implementation ($d>0.30$): 90651-mistakes ($d=0.66$), 20821-social embeddedness of science ($d=0.41$), 60111-motivation ($d=0.59$), 70211-disagreements ($d=0.31$). Three of these remarkable items address the sociological dimension of NOS (20821, 60111, and 70211) and one of them, the epistemological one (90651). The differences were statistically significant ($p<0.05$) in three of the former items (20821, 60111, 90651) (Wilcoxon signed-rank test). Respect to the remaining items, three of them show a moderate improvement (90411-tentative, 60211-standards and values, 70221-decision-making) and two items show a weak improvement (10113-science procedure, 70411-competition). The item 90111, related to theory-laden nature of observations (epistemological dimension of NOS), practically maintains its initial score after the implementation of the TLS.

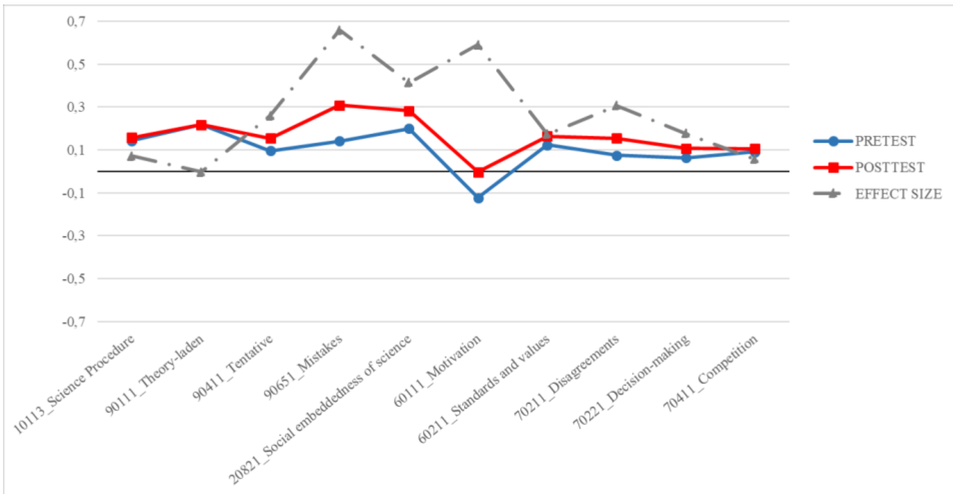

Figure 1. Average scores for the experimental group in the pretest and posttest, and effect size of index differences between two tests.

On the other hand, Figure 2 shows the descriptive statistics of the control group in the items applied. If we attend to pretest scores, they are similar to that obtained in the experimental group (Figure 1), with a negative score in the item 60111 and slight positive scores in the remaining items. However, the overall profile in the posttest is quite different from that in the experimental group. Despite of the fact that three items show a relevant improvement (20821, d=0.32; 60111, d=0.50; 70221, d=0.38), the other scores decline. As we can see, two items (20821 and 60111) improved in both groups in a relevant way, though the effect sizes in the experimental group are higher (0.41 and 0.59, respectively) than those in the control one (0.32 and 0.5, respectively). Finally, the differences are statistically significant in one item (70211) (Mann-Whitney U test), which shows a decline.

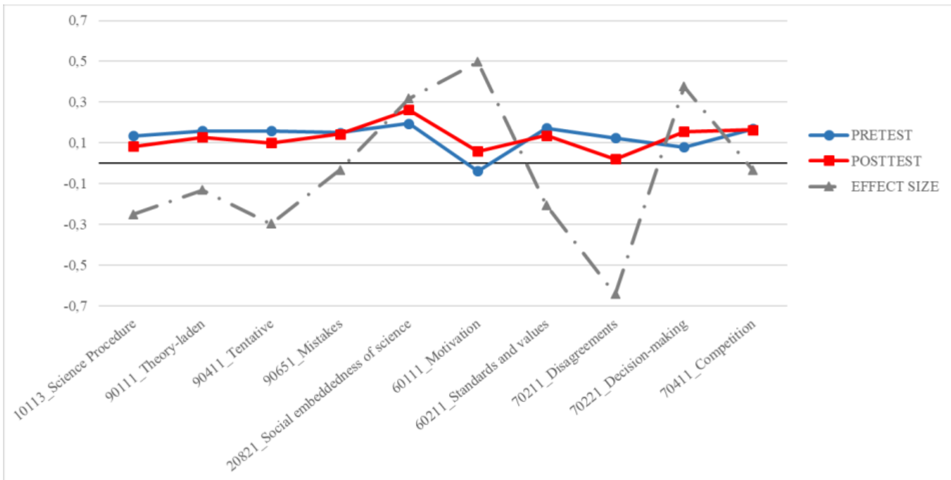

Figure 2. Average scores for the control group in the pretest and posttest, and effect size of index differences between two tests.

DISCUSSION AND CONCLUSIONS

This study presents the evaluation of an innovative intervention integrating different educational approaches (IBT, history of science and explicit reflection about NOS), using a pretest-posttest-control group design.

In this evaluation, the analysis of pretest and posttest scores and the effect size statistic provide useful information to determine the magnitude of the TLS effectiveness in improving pre-service teachers' view of NOS.

First, the experimental and the control groups sustain similar conceptions about NOS, with a remarkable naïve conception about the motivations that lead scientists to conduct their research. Nevertheless, after the intervention, both groups show different patterns. Respect to experimental group, according to effect size, students undergo a positive learning evolution in nine of the ten items evaluated, except for the item related to theory-laden nature of observation, which shows a very slight decline. In the control group, seven items show a negative learning progress.

Second, taking into account the progress of both groups, with regard to the four epistemological issues evaluated, the main strengths of the TLS intervention deal with the tentative nature of scientific knowledge (90411) and the role of mistakes in science (90651). Regarding the six sociological issues, the most remarkable improvements deal with the standards and values of scientists (60211) and the disagreements in the scientific dialogue of new theories acceptance (70211), as well as with the social embeddedness of science (20821) and the motivations of scientist (60111). These two last items are considered as strengths since the effect size scores obtained in the experimental group were considerable higher with respect to those in the control group.

These results can be discussed considering the reinforcing and highly contextualized nature of the TLS implemented (Clough, 2018). This approach deals with key aspects of NOS through a hands-on activity based on IBT and a deep analysis of the history of science, in an explicit and a reflective framework, to promote the conceptual change to a naïve to an adequate view of NOS (Abd-El-Khalick, 2013). As consequence, regarding the most improving epistemological issues after the TLS implementation, the structure of this intervention support the construction of an adequate view of the tentative nature of scientific knowledge and the intrinsic feature of mistakes in science. In fact, the TLS shows the change of mind of several scientists along the history in their attempt to determine the origin of living beings, as well as the fact to consider mistakes as an opportunity to learn and not to consider them as obstacles to solve the spontaneous generation controversy. Respect to the most improving sociological issues, the TLS reveals how scientists' personality and interests determine their experimental designs and arguments, which may have fostered the evolution to an adequate view of the standards and values of scientists and scientific disagreements. Last, motivations of scientists and the social embeddedness of science are issues widely addressed in the intervention. It points out the occupations and aspirations of the scientists involved in the controversy, as well as the highly rooted belief about spontaneous generation in society, that kept off any experimental explanation against it. These two aspects are embedded in our daily life, and that might be the reason of the improving showed in the control group, although it is minor than the improving identifying in the experimental group, probably due to the explicit and reflective instruction received.

Therefore, the assessment of the TLS effectiveness exhibits that the experimental group achieved a significantly better understanding of NOS. This modest increase replies the results of other studies, although with a higher sample (Vázquez-Alonso et al., 2016). Besides, the TLS described involves both dimensions of NOS in a more equitable way than those reported in other researches (Abd-El-Khalick & Lederman, 2000; Akerson et al., 2000; Kartal et al., 2018; Schwartz, Lederman & Crawford, 2004; Williams & Rudge, 2019).

Finally, to better understand the potential of this TLS on improving pre-service teachers' view of NOS, we have to focus on the short duration of this instruction (three sessions of two hours). Besides, naïve conceptions may be highly rooted in pre-service teachers so, despite the explicit and reflective instruction, they may try to dismiss or transform some of the new aspects addressed in the TLS to defend their prior mistaken conceptions (Clough, 2011). This fact reveals the need for meaningful, constructive, appealing and contextualized methodologies which promote an effective teaching of NOS.

In short, this research work offers insights into effective methodologies to achieve significant improvements in key aspects related to the broad nature of scientific knowledge, which is essential to acquire a proper scientific literacy. Likewise, the strengths and weakness identified feature some aspects about NOS that must be reinforced in the TLS and deserve special attention. Science educators must strive to face on diverse challenges in the Didactics of Science to contribute to a better understanding about science and science teaching process.

Supporting this cause, this TLS, evaluated through evidences based on the practice, provides some courses of action to foster preservice science teacher development and to guide future interventions.

ACKNOWLEDGEMENTS

The authors would like to acknowledge the Education of Scientific, Technological and Critical Thinking Competences by Teaching Nature of Science and Technology Themes (CYTPENCRI) Project EDU2015-64642-R (MINECO/FEDER), funded by the Spanish Ministry of Economy and Competitiveness and the European Regional Development Fund. Likewise, we acknowledge the PhD financial support for the Research Personnel Training of the University of Jaén 2017-2019 (R5/04/2017).

REFERENCES

Abd-El-Khalick, F. (2013). Teaching *with* and *about* nature of science, and science teacher knowledge domains. *Science & Education*, *22*, 2087-2107. doi: 10.1007/s11191-012-9520-2

Abd-El-Khalick, F. & Lederman, N.G. (2000). The influence of history of science courses on students' views of nature of science. *Journal of Research in Science Teaching, 37*, 1057-1095. doi: 10.1002/1098-2736(200012)37:10<1057::AID-TEA3>3.0.CO;2-C

Acevedo-Díaz, J.A. & García-Carmona, A. (2016). Algo antiguo, algo nuevo, algo prestado. Tendencias sobre la naturaleza de la ciencia en la educación científica. *Revista Eureka sobre Enseñanza y Divulgación de las Ciencias*, *13*, 3-19. doi: 10.25267/Rev_Eureka_ensen_divulg_cienc.2016.v13.i1.02

Acevedo-Díaz, J.A., García-Carmona, A. & Aragón, M.M. (2017). Historia de la ciencia para enseñar naturaleza de la ciencia: una estrategia para la formación inicial del profesorado de ciencia. *Educación Química*, *28*, 140-146. doi: 10.1016/j.eq.2016.12.003

Akerson, V.L., Abd-El-Khalick, F. & Lederman, N.G. (2000). Influence of a reflective explicit activity-based approach on elementary teachers' conceptions of nature of science. *Journal of Research in Science Teaching*, *37*, 295-317. doi: 10.1002/(SICI)1098-2736(200004)37:4<295::AID-TEA2>3.0.CO;2-2

Akerson, V.L., Erumit, B.A. & Kaynak, N.E. (2019). Teaching nature of science through children's literature: an early childhood preservice teacher study. *International Journal of Science Education*, *41*, 2765-2787. doi: 10.1080/09500693.2019.1698785

Allchin, D. (2011). Evaluating knowledge of the nature of (whole) science. *Science Education*, *95*, 518-542. doi: 10.1002/sce.20432

Clough, M.P. (2011). The story behind the science: bringing science and scientists to life in post-secondary science education. *Science & Education*, *20*, 701-717. doi: 10.1007/s11191-010-9310-7

Clough, M.P. (2018). Teaching and learning about the nature of science. *Science & Education*, *27*, 1-5. doi: 10.1007/s11191-018-9964-0

Cobo-Huesa, C., Abril, A.M. & Ariza, M.R. (2019). Propuesta didáctica en la formación de profesorado para trabajar naturaleza de la ciencia y pensamiento crítico. *Ápice. Revista de Educación Científica*, *3*, 15-28. doi: 10.17979/arec.2019.3.1.4630

Dagher, Z.R. & Erduran, S. (2016). Reconceptualizing the nature of science for science education. Why does it matter? *Science & Education*, *25*, 147-164. doi: 10.1007/s11191-015-9800-8

Driver, R., Learch, J., Millar, R. & Scott, P. (1996). *Young People's Images of Science*. Philadelphia: Open University Press.

García-Carmona, A., Vázquez-Alonso, A. & Manassero-Mas, M.A. (2011). Estado actual y perspectivas de la enseñanza de la naturaleza de la ciencia: una revisión de las creencias y obstáculos del profesorado. *Enseñanza de las Ciencias*, *29*, 403-412. doi: 10.5565/rev/ec/v29n3.443

Hodson, D. (2014). Nature of science in the science curriculum: origin, development, implications and shifting emphases. In M.R. Matthews (Ed.), *International Handbook of Research in History, Philosophy and Science Teaching* (pp. 911-970). Dordrecht: Springer.

Kampourakis, K. (2016). The "general aspects" conceptualization as a pragmatic and effective means to introducing students to nature of science. *Journal of Research in Science Teaching*, *53*, 667-682. doi: 10.1002/tea.21305

Kartal, E.E., Cobern, W.W., Dogan, N., Irez, S., Cakmakci, G. & Yalaki, Y. (2018). Improving science teachers' nature of science views through an innovative continuing professional development program. *International Journal of STEM Education*, *5*. doi: 10.1186/s40594-018-0125-4

Kötter, M. & Hammann, M. (2017). Controversy as a blind spot in teaching nature of science: Why the range of different positions concerning nature of science should be an issue in the science classroom. *Science & Education*, *26*, 451-482. doi: 10.1007/s11191-017-9913-3

Lederman, N.G. (2007). Nature of science: Past, present, and future. In S.K. Abell & N.G. Lederman (Eds.), *Handbook of Research on Science Education* (pp. 831-880). Mahwah: Erlbaum.

Manassero, M.A., Vázquez, A. & Acevedo, J.A. (2001). *Avaluació dels temes de ciència, tecnologia i societat*. Palma de Mallorca: Conselleria d'Educació i Cultura del Govern de les Illes Ballears.

McComas, W.F. (2011). The history of science and the future of science education: a typology of approaches to history of science in science instruction. In P.V. Kokkotas, K.S. Malamitsa & A.A. Rizaki (Eds.), *Adapting Historical Knowledge Production to the Classroom* (pp. 37-53). Rotterdam: SensePublishers.

McDonald, C.V. & McRobbie, C.J. (2012). Utilising argumentation to teach nature of science. In B.J. Fraser, K. Tobin & C.J. McRobbie (Eds.), *Second International Handbook of Science Education* (pp. 969-986). Dordrecht: Springer.

Morris, S.B. (2008). Estimating effects sizes from pretest-posttest-control group designs. *Organizational Research Methods*, *11*, 364-386. doi: 10.1177/1094428106291059

Nelson, C.E., Scharmann, L.C., Beard, J. & Flammer, L.I. (2019). The nature of science as a foundation for fostering a better understanding of evolution. *Evolution: Education and Outreach*, *12*. doi: 10.1186/s12052-019-0100-7

Next Generation Science Standards (2013). *The Next Generation Science Standards: For States, By States*. Washington D.C.: National Academy of Sciences Press.

OECD (2019). *PISA 2018 Assessment and Analytical Framework*. Paris: PISA OECD Publishing.

Schwartz, R.S., Lederman, N.G. & Crawford, B.A. (2004). Developing views of nature of science in an authentic context: an explicit approach to bridging the gap between nature of science and scientific inquiry. *Science Education*, *88*, 610-645. doi: 10.1002/sce.10128

Vázquez-Alonso, A., Aponte, A., Manassero-Mas, M.A. & Montesano, M. (2016). A teaching-learning sequence on a socio-scientific issue: analysis and evaluation of its implementation in the classroom. *International Journal of Science Education*, *38*, 1727-1746. doi: 10.1080/09500693.2016.1212289

Williams, C.T. & Rudge, D.W. (2019). Effects of historical story telling on student understanding of nature of science. *Science & Education*, *28*, 1105-1133. doi: 10.1007/s11191-019-00073-x

Yacoubian, H.A. & BouJaoude, S. (2010). The effect of reflective discussions following inquiry-based laboratory activities on students' views of nature of science. *Journal of Research in Science Teaching*, *47*, 1229-1252. doi: 10.1002/tea.20380

EXPLORING PHYSICS TEACHERS' CONCEPTIONS OF THE NATURE OF THE SCIENCES

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The present study investigates how Greek in-service physics teachers understand the unique features of school physics and biology. Our theoretical framework focuses on the notion of worldview and important differences that exist between the Newtonian and the neo-Darwinian worldviews, whereas our methodology involves questionnaires and mainly individual interviews. The empirical findings indicate that participants understand the nature of the sciences (NOTSs) from the perspective of how they understand their own science and tend to share homogeneous NOTSs conceptions that mostly stem from how they have assimilated positivistic tenets. As a result, they have serious misunderstandings regarding several NOS items and project upon biology epistemological characteristics that biology does not possess. Remarkably, when participants accept that there are differences among biology and physics they resort to a pre-Darwinian (non-scientific), namely teleological way of thinking.

Keywords: Misconceptions; Nature of sciences; Teacher thinking.

INTRODUCTION

While there is a large number of research studies that have explored what teachers know about Nature Of Science (NOS; e.g., Lederman, 2007; Vázquez-Alonso et al., 2013), there are no studies that have explored teachers' NOS conceptions with a focus on epistemological differences between the natural sciences. This gap in the literature may be attributed to the current consensus NOS view; NOS researchers focus more on a universal view of science and less on specific features of individual natural sciences.

Recently there is certain criticism against this domain-general approach to NOS (for a synopsis, see Kampourakis, 2016) and many science educators argue that research should also focus on the differences between the various natural sciences (Schizas, Psillos & Stamou, 2016). However, the suggestions of these critics have not been employed in empirical research.

The purpose of this study is to conduct such research by employing an alternative domain-specific NOS or Nature Of The Sciences (NOTSs) perspective. In particular, we aim at exploring how in-service physics teachers address the unique features of Newtonian physics and Neo-Darwinian biology by focusing on how they understand the respective worldviews. Thus, the following research questions are considered important: (a) Do physics teachers use homogeneity as a starting point in addressing the unique features of Newtonian (school) physics and Neo-Darwinian biology? (b) Do they share a kind of epistemological idiosyncrasy that results from how they perceive the Newtonian worldview or are their conceptions simply fluid, inconsistent and naive, as current NOS research demonstrates (e.g., Abd-El-Khalick & BouJaoude, 1997; Apostolou & Koulaidis, 2010).

Before embarking on the results of our study, it is necessary to present a brief description of the main differences between the Newtonian and Neo-Darwinian worldviews along with aspects of our methodology.

THEORETICAL FRAMEWORK

Our choice to focus on how in-service physics teachers perceive domain-specific epistemologies by using the notions of Newtonian and Neo-Darwinian worldviews is grounded in (a) epistemological assumptions that consider the notion of worldview as crucial in epistemological studies of sciences and (b) didactic assumptions that concern the nature of school physics and biology (Schizas, Psillos & Stamou, 2016). The Newtonian and Neo-Darwinian worldviews are not only important in the world of natural sciences but also influential in considerable sections of physics curricula (e.g., classical mechanics and geometrical optics) and biology curricula (e.g., molecular, cellular and evolutionary biology), respectively.

The Newtonian worldview embraces all physical scientific fields that constitute the so-called classical physics and complies with positivism (Frodeman, 1995), which flourished in school and academic environments for many years and advanced Newtonian physics to the status of model science and standard for all others.

Newtonian physics is predominantly nomothetic and possesses a mathematical theoretical structure consisting of interconnected universalities (i.e., scientific laws) that are (a) deterministic, (b) causally-closed, i.e., everything that explains a physical system is already contained within the mathematical equations that describe this system, (c) timeless or reversible, i.e., laws are assumed to work the same towards the past or the future, (d) fully known, i.e., Newtonian physics eliminates the presence of unforeseen events and (e) predictable, i.e., Newtonian physics possesses the positivist feature of making certain predictions because of reductionist and essentialist methodological choices. Interestingly, because of these choices the empirical phenomena under study can be experimentally reproduced under laboratory conditions and thus the experimental method has been considered the proper scientific method for a long time (Baltas 1988; 2004).

On the contrary, the Neo-Darwinian worldview draws its assumptions from evolutionary biology and is mostly based on the techniques of hermeneutics and historical sciences (Smocovitis, 1992). Neo-Darwinian biology lacks the kind of mathematical and universal statements that are widely recognized as ‘Newtonian laws’ (Sober 1993) and it is not necessarily underpinned by mathematical structures. Thus, compared to Newtonian physicists, biologists do not grasp empirical phenomena as if they were simply representatives of general phenomena and explore how these phenomena manifest themselves in specific places and times, finding thus regularities that are (a) causally complex, i.e., various causal factors are interrelated and form a causal structure, (b) contingent, i.e., an event does not necessarily occur because the presence of another event as in determinism, but has a tendency to occur in a particular context, (c) causally open, i.e., the action of a causal agent is interrelated with the effects of other causal factors that belong to many different organizational levels, (d) nonreversible, i.e., unexpected and unique events such as mutations and stochastic changes in environmental conditions often create discontinuities in the behavior of biological systems and make this behavior a historical outcome and (e) more or less unpredictable, i.e., historicity does not allow certain predictions, such as the predictions made by Newtonian physics, because predictions are based on the interpretation of historical processes, which leaves substantial variability unexplained (Stamou 2002).

METHODOLOGY

According to Greek legislation, secondary education physics teachers possess the appropriate qualifications to teach not only physics but also biology. Since the present study aims at an in depth analysis of their NOTSs views rather than statistical generalizability, the sample size is not required to be large. Thus, our sample involved fourteen Greek acting physics teachers (8 males, 6 females) who were purposefully selected out of a larger pool of physics teachers willing to participate in our research, and represented a range of individual and educational profiles.

Data were collected through questionnaires and mainly through individual interviews, which seem to be the appropriate research choice for studying learners' NOS views in depth (Lederman, Abd-El-Khalick, Bell, & Schwartz, 2002). Prior to the interview sessions, each teacher was asked to complete a multiple-choice questionnaire whose items focused on differences between classical (Newtonian) physics and Neo-Darwinian biology and were different from the usual ones (VOSTS or VNOS for example; Lederman, Abd-El-Khalick, Bell, & Schwartz, 2002) employed in contemporary studies during which teachers' conceptions of NOS items are examined. These items presented respondents with bipolar agree–disagree statements or positions coupled with several reasoned viewpoints or justifications to choose from. Each couple was classified as either an informed (I) or a non-informed (NI) NOTSs view and each questionnaire item involved only one informed position and justification. The final version of the questionnaire resulted from a developmental procedure that involved several stages and consisted of 6 items concerning the presence or absence of scientific laws in natural sciences, the nature of scientific methods and the nature of scientific predictions and explanations.

Our purpose behind the administration of the questionnaire was to trigger teachers' thinking of NOTSs and create a context in which these views could be discussed. This discussion was carried out during in-depth individual interviews that lasted approximately 60 min. each.

During the interview sessions, all participants were handed their questionnaires and were encouraged to explain their responses, clarify the meanings they ascribed to key epistemological terms, and provide specific examples to illustrate and contextualize their NOTSs views. Follow-up and probing questions were used to clarify vague or obscure statements in the participants' responses, whereas due to digressions we often paraphrased the questionnaire's questions and used many other open-ended questions to further investigate the respondents' lines of thought.

All interviews were recorded verbally and fully transcribed afterwards. Interview transcripts were then content-analysed by the authors and one experienced science teacher. Inter-rater agreement was considered necessary to be established before the analysis of the whole dataset and was accomplished by a two-round analysis of randomly selected data sets.

RESULTS-DISCUSSION

Scientific theories and laws

All participants disregard the presence of non-nomothetic natural sciences and to some degree they comply with positivism in defending the necessity for sciences to possess scientific laws. Moreover, all participants hold the number one NOS myth (McComas and Olson 1998: 54) "...that with increased evidence there is a developmental sequence through which scientific ideas pass on their way to final acceptance as mature laws" when agreeing with that in each natural science, scientists make scientific hypotheses that, if verified, become scientific theories, which in turn, with much more evidence, become higher order generalizations referred to as scientific laws.

The presence of this misconception in participants' mind motivated us to explore how they understand the distinction between the concepts of scientific laws and theories along with how they understand the relation between the concept of law and the empirical world. In both cases there are misunderstandings that indicate more serious misunderstandings about the very nature of Newtonian science. Most participants overlook that scientific laws are primarily ideal constructs resulting from idealistic rather than inductive reasoning, thereby reflecting how things must behave as opposed to merely reflecting how things happen to behave. They also disregard the fact that the concrete empirical phenomena that Newtonian physics grasps and handles through the use of experimental methods are simple representations of the relevant general phenomena and thus, they miss a lot of epistemological qualities behind how Newtonian physics transforms empirical phenomena to physical phenomena. Remarkably, due both to reasonable difficulties they encounter in finding or recalling physical theories independently of physical laws (thus resulting in misleading definitions of the concepts of 'theories' and 'laws') and their strong belief in the nomothetic character of natural sciences, they are triggered to believe that scientific laws are superior to scientific theories.

Scientific methods

Most participants view the scientific method as a lock-step and a universal step-wise procedure) in which experiment is a necessary prerequisite for validating scientific theoretical constructs when agreeing with that in all scientific research, the scientist observes and records natural facts, provides explanations on the basis of those facts, and then tests whether these explanations are true or not through experiments. This positivistic view complies with the ability of Newtonian physics to transform all natural phenomena into experimental phenomena and helps participants to determine the relation between the scientific and natural worlds and define the notion of scientific-ness.

This positivistic view is also accompanied by misunderstandings regarding what an experiment is. Because of losing sight of the transformations that are carried out during experimental implementation, participants encounter difficulties in defining the concept of experiment as a technical means of reproducing natural phenomena under laboratory conditions and possess several misunderstandings. For example, some participants confuse experiment with observation and the manipulation/control of experimental variables with their estimation. Irrespective of these misunderstandings, however, all participants consider experiment as any interaction of scientists with the empirical world that involves the comparison of some deduced state of affairs with some observed state of affairs. Thus, participants are prone to deductive reasoning and this is why they reject the presence of qualitative scientific studies that only involve descriptions.

Scientific predictions

Most participants disagree with the positivistic view of predictability as an essential feature of every science and hold that natural sciences do not have the same predictability. However, they fail to recognize this feature as a fundamental difference between biology and physics because they consider time as a neutral background on which timeless laws of nature unfold (Kwa 2010), exactly as positivism and the deductive-nomological model wish. Thus, they fail to associate the behaviour of biological systems with historical events and encounter serious difficulties in relating the notion of predictability with the historical nature of biological science.

There are also participants who assume that problems concerning prediction are common to both biology and physics. For example, there are participants who maintain that predictability problems in biology are analogous to those in weather models where the parameters involved cannot be estimated with mathematical accuracy, whereas other participants hold that certain predictions are impossible because of the non-linearity of natural systems.

Scientific explanations

Most participants hold that in biology there are no generalizations capable of explaining how biological entities will behave in each environment. However, they fail to recognize this feature as a fundamental difference between biology and physics. Either they hold that biology employs teleological explanations in parallel with deductive-nomological explanations, or they state that the use of deductive-nomological explanations in biology encounters serious difficulties, which, rather than resulting from the unique epistemological features of biology, are similar to those that are sometimes encountered by physicists.

All participants have considerable difficulties in capturing how biological evolution makes biological explanations different from physical explanations. The cause of such difficulties is not only their ignorance of significant aspects of evolutionary theory (which is justifiable for physics teachers). Important causes are (a) their strong belief in the nomothetic character of natural sciences, (b) their misconceived views of the concept of "qualitative data", (c) their adherence to the Newtonian notion of time, (d) their belief that teleological explanations are in principle acceptable and may distinguish biology from physics and (e) difficulties concerning how higher organizational levels are related to evolutionary explanations.

CONCLUSIONS

While at the beginning of our research the participating teachers admit their ignorance about biological topics, they do not hesitate to discuss NOTSs questions concerning biology. This is indeed feasible because most of the participants view the nature of Newtonian physics and Neo-Darwinian biology from a perspective that focuses on what a science should be if it is to be called ‘science’, thereby defining beforehand what can be referred to as ‘essence’ of science.

This essentialist and rather universalist perspective calls the participants to search for a priori criteria that may distinguish sciences from non-sciences in the science they know best; namely, Newtonian physics. Thus, while until now, research has shown that science teachers possess heterogeneous, fluid, incoherent and rather eclectic aspects of NOS (Abd-El-Khalick & BouJaoude, 1997; Apostolou & Koulaidis, 2010), our study demonstrates that behind participants’ NOS and NOTSs aspects may be found homogeneous conceptions that stem from how have assimilated epistemological aspects of school physics and of the underlying positivism.

Moreover, although the participating teachers are not rigidly committed to a coherent and consistent positivistic position because of several misconceived views of key epistemological terms, their homogeneous framework provokes troublesome situations in how they understand the nature of physics and biology. For example, they project upon biology epistemological characteristics that biology does not possess and when they accept that there are differences among biology and physics they resort to a pre-Darwinian (non-scientific), namely teleological, way of thinking.

ACKNOWLEDGEMENT

This study is supported by the program «Study of the development aspects of scientific literacy learners informal and informal education conditions using online virtual labs and use of geographical data», funded by the sectoral operational program “Competitiveness, Entrepreneurship and Innovation 2014-2020” under the Partnership and Cooperation Agreement (NSRF) for the period 2014-2020.

REFERENCES

Abd-El-Khalick, F., & BouJaoude, S. (1997). An exploratory study of the knowledge base for science teaching. *Journal of Research in Science Teaching*, *34(7)*, 673-699.

Apostolou, A., & Koulaidis, V. (2010). Epistemology and science education: a study of epistemological views of teachers. *Research in Science and Technological Education*, *28(2)*, 149-166.

Baltas, A. (1988). On the structure of physics as a science. In D. Batens & Jean-Paul Bendegem (Eds.), *Theory and experiment* (pp. 207–225). Dordrecht: D. Reidel Publishing Company.

Baltas, A. (2004). The Freud’s apple and the Newton’s unconscious. Athens, Greece: Exantas (in Greek).

Frodeman, R. (1995). Geological reasoning: Geology as an interpretive and historical science. *Geological Society of America Bulletin*, *107(8)*, 960-968.

Kampourakis, K. (2016). The “general aspects” conceptualization as a pragmatic and effective means to introducing students to nature of science. *Journal of Research in Science Teaching*, *53(5)*, 667-682.

Kwa, C. (2010). Agency and space in Darwin's concept of variation. In: L. Kavanaugh (Ed.), *Chrono-topologies, hybrid spatialities and multiple temporalities* (pp. 79-90). Amsterdam, The Netherlands: Rodopi.

Lederman, N. G. (2007). Nature of science: past, present, and future. In: S. K. Abell and N. G. Lederman (Eds.), *Handbook of research on science education* (pp. 831-879). Mahwah: Lawrence Erlbaum Associates.

Lederman, N., Abd-El-Khalick, F., Bell, R., & Schwartz, R. (2002). Views of nature of science questionnaire: Toward valid and meaningful assessment of learners' conceptions of nature of science. *Journal of Research in Science Teaching*, *39(6)*, 497-521.

McComas, W. F., & Olson, J. K. (1998). The nature of science in international science education standards documents. In W. F. McComas (Ed.), *The nature of science in science education: Rationales and strategies* (pp. 41–52). Dordrecht: Kluwer Academic Publishers.

Schizas, D., Psillos, D., & Stamou, G. (2016). Nature of Science or Nature of the Sciences?. *Science Education*, *100*(4), 706-733.

Smocovitis, V. (1992). Unifying Biology: The Evolutionary Synthesis and Evolutionary Biology. *Journal of the History of biology*, 25(1), 1-65.

Sober, E. (1993). Philosophy of Biology. Boulder, CO: Westview Press.

Stamou, G. (2002). An introduction. In P. Thompson (Ed.), The structure of biological theories. Crete, Greece:Crete University Press (in Greek).

Vázquez-Alonso, Á., García-Carmona, A., Manassero-Mas, M. A., & Bennàssar-Roig, A. (2013). Science Teachers' Thinking About the Nature of Science: A New Methodological Approach to Its Assessment. *Research in Science Education*, 43(2), 781-808.

ADDRESSING NATURE OF SCIENCE ASPECTS ON A PD-PROGRAM FOR GREEK SCIENCE TEACHERS: DESIGN – IMPLEMENTATION &VALIDATION

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A Science Teachers' Professional Development (PD) Program on Nature of Scientific Knowledge (NOSK) aspects is designed, implemented and evaluated, based on the cycle of expansive learning. A needs analysis showed that NOSK is not explicitly included in Greek Science classes and its integration might be a solution to students' indifference towards them (questioning phase). A relevant literature review highlights three approaches to teach NOSK: through History of Science (HOS), Scientific Inquiry (SI) and Socio-scientific Issues (SSI). The PD-program includes all three, in that order, to provide the 49 participant-teachers alternative paths to embed NOSK in more school science units, designed according to the community of trainees' Cultural-Historical characteristics and the Principles of Adult Education (analysis and modelling phases). Teachers examine and test the new model (4th phase) through a voluntary assignment to design and present a lesson plan to the plenary. The implementation phase consists of classroom observations and a 5th meeting, finishing with a 6th meeting (reflecting phase). Arisen contradictions are dealt to evolve the whole activity system. Tasks for evaluation are included in all phases. Results to that point show that the PD-program is successful.

Keywords: Nature of Science, Continuing Professional Development, Secondary School

INTRODUCTION

The importance to include Nature of Science (NOS) aspects in Science teaching is acknowledged among all researchers. The arguments for this are: a) better understanding of the limitations of science, b) increase interest in classroom, c) achieve better understanding of scientific knowledge and d) achieve scientific literacy (related to citizen education) (Matthews, 1997; Lederman, 2019). Especially the one about scientific literacy is widely adopted worldwide in science curricula (Allchin, 2014, Lederman et al, 2014). However, even though researchers and curricula designers agree that NOS needs to be taught – and specifically in an explicit way (Lederman et al, 2014, Lederman 2019), there is no consensus on a common list of NOS aspects (Lederman, 2019; McComas, 2017; Clough, 2007; Allchin, 2011; Matthews, 2012; Erduran & Dagher, 2014; Van Dijk, 2011).

As for Greece, even though there is academic work in the field (Piliouras & Plakitsi, 2015, Piliouras et al, 2017, Stefanidou & Skordoulis, 2017, Kampourakis, 2016), a survey (Koumara & Plakitsi 2017, 2019) showed that NOS is not included in the Greek secondary education and graduates have naïve views on it.

In the present work, the design, implementation, works for evaluation and initial results of a Professional Development (PD) program on teaching NOS aspects to 49 science teachers are presented in brief. We prefer to use the term "Nature of Scientific Knowledge" (NOSK), to communicate more accurately what is meant by NOS (Lederman 2019), to refer to the characteristics of scientific knowledge that are inherently derived from the manner in which it is produced (Scientific Inquiry) and are suitable for K-12 students to learn about.

We adopt Cultural Historical Activity Theory (CHAT) (Engeström 2001, Engeström & Sannino 2010) as a guiding framework for the design and analysis of the PD-program, something that is in agreement with Roth & Lee's view (2007): *"adopting CHAT as a guiding framework allows for a questioning of the structural determinations of current educational practices"* and also it has been used by many other researchers in the field of Curricula design and teacher training, in Science and other fields (Kolokouri et al, 2012; Kornelaki, 2018, p.20; Rodrigues et al, 2011; Jóhannsdóttir, 2014; DeWitt & Osbourne, 2007).
Education is a complex, multi-parametric activity system, that interacts in network relations with other systems, via the conceptual tools it has developed (Engeström, 2001), where they merge as *"a constellation of two or more activity systems that have a partially shared object"* (Engeström & Sannino, 2010). CHAT was selected so that we can be able to deal with the complexity of education's activity system. For example, the analysis of what the trainer is doing, using tools (educational means) to teach his/her trainees (a common ternary relation) is not an analysis of the activity system of education. The framework of Activity Theory suggests the excess of the directly visible dual and ternary relations among the nodes of the system, to define the way in which the other nodes are present and influence the examined condition (Kornelaki 2018, p.20).

NOSK ASPECTS

According to Lederman et al (2014) those characteristics are: (a1) Scientific knowledge is empirical, (a2) Scientific knowledge is inferential, observations and inferences are different, (a3) Scientific knowledge is durable but changes in the light of new evidence, (a4) Scientists' creativity and imagination are needed in all parts of a scientific research, (a5) Even though objectivity is the goal, subjectivity within scientists is inevitable, derived from scientists' personal beliefs, background knowledge, training, expectations, etc. (a6) Scientific knowledge is culturally embedded and (a7) Scientific Laws and Theories are different kind of knowledge.

CULTURAL-HISTORICAL ACTIVITY THEORY (CHAT)

CHAT is a "cross-disciplinary framework to study how humans purposefully transform natural and social reality, including themselves, as an ongoing culturally and historically situated process" (Roth et al, 2012). The first generation of CHAT was introduced by Vygotsky and the second by Leontiev (1978) with his perception on a collective system of human activity. Engeström (1987) illustrated Leontiev's views, introducing the triangle for human activity systems, see Figure 1 (Barma, 2011, Plakitsi et al, 2018, p. 50-52).

The relations between the Subject (usually people, lately they are also corporations that move towards a desired goal) and the Object (the goals of the activity) are mediating through tools, community, rules and division of labor (Igira & Gregory 2009). Tools/artefacts are culturally produced means that subjects use to perform the activity. They may be material, or mental, like language. Community refers to all the participants who share the same object, shape and direct individual actions to the collective activity. Division of labor refers to the way subjects –

members of the community divide their responsibilities during an activity. The triangle of the activity system refers both to the horizontal actions and interrelations between the members of the community and the vertical distribution of power, resources and relative societal/professional status (Plakitsi et al, 2018, p.53). The nodes of an activity system are not static and isolated to each other, but they are dynamically connected; the system is regarded as a unity (Hasan & Kazlauskas, 2014).

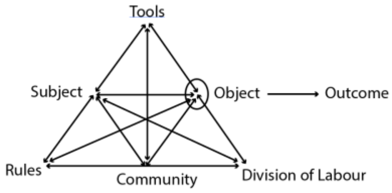

Figure 1: The structure of a human activity system

The third generation of CHAT (Engeström, 2001), moved beyond the barriers of one activity system, including minimally two activity systems that interrelate, promoting multiple perspectives, dialectics and networks for collaboration. Contradictions and tensions that might appear would play a crucial role as the most important motive for development of human actions, transforming both the activity and the outcome (Plakitsi et al, 2018, p.55). The 3rd generation of CHAT could be summarized in the following five principles: an activity system a) is the unit of analysis, b) is multi-voiced, c) its problems and potentials can be understood against their own history, d) Contradictions are the driving force of change and e) through the cycle of expansive learning it is possible to study the transformations of the activity system, while it is reconceptualized to embrace a radically wider horizon of possibilities than in the previous mode of the activity (Engeström 2001).

Engeström & Sannino (2010) give an ideal-typical sequence of actions in an expansive cycle, which is presented in detail, because the whole PD-program was designed and implemented based on the cycle of expansive learning:

- The first action is that of questioning. Participants in an activity system are criticizing or rejecting some aspects of the accepted practice and existing knowledge. Primary contradictions appear, within each and any of the nodes of the activity system.
- The second action is an analysis of the situation to identify systemic tensions or contradictions within and between activity systems. Secondary contradictions appear between two or more nodes, eg. a new object and an old tool.
- The third action is that of modeling, to construct an explicit, simplified model of the new idea that explains and offers a solution to the problematic situation.
- The fourth action is about examining and testing of the model to establish its potential and limitations
- The fifth action is that of implementing the model by means of practical applications, enrichments, and conceptual extensions. Tertiary contradictions appear, between a newly established mode of activity and remnants of the previous mode.
- The sixth and seventh actions are those of reflecting on and evaluating the process and consolidating its outcomes into a new stable form of practice. Quaternary contradictions appear, between the newly recognized activity and its neighboring activity systems.

The above are illustrated in Figure 2 (Engeström & Sannino, 2010)

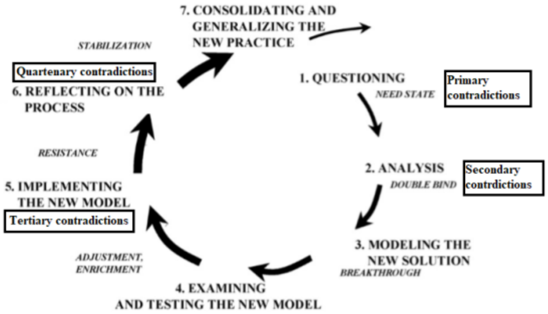

Figure 2. Actions and corresponding contradictions in the cycle of expansive learning (Engeström & Sannino 2010, Engeström 2001).

The process of expansive learning should be understood as construction and resolution of successively evolving contradictions. It is worth mentioning that all strategic actions presented in Fig. 2 are an indicative series of steps and not a “universal formula” that follow each other automatically; any step might be missed (Plakitsi et al., 2018, p. 81).

DESIGN & IMPLEMENTATION OF THE PD-PROGRAM

The PD-program was co-organized with the 4 Lab Centers (EKFE) of Thessaloniki. 49 science teachers participated voluntarily; their average age was 50 years old and they worked in education for 10-30 years. It took place in twilight courses and during mornings teachers followed their regular program at school: that was deterring for a long-last program. It was decided to contain four 3-hour meetings, one per fortnight. The first one took place on April 2018. At the end of the 4th meeting, teachers asked for a 5th meeting, that took place on December 2018 and lead to another one, on May 2019. The first writer, after the required permission, observed 9 of the above teachers in their classrooms during the school year 2018-19. All the PD-program was designed, implemented and took its final form and presented as a cycle of expansive learning (see Fig.2).

Before the first meeting between teachers – research group there were two separate activity systems, one of the Greek educational system and one of the research group. Through the interaction between those two systems, we target on expansive learning: both teachers and researchers participate in the design and implementation of a radically new, wider and processed object for their activity.

Each one of those systems are presented below in brief and then the shared system of teachers & researchers through the cycle of expansive learning.

1. **Activity system of a Greek science teacher**

Earlier surveys (Koumara & Plakitsi 2017 & 2019) pointed out that the Greek Science Curriculum does not include teaching of NOSK aspects, textbooks prompt – in a small degree – to discuss about only some of them, teachers haven’t learned them during their studies, so they intuitively refer to some of them, without assessment, and finally students have naïve views on NOSK aspects. Success in the National exams to enter university is a major value among the Greek families, so students’ preparation for the exams begin many years before. As a result, parents are an integrant part of the community, who press teachers and students for good grades and success in tests. Teachers end up focusing on the body of knowledge (definitions, laws, equations) and solving mathematical problems, which is what is examined in the National exams. Teachers have primary contradictions with the above, because students don't participate actively in classes, claiming that school is far from their interests.

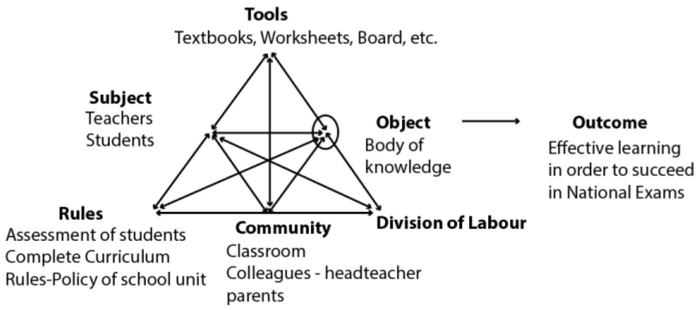

Figure 3: Activity system of the Greek science teacher

2. Activity system of the research group

Researchers in their own activity system have recorded three approaches to teach NOSK aspects, through a) History of Science (HOS), b) Scientific Inquiry (SI) and c) Socio-Scientific Issues (Lederman, 2009; McComas, 2017). For each approach, there are advantages (i.e. Matthews, 2015; Abd-El-Khalick & Lederman, 2000; Schwartz, 2006; Akerson, 2007; Eastwood et al, 2012; Zeidler & Sadler, 2011) and disadvantages (Lederman 2009; Bell et al, 2013; Allchin et al, 2014). From the above, it is concluded that none of the three approaches alone is enough. Furthermore, according to Allchin (2011), all teachers don't regard each approach to be as important as another, which was also a conclusion from our interviews with teachers (Koumara & Plakitsi, 2017). In our opinion, it is justified from their different cultural characteristics.

Taking that into consideration, it was decided to include all three approaches in the PD-program. As for the order of presentation: teachers' interviews showed that most of them don't regard NOSK to be as important as the body of knowledge. This can be explained from their cultural characteristics: they were trained in Science Departments, without any pedagogical instruction, and the activity system they lived in – both as students and teachers – was that of the National exams, the solution of advanced mathematical problems, without tasks that include or assess NOSK aspects.

In order to change their attitude, it was regarded to be important to start the PD-program with HOS, to recognize NOSK aspects throughout the evolution of scientific knowledge, and to realize that NOSK is part of science. The SI approach follows, which is within the desired culture of Greek Science Education. Finally, the PD-program closes with SSI, that our previous survey showed that is the most contradictory among the three.

Apart from that, the research group included in the design of the PD-program the basic principles of Adult Education: a) Adults learn more effectively when they participate in the learning process, when the content is focused on their needs and their previous knowledge and experience are used and b) Adults prefer to learn in their personal manner, according to their special cultural characteristics and abilities (Jarvis, 2010, p.106-110).

3. Cycle of expansive learning

3.1. Questioning

At the beginning of the PD-program, teachers were asked why they attended the program. Their answer was a description of the classroom activity system, similar to the one described on paragraph 1. The primary contradiction to the accepted practice was that their students don't participate actively, which makes their job tiring. They attended the program, because they were already critical towards the existing system and they seek for anything that could inspire their students to be more energized.

3.2 Analysis

Teachers knew the schedule of the program from its announcement. When the lecturer informed them that the goal was to a) learn NOSK aspects and b) be able to teach them themselves, secondary contradictions arose: a) in order to teach a new object they had to design new resources (tool), since there are none in the textbooks and b) there might be opposition, mainly from parents, if teaching is completely different from the regular.

Discussion lead to their suggestions, some of which were based on the inclusion of all three approaches of NOSK teaching: for example, teachers who already used HOS in their teaching, could add NOSK aspects to that content. Respectively, teachers who use SI and SSI could add NOSK aspects to what they already do, based on extracts vaguely derived from the textbooks. So, on the one hand teachers could design lesson plans easier and on the other students would not attend completely different classes than the ones they were used to. Also, it was decided not to do any intervention in the 12th Grade, the exams year.

3.3 Modelling the new solution

Each one of the first three meetings was dedicated to a NOSK teaching approach (HOS/SI/SSI). Their content was both original tasks and adjustments from the literature. The PD-program began with an induction to NOSK aspects.

1st meeting: HOS approach. The evolution of the concept "pressure" from 1638 to 1662 was presented. The choice was made firstly because the same phenomena are interpreted through different inferences: a) the partial abhorrence to a vacuum (Galileo), b) the weight of the air (Torricelli and Pascal), the infamous experiment on Puy-de-Dome being a crucial experiment and c) the "springs of air" (Boyle) developing the air-pump for the crucial experiment (Koumara, 2019) and secondly because of the intense effect of the new philosophical stream (Mechanical Philosophy). Before the presentation, teachers were asked to recognize and note down NOSK aspects. By the end of the lesson, these aspects were summarized in a table.

2nd meeting: SI approach. Teachers participated in a Black Box activity (Koumara & Plakitsi, 2018) and recognized NOSK aspects during its solution. Black boxes' computer applications and other classification tasks were also included (Bell, 2008). The meeting ended with a task where different inferences came from the same observations[1].

[1] https://scienceonline.tki.org.nz/Nature-of-science/Nature-of-Science-Teaching-Activities/Conflicting-theories-for-the-origin-of-the-Moon

3rd meeting: SSI approach. The topics were a) different inferences from interpreting the same diagram for the reasons of climate change (IPCC, 2001), and 2) advantages and disadvantages of using nuclear energy vs. coal for electricity (Sadler et al, 2007).

3.4 Examining and Testing the new solution

Teachers knew from the announcement of the program that they had to present a lesson plan as a final assignment, based on any school unit they wished, using NOSK aspects explicitly. Also, the assignment was not mandatory, so that teachers with increased responsibilities were not discouraged to participate in the program.

Even though the assignment was voluntary and occurred on the end of May, a season with increased responsibilities for teachers, 30/49 teachers delivered 29 lesson plans (2 teachers cooperated). 21 of them were successful. On the other 8, there was either incomplete application of the new model of activity or the old model remained. 7 of them were presented in the 4th meeting. Discussion followed each presentation between teachers and researchers. Questions, claims, different opinions and suggestions were heard. The program ended with teachers ask for a 5th meeting by next winter, after they would teach NOSK in their classes.

3.5 Implementing the new solution

Throughout school year 2018-19, the first of the writers observed 9 of 49 teachers in the classroom, in order to study how they embedded NOSK in their teaching. It was found that, in some occasions, there was disharmony between the suggested tasks for NOSK teaching and the daily school practice (tertiary contradiction). That was the theme of the 5th meeting (December 2018), where two videotaped lessons on NOSK teaching – of different character – were shown, analyzed and discussed. Through them and teachers' experience in NOSK teaching, contradictions appeared for some teachers between the object of the activity and its motive, which lead to upgrades of the activity.

3.6 Reflecting on the Process

The final 6th meeting took place on May 2019, where teachers whose lessons the first author observed, presented their experience to the plenary. Discussion followed. Quaternary contradictions arose, directly connected to other network activity systems, like the request to make changes in the curriculum and the textbooks. Teachers – having a first-hand experience themselves – have affected their schools and prepare for change.

3.7 Consolidating and Generalizing the new practice

We would reach that stage when the Curriculum changes and NOSK aspects are included.

EVALUATION OF THE PROGRAM – RESULTS

In order to evaluate the program, participant teachers were given the following tasks: a) before the 1st meeting they completed the VNOS-D+ questionnaire (pre-test) and 10 of them gave semi-constructed interviews, b) in the 4th meeting they: i) delivered their designed lesson plan on NOSK teaching, ii) completed a post-training evaluation form and iii) completed the post-test VNOS-D+ questionnaire, c) throughout school year 2018-19 classroom observations took place on how NOSK is integrated in the Greek school reality, using a protocol (and taken field notes) d) in the 5th meeting they completed a questionnaire on the usability of the three approaches in NOSK teaching and e) in the 6th meeting they wrote a report on their activities through the whole year, any difficulty they came through, what helped them to overcome it and how they regard their results.

All the above are analyzed. Initial results show that the PD-program improved their knowledge on NOSK, created a positive view towards its integration in the classroom, trained them to design their own lesson plan and teach NOSK. It is also positive that they asked for more interactive meetings, in order to exchange their views after their teaching experience.

Regarding the three approaches, they mention that a) students want variety in the tasks they are occupied with and b) more chances are given to teachers to embed NOSK aspects. Most of them mention that HOS is useful for teachers' training on NOSK, SI for students to perform tasks and SSI is for the desirable teaching.

REFERENCES

Abd-El-Khalick, F. Lederman, N.G. (2000). Improving science teachers' conceptions of nature of science: a critical review of the literature, *International Journal of Science Education*, 22(7), 665-701.

Akerson, V. Hanuscin, D. (2007). Teaching Nature of Science Through Inquiry: Results of a 3-year professional development program, *Journal of Research in Science Teaching*, 44(5), 653-680.

Allchin, D. (2011). Evaluating knowledge of the nature of (whole) science. Science Education, 95(3), 518–542.

Allchin, D. Andersen, H.M. Nielsen, K. (2014). Complementary Approaches to Teaching Nature of Science: Integrating Student Inquiry, Historical Cases and Contemporary Cases in Classroom Practice, *Science Education*, 98(3), 461-486.

Barma, S. (2011). A sociocultural reading of reform in science teaching in a secondary biology class, *Cultural Stud of Science Education*, 6(3), 635-661.

Bell, R. (2008). *Teaching the Nature of Science through Process Skills, Activities for Grades 3-8*, Pearson Education Inc.

Bell, R. Maeng, J. Peters, E. (2013). Teaching About Scientific Inquiry and the Nature of Science: Toward a More Complete View of Science. *The Journal of Mathematics and Science: Collaborative Explorations*, 13, 5-25.

Clough, M. (2007). Teaching the Nature of Science to Secondary and Post-Secondary Students: Questions rather than tenets, *The Pantaneto Forum*, Issue 25.

DeWitt, J. Osborne, J. (2007) Supporting Teachers on Science-focused School Trips: Towards an integrated framework of theory and practice, *International Journal of Science Education*, 29:6, 685-710.

Eastwood, J.L. Sadler, T. Zeilder, D. Lewis, A. Amiri, L. Applebaum, S. (2012). Contextualizing Nature of Science Instruction in SocioScientific Issues, *International Journal of Science Education*, 34(15), 2289-2315.

Engeström, Y. (1987). *Learning by expanding: An activity-theoretical approach to developmental research.* Helsinki, Orienta-Konsultit.

Engeström, Y. (2001). Expansive Learning at Work: toward an activity theoretical reconceptualization. *Journal of Education and Work, 14*(1), 133-156.

Engeström, Y. Sannino, A. (2010). Studies of expansive learning: Foundations, findings and future challenges, *Educational Research Review*, 5, 1–24.

Erduran, S., & Dagher, Z. (2014). Reconceptualizing the nature of science in science education. Dordrecht, The Netherlands: Springer.

Hasan, H. Kazlauskas, (2014). Activity Theory: who is doing what, why and how. In H. Hasan (Eds.), Being Practical with Theory: A Window into Business Research (pp. 9-14). Wollongong, Australia: THEORI.

Igira, F.T. Gregory, J. (2009). Cultural Historical Activity Theory, Handbook of Research on Contemporary Theoretical Models in Information Systems, 434-454.

IPCC, 2001: Climate Change 2001: The Scientific Basis. Contribution of Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change [Houghton, J.T., Y. Ding, D.J. Griggs, M. Noguer, P.J. van der Linden, X. Dai, K. Maskell, and C.A. Johnson (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 881pp.

Jarvis, P. (2010). Adult Education and Lifelong Learning: Theory and Practice, New York, Routledge

Jóhannsdóttir, T. (2014). Responsive Practices in Online Teacher Education, In book: Contemporary Approaches to Activity Theory: Interdisciplinary Perspectives on Human Behavio, Publisher: IGI Global, Editors: Thomas Hansson

Kampourakis, K. (2016). The "general aspects" conceptualization as a pragmatic and effective means to introducing students to nature of science, *Journal of Research in Science Teaching,* 53(5), 667-682.

Kolokouri, E. Theodoraki, X. Plakitsi, K. (2012). A Cultural Historical Activity Theory Approach In Natural Sciences Education Laboratory Lessons Towards Reforming Teachers Training, *World Journal of Education*, 2(2), 23-40.

Kornelaki, A. (2018). Educational program design in the field of science education for Informal settings under the prism of activity theory. Ioannina, Doctoral thesis

Koumara, A. Plakitsi, K. (2017). The nature of science in lower secondary school: the case of Greece. *Science Education: Research and Praxis*, (64-65), 104-114.

Koumara, A. Plakitsi K. (2018). Black Boxes in teaching Nature of Science aspects in Secondary Education, *3rd National Conference for Educational Resources on Science and Mathematics*, e-proceedings, 409-418.

Koumara, A. Plakitsi, K. (2019). An Evaluation study of the extent that Nature of Scientific Knowledge aspects are included in science classes of Greek Secondary Schools, Florina, ENEFET National Conference

Koumara, A. (2019). History of pressure implemented in a Nature of Science Professional Development Program for Science Teachers, IHPST proceedings, Thessaloniki, 396-405.

Lederman, N.G. Abd-El-Khalick, F. Bell, R.L. Schwartz, R.S. (2002). Views of Nature of Science Questionnaire: Toward Valid and Meaningful Assessment of Learners' Conceptions of Nature of Science, *Journal of Research in Science Teaching,* 39(6), 497-521.

Lederman J.S. (2009). Teaching scientific inquiry: Exploration, directed, guided, and open-ended levels. In: National Geographic Science: Best Practices and Research Base. Hapton-Brown, 8-20.

Lederman, N.G., Antink, A., Bartos, S. (2014). Nature of Science, Scientific Inquiry and Socio-Scientific Issues Arising from Genetics: A Pathway to Developing a Scientific Literate Citizenry, *Science & Education*, 23, 2, 285-302.

Lederman, N.G. (2019). Contextualizing the Relationship Between Nature of Scientific Knowledge and Scientific Inquiry Implications for Curriculum and Classroom Practice, Science & Education 28, 249–267

Matthews, M. R. (1997). Editorial, Science & Education, 6, 323-329.

Matthews, M. R. (2012). Changing the focus: From nature of science (NOS) to features of science (FOS). In M. S. Khine (Ed.), Advances in nature of science research: Concepts and methodologies pp. 3–26). Dordrecht, The Netherlands: Springer.

Matthews, M. R. (2015). Science teaching: The role of history and philosophy of science. (20th anniversary revised and expanded edition). NewYork,NY: Routledge.

McComas, W. (2017). Understanding how Science works: The nature of science as the foundation for science teaching and learning, *The School Science Review*, 98(365), 71-76.

Piliouras, P. Plakitsi, K. (2015). Discourse Analysis of Science Teachers Talk as a Self-reflective Tool for Promoting Effective NOS Teaching, *World Journal of Education*, 5(6), 96-107.

Piliouras, P. Plakitsi, K. Seroglou, F. Papantoniou, G. (2017). Teaching Explicitly and Reflecting of Elements of Nature of Science: a Discourse-Focused Professional Development Program with Four Fifth-Grade Teachers, *Research in Science Education*, 1-28.

Plakitsi, K. Stamoulis, E. Theodoraki, X. Kolokouri, E. Nanni, E. Kornelaki, A. (2018). Activity Theory and Science Education, Athens, Gutenberg.

Rodrigues, A. Camillo, J. Mattos, C. (2011). Cultural-Historical Activity Theory and Science Education: Foundational Principals and Potentialities, *Scientific Papers*, University of Latvia, 778, 191-200.

Roth, W.M. Lee, YJ. (2007). “Vygotsky’s neglected legacy”: Cultural-historical activity theory. *Review of Educational Research*, 77(2), 186- 232.

Sadler, T. Barab, S. Scott, B. (2007). What do Students Gain by Engaging in Socioscientific Inquiry?, Research in Science Education, 37, 371-391.

Schwartz, R. Crawford, B. (2006). Authentic Scientific Inquiry as Content for Teaching Nature of Science, In Scientific Inquiry and Nature of Science: Implications for Teaching, Learning and Teacher Education, Edited by Flick L.B. and Lederman N.G, Springer, 331-355.

Stefanidou, C. Skordoulis, K. (2017). Primary Student Teachers’ Understanding of Basic Ideas of Nature of Science: Laws, Theories and Models, *Journal of Studies in Education*, 7(1), 127-153.

van Dijk, E.M. (2011). Portraying real science in science communication. Science Education, 95(6), 1086 – 1100.

Zeidler, D.L. & Sadler, T. (2011). An inclusive view of scientific literacy: Core issues and future directions of socioscientific reasoning. In C. Linder, L. Ostman, D.A. Roberts, P. Wickman, G. Erickson, & A. MacKinnon (Eds.), Promoting scientific literacy: Science education research in transaction (pp. 176–192). New York: Routledge/Taylor & Francis Group.

STEREOCHEMISTRY IN HIGH SCHOOL: HISTORICITY IN BRAZILIAN TEXTBOOKS OF ORGANIC CHEMISTRY

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In this paper, we intend to present a brief analysis of how historical aspects related to stereochemistry are being addressed in Brazilian high school's textbooks. The reason for this research focuses on two points. Firstly, in Brazil, the textbook as a guide to classroom work is a reality, especially since the Federal Government established the National Textbook Program, which consists of free distribution of textbooks for public school students across the country. Second, stereochemistry comprehension is challenging because, in addition to requiring of visuospatial skills, it is sometimes introduced arduously to students who fail to relate this knowledge to their previous experiences, once their teaching is focuses on formulas and nomenclatures, without proper contextualization. This could be one reason that explains why some students show resistance to learn Chemistry. We believe that an approach of using the historical context can awaken a lost motivation on the students, since stereochemistry has many interesting aspects when taught within this perspective. Moreover, motivation can be considered as a requirement for learning. To achieve the proposed goal we analyzed five chemical textbooks approved by the National High School Textbook Program. Applying a methodology to analyze the historical content of science textbooks, we decided to focus on type and organization of historical information, since it provide guidelines for a comprehensive analysis and it is a dimension commonly used in books that seek the application of a story-related approach. The analyzes reveal a deficiency in the historical approach, and the reason may be due to the lack of formal education that most writers (themselves chemistry teachers) have about the history of science. This associated with the fact that teachers rely heavily on textbooks to select historical content to include in their science classes, contribute to a poor understanding of historicity by chemistry students in Brazil.

Keywords: *Secondary school, History of science, motivation.*

INTRODUCTION

The problems related to the formation of scientific concepts of stereochemistry have been widely discussed in the literature. Some researchers pointed out that the main difficulty in solving those problems resides in understanding the three-dimensional level. Difficulty occurs since the ability to visualize three-dimensional aspects of molecules and their relations with other molecules is a considerable challenge (Wu & Shah, 2004; Kozma, Chin, Russel, & Marx, 2000). The complexity of problem solving at this level (Baker, George, Harding, 1998) justifies the fact that for some students learning stereochemistry can be difficult and sometimes traumatic (Kurbanoglu, Taskesenligil, Sozbilir, 2006). Others researchers, however, argue that the learning problem is related to the fact that the topics in organic chemistry are introduced in a way so arid for students who cannot relate this 'school science' with his previous daily experiences. This reflects the thinking of Lima, Pina, Barbosa, & Jófoli (2000) who claim that "Teaching chemistry often has summarized the mathematical calculations and memorization of formulas and nomenclature of compounds". Correia, Donner Jr, & Infante-Malachias comment on the specific case of Organic Chemistry claim that it "is introduced so barren for students who cannot relate this school knowledge with previous experience" (2008, p.489). As a result, the weeks spent studying stereochemistry are somehow viewed as frustrating for students (Evans, 1963). In addition to the students' difficulty in transposing 2D structures in 3D to solve problems in the area, there is this another barrier to be transposed in the classroom: the student's motivation for learning (Cardoso, Colinvaux, 2000). According to Pozo (2002), motivation can be considered as a requirement, a precondition for learning. When the student has an interest in a certain area, that interest impels him to go deeper into it and to overcome the obstacles that may arise during the learning process (Fita, 1999).

Therefore teaching stereochemistry is also a challenge for teachers, as well as to develop strategies that facilitate the understanding of scientific concepts, as one must address the lack of motivation to study chemistry. The complexity of the issue becomes even clearer when we study the early history of stereochemistry. The concept of chemical space (one of the original names of stereochemistry) for some scientists was considered a reverie, being violently criticized, is now considered a key concept, without which modern chemistry would be almost inconceivable (Ramberg, 2000). The idea that there was a spatial arrangement of atoms in the molecule was a scandal in the early nineteenth century, for the prevailing idea was that molecules had no dimensions (Spek, 2006). The history of how the foundations of stereochemistry were constructed reveals a real scientific battle between influential chemists and young scientists. Disagreements did not prevent young researchers from trying to convince their opponents using experimental evidence. The concept of stereochemistry has made it possible to understand how a small number of chemical elements can form millions of compounds and the relationships between structure and properties. Without this key concept, used extensively not only in the field of Organic Chemistry, modern chemistry would be almost inconceivable. So much so that over the last few decades, most of the discoveries in chemistry are related to structural aspects, with several of them being awarded the Nobel Prize in Chemistry.

Thus, we consider that an approach using historical contextualization can increase students' motivation and to contribute to the motivation for learning and the consequent development of competences and desirable skills such as understanding global stereochemistry. So, our research question is: *How are historical aspects related to stereochemistry being addressed in Brazilian high school textbooks?* That´s because in Brazil, the textbook as a guide to classroom work is a reality, especially since 1985, when the Federal Government established the National Textbook Program, which consists of free distribution of textbooks for public school students across the country. So, the purpose of this paper is to present a brief analysis of how historical aspects related to stereochemistry are being addressed in Brazilian high school's textbooks.

TEXTBOOKS AND HISTORICAL CONTENT OF SCIENCE

In the last decades, textbooks have sparkled interest on the part of researchers, due to its importance in the teaching and learning process. As learning resources, textbooks are universal and available to both students and teachers. (García, Izquierdo, Fiedler-Ferrara, & Mattos, 2002; Upahi & Ramnarain, 2019). Some studies point that textbook writers do not seem to pay sufficient attention to historical research on science (Brush, 2000) as a result, there is inadequately addressed in textbooks (Niaz, 2000). This seems to occur not because space limitation, but because of a lack of knowledge of the history and philosophy of science.

According to Leite (2002), the historically organized presentation of science content would be the correct way to give students an adequate idea about the nature of science, how it develops, and how scientists work, some of the concepts or principles; so that students could acquire a sense of how science evolves under the influence of internal and external factors. In addition, the textbook may hold the potential to help students comprehend the relevance of science to their everyday lives, and recognize the scientific process as closer to the real work of scientists (Pellegrino, Peters-Burto, & Gallagher, 2018).

It is necessary to demystify the image of chemistry as a dogma to avoid the idea of a science basically done by geniuses or that is far from done (de Quadros Loguercio & Del Pino, 2007). For this, not only the type of historical material used but also the way it is used are determinants for the type of image of science, scientists and scientific practice given to students (Leite, 1986). There is evidence that, not only in Brazil, teachers rely heavily on books to select the historical content they include in their science classes (Leite, 1986), so the quality of the information presented becomes a crucial point in the teaching of chemistry.

METHODOLOGY

The sample consisted five chemical textbooks (A, B, C, D, E) used in High School, approved for the National High School Textbook Program (Figure 1). When found, the chapters referring to stereochemistry were analyzed based on the dimension considered most relevant by Leite (2002) in her methodology to analyze the historical content of science textbooks: Type and organization of historical information.

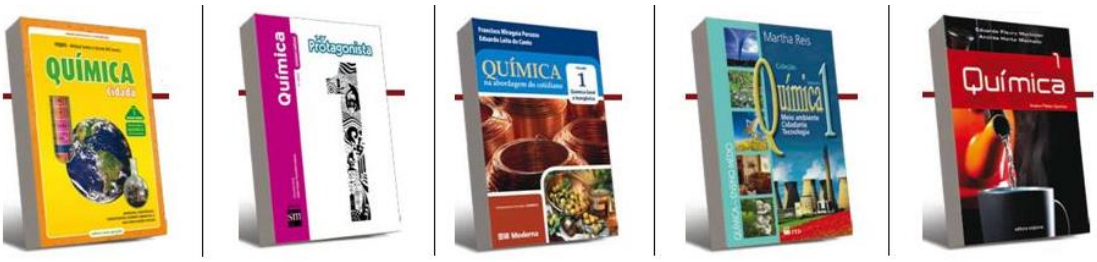

Figure 3. Books analyzed

This dimension provides guidelines for a comprehensive analysis and was chosen because it is a dimension commonly used in books that seek the application of a story-related approach. From these dimensions we selected the following subdimensions (Leite,2002, p.344):

a) Scientists' life

• biographic data (at least name, and date of birth and death)

• personal characteristics (feelings, character, mood, etc.)

• episodes/anecdotes (married to...,decapitated by ...)

b) Type of evolution of science

• mention to a science discovery (a discovery or historical idea is mentioned)

• description of a science discovery (the happening of a certain discovery is described)

• mention to discreet periods (two or more periods/discoveries are mentioned but not related)

• linear and straightforward (one period is related to the following, keeping the direction)
• real evolution (movement 'back and forth' between opinions, including controversies, etc.)

In addition, the names of the scientists mentioned, and the episodes covered in the analyzed books were pointed out.

RESULTS AND DISCUSSION

In general, in the books analyzed, the topic is approached more broadly with the title "Isomeria". It was found that Book C does not address the topic at any time. Books A, B and D, on the other hand, present the content with the aforementioned title and use a classification that contains in addition to the flat isomer the terms and geometric isomer and optical isomer. It has been found that Book C does not address the topic and Book D presents only scientific concepts on content without any mention to scientists or the history of stereochemistry.

It should be noted that both terms are obsolete, and their use is strongly discouraged by the guidelines of IUPAC (2014). According to Gouveia-Matos (1997, p.20) these terms "are known to any high school student of today when studying what is still, unduly, called optical isomerism, and not enantiomers". This improper classification occurs precisely because current books continue to use obsolete terms. Only book E, that is, only one of the five analyzed books names the chapter referring to the content as "Stereoisomerism" and classifies the stereoisomers correctly, (according to IUPAC's recommendation) into two main groups: diastereomers and enantiomers.

Table 1 presents the summary of the analysis.

Table 1.Type and organization of historical information in the Brazilian textbook.

	Scientists		Evolution of science	
Book	Scientists mentioned	Scientists' life (number of citations)	Description of a scientific discovery	Mention of a scientific discovery
A	Friedrich Wöhler Louis Pasteur Jacobus van't Hoff Joseph Le Bel William Knowles Barry Sharpless Ryoji Noyori	Biographical Information (0) Personal characteristics (0) Episodes (3)	Separation of enantiomers (Nobel Prize 2001)	Finding the isomerism
B	William Knowles Barry Sharpless Ryoji Noyori	Biographical Information (3) Personal characteristics (0) Episodes (1)	-	Separation of enantiomers (Nobel Prize 2001)
C	-	-	-	-
D	-	-	-	-
E	Melvin Spencer Newman Jacobus van't Hoff Joseph Le Bel Adolph Kolbe	Biographical Information (3) Personal characteristics (0) Episodes (1)	-	Discovery of Chirality (Nobel Prize 1901)

In Book A, the episode of the urea synthesis, a historical fact of the finding of isomerism by the chemist Friedrich Wöhler, is quoted, it can be seen that in the description there is no biographical information (not even nationality). Described as the work of an isolated scientist, when in fact a group of scientists was responsible for it. The pattern is followed for Louis Pasteur, van't Hoff and Le Bel. Louis Pasteur is quoted in the episode "Discovery of Optical Isomerism" by his study of polarized light which is continued by van't Hoff and Le Bel. Classified as a description of a scientific discovery, because it explains with some level of detail the experiment performed with polarized light. The asymmetric synthesis research conducted by Knowles, Sharpless and Noyori points out that they were awarded the Nobel Prize in Chemistry in 2001 for being responsible for developing methods to obtain enantiomerically pure compounds on an industrial scale. There is no information about the method or how the work was developed and so classified as mention.

The award is also cited in Book B, the only mention being made to scientists throughout the chapter, presented in a table "Chiral Drugs: Asymmetric Catalysis gives Nobel Prize." The authors, in this case, inform the nationality of the scientists. In Book E, the first scientist mentioned is Newman in the passage that presents the concept of conformational isomers, only a mention to explain the origin of the name of the representation, without bringing any data from the scientist. In the "Curiosity" box titled "The Asymmetric Carbon Controversy" he deals in detail by citing the scientists involved (van't Hoff, Joseph Le Bel and Kolbe) as well as acceptance in the scientific community. The text presents biographical information as well as the dates in which the facts occurred, from the beginning of the researches in 1874, as well as the harsh criticisms that the discovery provoked in the scientific community until its acceptance the consecration of van't Hoff, like the first chemical to receive the Nobel Prize in 1901. Thus this episode is classified as a description of a scientific discovery containing detailed information that allows the understanding of the episode as a fact that contributed to the evolution of the field.

It is clear that only the categories mention and description of a scientific discovery are identified in the analyzed materials. This shows the reduction of the historical content to biographies and superficial discussion about the way that the science is built. That is considered one of the problems that may arise when history of science is included in science teaching; Leite (2002) argues that, naturally, there is nothing wrong in using them, since ‘It is as valuable to know something of the lives of great scientists, but the point is that, perhaps unconsciously, sometimes history of science is reduced to names and dates’.

ACKNOWLEDGEMENT

PROPESQ - Dean of Research - Federal University of Rio Grande Do Sul

FINAL CONSIDERATIONS

In general, answering the research question, the books analyzed do not privilege the understanding of the historical evolution of stereochemistry. Books A, B, and E cite some scientists who are part of the construction of this field as well as historical facts. Nevertheless, some author's concern to present information related to daily life is noticed, even if most of it is done superficially. Thus, the presentation of the historical content in the analyzed High School textbooks seems to us unsatisfactory, since the understanding of the concepts must be done in a socio-historical perspective so that students can attribute meaning to the field of study, noting the evolution of the area and its importance in everyday life. If the story or even the everyday-related examples are treated as mere additional information or a "curiosity", students can get the message that names and formulas are the focus of study and that the understanding of other aspects are unnecessary or irrelevant. Even more when we consider the fact that students may not understand phenomena that are not related to their daily life. Finally, a motivational approach to science teaching must be with a context-based to promote the relevance of learning in the students' view (Gabel, 1993; Holbrook & Rannikmae, 2017) mainly on stereochemistry, once comprehension is challenging, and without proper contextualization it becomes even more difficult for students. The great advantage is that stereochemistry has many interesting aspects and an interesting and rich history to be learned within an historical perspective.

REFERENCES

Baker, R. W., George, A. V., Harding, M. M. (1998). Models and Molecules-a workshop on stereoisomers. *Journal of chemical education*, *75*(7), 853.

Brush, S. G. (2000). Thomas Kuhn as a historian of science. *Science & Education*, *9*(1-2), 39-58.

Cardoso, S. P., Colinvaux, D. (2000). Explorando a motivação para estudar química. *Química Nova*, *23*(3), 401-404.

Correia, P. R. M., Donner Jr, J. W., Infante-Malachias, M. E. (2008). Mapeamento conceitual como estratégia para romper fronteiras disciplinares: a isomeria nos sistemas biológicos. Ciência & Educação (Bauru), 14(3), 483-495.

de Quadros Loguercio, R., Del Pino, J. C. (2007). Em defesa do filosofar e do historicizar conceitos científicos. *História da Educação*, *11*(23), 67-96.

Evans, G. G. (1963). Stereochemistry in the terminal course. *J. Chem. Educ.40(8),* p.438.

Fita, E. C. (1999). O professor e a motivação dos alunos. In: Tapia, J.A, Fita, E.C. *A motivação em sala de aula: o que é, como se faz, 4*, 65-135. Loyola: São Paulo.

Gabel, D. L. (1993). Use of the particle nature of matter in developing conceptual understanding, *J. Chem. Educ., 70(3),* p. 193.

García, M. M. T., Izquierdo, A. M., Fiedler-Ferrara, N., Mattos, C. R. (2002). Un estudio sobre la evaluación de libros didácticos. *Revista Brasileira de Pesquisa em Educação em Ciências*, *2*(2).

Gouveia-Matos, J. A. (1997). Pasteur: ciência para ajudar a vida. *Química Nova na Escola*, *6*, 20-22.

Holbrook, J., & Rannikmae, M. (2017). Motivational Science teaching using a Context-based Approach. In *Science Education: A Global Perspective* (pp. 189-217). Springer, Cham.

IUPAC. (2014). *Compendium of Chemical Terminology*, 2nd ed. (the "Gold Book"). Retrieved from: http://goldbook.iupac.org.

Kozma, R., Chin, E., Russell, J., Marx, N. (2000). The roles of representations and tools in the chemistry laboratory and their implications for chemistry learning. *The Journal of the Learning Sciences*, *9*(2), 105-143.

Kurbanoglu, N. I., Taskesenligil, Y., Sozbilir, M. (2006). Programmed instruction revisited: a study on teaching stereochemistry. *Chemistry Education Research and Practice, 7*(1), 13-21.

Leite, L. (1986). Teaching science through history: A comparative study in England and in Portugal of the use of the history of science in the teaching of physical sciences. *Unpublished master dissertation, University of London Institute of Education*.

Leite, L. (2002). History of science in science education: Development and validation of a checklist for analysing the historical content of science textbooks. *Science & Education*, *11*(4), 333-359.

Lima, J. D. F., Pina, M. D. S., Barbosa, R. M. N., Jófili, Z. M. S. (2000). A contextualização no ensino de cinética química. *Química Nova na Escola, 11*(11), 26-29.

Niaz, M. (2000). A rational reconstruction of the kinetic molecular theory of gases based on history and philosophy of science and its implications for chemistry textbooks. *Instructional science*, *28*(1), 23-50.

Pellegrino, A., Peters-Burton, E., Gallagher, M. (2018). Considering the Nature and History of Science in Secondary Science Textbooks. *The High School Journal*, *102*(1), 18-45.

Pozo, J. I. (2002). *Aprendizes e Mestres– a nova cultura da aprendizagem,* trad. Ernani Rosa. Porto Alegre-RS, Brazil: Artmed.

Ramberg, P. J. (2000). *Pragmatism, belief and reduction*. Hyle, 6, 35-61.

Spek, T. M. (2006). Selling a theory: The role of molecular models in JH van't Hoff's stereochemistry theory. Annals of science, *63*(02), 157-177.

Upahi, J. E., & Ramnarain, U. (2019). Representations of chemical phenomena in secondary school chemistry textbooks. *Chemistry Education Research and Practice*, 20, 146-159.

Wu, H. K., & Shah, P. (2004). Exploring visuospatial thinking in chemistry learning. *Science education, 88*(3), 465-492.

PART 7: STRAND 7

Discourse and Argumentation in Science Education

Co-editors: *Maria Andrée & Kalypso Iordanou*

CONTENTS

STRAND 7: INTRODUCTION

DISCOURSE AND ARGUMENTATION IN SCIENCE EDUCATION

Strand 7 Discourse and argumentation in science education includes research on the understanding, supporting and promoting use of evidence and argumentation discourse in science education. The strand also includes research on scientific practices related to knowledge evaluation and communication, supporting the development of critical thinking, discourse analysis, meaning making in science classrooms and talking and writing science in the classroom. Although there has been substantial interest in discourse and argumentation in the field of science education research for the past decades, the developments of what is called the 'post-truth era' or the 'post-truth society' has emphasised the urgency of attending to matters of critical examination and argumentation in science education. To science teachers these societal developments poses challenges regarding how to teach appreciation of scientific evidence and argument while, at the same time, establishing inclusive science teaching practices where students' personal experiences, views and emotions are acknowledged and welcomed. This E-proceeding includes nine contributions; all contributing to advancing the understanding of potential roles of argumentation and critical thinking in science education from primary school practices to undergraduate studies.

Taking the post-truth era as a starting-point, Yann Shiou Ong and Richard Duschl argue that engaging students in problematizing data and evidence in scientific inquiry is an essential part of what activities are required in science education for supporting the development of students' critical stance. Ong and Duschl contribute to the proceedings with a study of students' problematizing data and measurement issues during an extended group discussion. Their findings provide suggestions with regards to the instructional design and moves that might be useful for sustaining students' problematisation of data and validity of claims. The proceedings include additional contributions pointing to the importance of focussing on qualities of scientific argumentation.

Maria-Antonia Manassero-Mas and Ángel Vázquez–Alonso point to the importance of problematising the concepts for discussing argumentation. More specifically they discuss the importance of the different geneologies of critical thinking and scientific thinking. Manassero-Mas and Vázquez–Alonso argue that critical thinking is a construct created stemming from cognitive psychology and developed in philosophy, whereas the notion of scientific thinking has emerged from scientific practice in science education from the studies of history, philosophy, sociology, nature and processes of science (among many others).

The remaining contributions to the E-proceedings focus on the scrutiny of argumentation and discourse in science education classroom practices in different parts of the educational system.

- Argumentation in primary science education: Jennifer Krupinski, Sarah Rau-Patschke and Stefan Rumann have studied of how primary school students explain scientific phenomena orally and how their explanations change from 1st to 4th grade. The results are intended to be used for developing evaluations of oral explanations in primary school and future interventions.
- Argumentation in secondary science education: Gonzalo Bermudez, María Ottogalli, and Lía García examined the application of a learning sequence they developed on using Toulmin's Argument Pattern (TAP) to make decisions on biodiversity issues. Examining students' and teachers' discourse, results revealed several obstacles

including students' difficulty with terminology of TAP, little motivation to engage in group discussions and evaluation of knowledge claims, as well as limitations in students' epistemic judgments. Teachers contribution was found to be limited to knowledge activation and management of the activity.

- Argumentation in higher education: Maria José Cano Inglesias, Antonio Joaquín Franco- Mariscal and Ángel Blanco-López compared the capacity of second-year engineering undergraduate students with pre-service science teachers to identify evidence in argumentation. The results show that both groups of students were able to provide arguments with evidence using a wide range of evidence, however the pre-service science teachers provided arguments of better quality of evidence. Based on the results, Inglesias and her colleagues argue there is a need for recognizing argumentation as a capacity that needs to be trained in education. Bruno Kestutis de Alvarenga Sipavicius, Jo Rodrigo Santos Silva and Daniel Manzonide-Almeida examined the production of arguments and graphic inscriptions in an inquiry-based learning activity. Results showed that students who were are not previously exposed to graphic and schematic literary inscriptions in basic biology classes before the application of the activity produced more arguments and drawings (graphic design, schematic design or free artistic design) compared to a group of students who first engaged in analysis of graphs and images and then pursued the inquiry-based activity. Welington Francisco, Lôany Gonçalves da Silva and Wilmo Ernesto Francisco Junior analysed the dialogues of six undergraduate Chemistry Course students, using a model which establishes relationships between the verbal actions performed in the pragmatic, argumentative and epistemic plans with the enunciative strategies. The results showed that the initiations of metaprocess - demanding a construction of ideas and major reflection - and process type - demanding an opinion or interpretation of who is answering - favored the argumentation because they demanded a higher level of students' reflection and engagement that triggered epistemic operations of low and higher cognition such as definition, classification, explanation and generalization.
- The role of teachers in promoting practices of argumentation. Based on an episode from chemistry teaching in a Brazilian public school, Gabriel Saraiva Gomes and Marcelo Giordan problematize the role of argumentation related to socio-scientific issues (SSI). They illustrate and discuss how the controversial character related to SSI need to be conceptualized as a discursive construction performed by teacher and students in the classroom. Ana Elisa Montebelli Motta and Marcelo Tadeu Motokane conducted a study of discursive moves of a pre-service biology teacher that are related to students' work with evidence. Their results suggest a relationship between discursive moves of the pre-service teacher and the students' construction of evidence and point to a lack of metacognitive moves. They argue the results reflect a lack of metacognition related to argumentation in teacher education.

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CLUSTER SIZE MEASUREMENT: A STUDY OF SECONDARY STUDENTS PROBLEMATISING DATA

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Taking a critical stance toward public information in the post-truth era is essential for citizens' decision making. Such a critical stance stems from problematising the evidence—consideration of what might be uncertain and thus problematic about a claim. This paper contributes to existing research on problematising by reporting on a discourse analysis of students' problematising data and measurement issues during an extended group discussion. Through moment-by-moment analysis of group discourse, problematising instances that sustained the discussion were identified. Findings suggest instructional design and moves useful for sustaining students' data problematisation and scaffolding their epistemic cognition around claim validity.

Keywords: Decision making, Instructional Strategies, Investigative Learning

INTRODUCTION

In the post-truth era, taking a critical stance toward public information tainted with misinformation, "alternative facts", and "fake news" is essential when making decisions with personal, social, community, and global impact. Such a critical stance stems from problematising the evidence when consumers of public information consider what might be uncertain and thus problematic about a claim. Problematising is a central activity across the sciences (Phillips, Watkins, & Hammer, 2018) as scientists constantly struggle with making epistemic decisions around what and how to measure/observe, what data to keep or discard, how to represent and interpret data and patterns, and what is the most scientifically sound explanation for the observed patterns as evidence (Grandy & Duschl, 2007). Thus, engaging students in problematising data and evidence in scientific inquiry is an essential part of scientific activity supporting students' critical stance development.

According to Engle and Conant (2002), problematising refers to opening up issues via students' questions, proposals, challenges, etc. Problems could be presented to students by their teachers or emerge during student activity. Focusing on what motivates problematising, Phillips and colleagues (2018) interpret problematising as students' intellectual efforts in conveying their feelings of uncertainty as a question. Through analysing episodes of class discussions around phenomena, demonstrations, and homework problems, Watkins and colleagues claimed students' demonstration of uncertainty by positioning themselves as not understanding, confused, or uncertain led to their scientific engagement (Watkins, Hammer, Radoff, Jaber, & Phillips, 2018). However, similar to many scientific argumentation interventions in K-12 classrooms, such discussions problematise what counts as evidence in support of claims but miss out on opportunities for students to problematise data. That is, students do not get to grapple with empirical uncertainties associated with making measurements and data representation/interpretation, all of which are essential to the work of scientists (Manz, 2018).

Motivated by the identified gap in existing literature, this paper contributes to research on epistemic cognition/practices by reporting on a study examining how problematisation of data was sustained among a group of ninth graders in a Singapore school, resulting in extended discussions examining data measurement issues. The paper seeks to answer the research question (RQ): How was problematisation of data sustained among students in a group (a) without and (b) with teacher involvement? Based on study findings, the paper highlights useful instructional designs and potential discourse and mediation moves for sustaining such discourse.

METHOD

The discourse data comes from a larger research study of four student groups' critique and construction of claims over a three-semester inquiry course in a Singapore secondary school (Ong, 2018). Each group worked on an open-ended inquiry project of their choice. In semester one, two groups (A1 and A2) experienced student-centred critique instruction designed using the Productive Disciplinary Engagement guiding principles (Engle & Conant, 2002) to foster students' engagement in scientific critique. Scientific reports and posters were *problematised* as research products to be critiqued, scientific soundness criteria (broadly aligned with the constructs of validity and reliability) were introduced as *critique resources*, students and teacher *shared epistemic authority* to critique, and ideas were held *accountable* to the scientific discipline via the scientific soundness criteria. A2, the group studied in this paper, comprises three students—Victoria (V), Jane (J), and Kang (K) (pseudonyms). A2 investigated the effects of vibration frequency on size of clusters formed by soap water droplets, which was inspired by a problem in the 2016 International Young Physicist Tournament ("ultrahydrophobic water" problem) ("IYPT Problems," n.d.). The group dropped soap water droplets using a dropper from a height above a water-filled petri dish placed above a sound amplifier, which functioned as a vertically vibrating source. At certain frequencies, the soap water droplets form clusters which remained for a while on the water surface. The group investigated how the vibration frequency of the source affected the size of droplet clusters formed on the surface of the water.

A2's discourse is selected for analysis as it represents a unique dynamic segment where students engaged in eight minutes of talk interrogating data and measurement issues around *how to measure cluster size of droplets from recorded videos*. The discourse segment is twice as long as other groups' longest singular topic segment (two to four minutes) about data collected during investigations. Following A2's group talk, the first author—also the inquiry course co-teacher—joined in A2's discussion for a further 13 minutes. All 21 minutes of the "cluster size" discourse segments were transcribed and analysed. Problematising instances were analysed first by examining questions (i.e. discourse moves to clarify a previously mentioned idea or to seek new ideas) and second by identifying challenges raised (i.e. discourses that identify problems with an idea) from the transcript. Talk turns around questions and challenges were interpreted to characterise how data was being problematised. Questions and challenges that shifted what was problematised yet sustained the cluster size measurement problem were coded as problematising instances.

FINDINGS

The "measuring cluster size" discourse segment started with A2 students reviewing videos they took of droplet clusters forming on the surface of a water-filled petri dish. Table 1 summarises the 8-minute group talk around how cluster size should be measured based on the problematising instances, what was problematised, and the students' proposed solutions. Students' pseudonyms are abbreviated as V, J, and K for Victoria, Jane, and Kang respectively.

Table 1. Summary of the "measuring cluster size" discourse segment

Problematising Instance #x = line no. (( )) = actions/inferred idea	**What's Problematised**	**Proposed Solution(s)** #x = line no. (( )) = actions/inferred idea
#1 V: When we look at the video, how will we know ((the diameter))?	How to measure cluster diameter?	#2 K: Find the longest point Note: A2's initial proposal was to measure cluster diameter
#14 V: If we have two frames that are very close, if the cluster width is about the same, do we have to measure every one?	What if clusters in two frames have similar widths?	#53 K: Focus on one area. #54 J's counter: Clusters move on their own.
#58 V: If we have a few clusters, what do we do?	Which cluster to measure if there are multiple clusters?	#59-61 K & J: Find biggest cluster size because that's the research question – how frequency affects cluster size.
#65 V: How do you know if this cluster is bigger, or this is bigger, or this is bigger? ((referring to image on laptop))	How to determine biggest cluster of droplets?	#67 J: Count the droplets. #70 V: Measure diameter of cluster in every frame #74 K: Take three or four frames that look the biggest then measure the diameter. #75 V's counter: Clusters all look about the same. #84 K: Measure diameter of cluster with most droplets.
#87 J: If we're measuring diameter, coz the droplets can move, what if it moves from like that ((gestures ⬯)) coz this is the maximum…into like that ((gestures ⬭))?	What happens if a cluster changes its shape?	#88-89 K & V: Measure the up-down ((cluster height)). #90 J's counter: It could be become a circle or an oval. #91 K: Find the bigger diameter. #94 J: Cluster has same amount of water droplets. #96-110 A2 decided to use two factors: (a) how many droplets and (b) diameter to find biggest cluster.
#113 V: What happens if we have two results: 1. the diameter is larger but there are less droplets. 2, the diameter is not so large but there are more droplets?	What happens if we have results with conflicting measures based on the two factors?	#116, 118 J: Compare the entire thing, the shape. #119 K: Take priority – diameter or number of droplets. #120 J: Number of droplets is priority. #121 V: But number can be ((incomplete sentence)) #122 J's counter: But the droplets are around the same size.
#123 V: Some droplets are small, some are big ((based on video)).	Are droplets of similar size?	#124 J: Droplets are quite around the same size. #124-127 J & K: There's definitely inconsistences in the droplets for every experiment.

#128 V: If we are finding number of droplets, why are we even finding the diameter?	Why do we need factor (b) diameter?	#130 K: Our main thing is to find cluster size. #131, 137 J: Cluster moves so its diameter changes ((c.f. #87)). You have to compare the entire size.
#144 V: Is there any way we can find the average of both?	Can we average factors (a) and (b)?	#145, 147 K: No way. One is length, one is amount. If such as situation happens, we find the priority. #148-151 V: That means in our experiment, we have to assume that all the droplets are the same size. K & J agrees.

In summary, the "measuring cluster size" segment saw A2 deliberating over two possible measures: number of droplets in a cluster or cluster diameter. The segment ended with the group concluding they had to assume all droplets are of the same size in order to use number of droplets as cluster size measurement. Note that the group's decision to use number of droplets differs from their initial plan to use cluster diameter as cluster size measurement, as stated in their investigation proposal (completed prior to the analysed discourse segments).

After A2 reached the conclusion, Kang sought confirmation with the co-teacher on their decision to use number of droplets as cluster size measurement and their proposed assumption. This led to the "validating assumption" discourse segment between the students (V, J, and K) and the teacher (T). Table 2 summarises the 13-minute group talk around how A2's proposed assumption could be validated.

Table 2. Summary of the "validating assumption" discourse segment

Problematising Instance #x = line no. (( )) = actions/inferred idea	**What's Problematised**	**Proposed Solution(s)** #x = line no. (( )) = actions/inferred idea
#158 K: Can we make an assumption that the droplets are all the same size?	Can we assume all droplets are of the same size?	#159-167 A2 justifies their change in cluster size measurement by highlighting problem with cluster diameter (c.f. Table 1, #87 for problem).
#168 T: Which one will be more scientifically sound? Let's say you try to present this to your peers or other scientists, what do you think they will say is the problem with your approach?	Which measurement, number of droplets or cluster diameter, is more scientifically sound?	#178 K: We should ditch diameter, cos if people are going to copy our experiment, they're going to work…make even more then they'll get at the exact same thing. Or, they'll just use amount like one drop, two drops, three drops, but assuming that it's all the same… ((K's idea seems to suggest using number of droplets would ensure reproducibility of their results by others carrying out the same investigation, or that others would make the same assumption about droplet size))
#190 T: How can you strengthen your argument? How can you make your case stronger?	How to strengthen argument for using number of droplets as cluster size measurement?	#191 J: I can make a diagram on the board. #194, 196 K: I think the idea we got is quite okay. It shows why we shouldn't use diameter. Over cluster size. ((referring to highlighted problem with diameter in #159-167))
#208, 210 T: So, is there some way you can provide us with more evidence…that your assumption is valid or sound?	What evidence supports validity of assumption (droplets are of same sizes)?	#213-216 V: ((From videos)), it's not that much difference with size.

#217 T: Am I supposed to visually see that they are not much different?	How to observe (lack of) difference in droplet size from videos?	#218 K: Use a ruler to measure. #228-239 A2 and T discussed the group could determine range of droplet sizes with a frame, and repeat it for a few video frames. #245-256 A2 and T discussed idea of finding average ((instead of range)) size of droplets over several frames. The idea was dropped because it would take too much time.
#260 T: How many frames do you need?	How many frames to sample?	#261 K: I think, five? #262 V: Three? #266, 268 J's counter: Three is too little…five? Five to ten. #269 K's counter: Ten is too much. #289, 293 J's counter: …it depends on how many…frames per second we are doing. Like 60 frames per second, we're doing like five frames? That's too little.
#270 T: How do you pick the frames?	How to sample the frames? Note: At this point, students and the teacher do not have common understanding of what they should measure in sampled frames: cluster size or droplet size	#270-274 K: Pick the five frames that are the biggest cluster. J agrees with K #275 T: Why the biggest cluster? #276-277 K & J: Because that's what we're finding…which is the biggest cluster size. #282 K: Among this entire video ((i.e. within the same video)), we find five frames that is the biggest cluster size.
No questions or challenges posed to cause shift in what was problematised.	How to measure "size"? Note: At this point, students and the teacher do not have common understanding of what they are measuring: cluster size or droplet size	#294 K: We can use a ruler and put it on the computer. #295 V's counter: Don't use a ruler. #295 K: Then we use…a scale. So if it's 12 cm on the computer, it is 8 cm in real life. #301 J's counter: But the Tracker ((a motion sensing software)) can already do it. #302-309: K & V do not want to use the Tracker as they find it weird and do not understand it. #312 T: Just print it ((image of cluster)) out and measure it ((droplet sizes)). #315 K's counter: If it expand and expand, then it will become a bit blurry.
#324 T: What's your ((referring to V)) concern if we sample based on one video? ((#283 V: You want to do it within the same video?))	Should sampled frames come from one or multiple videos? Note: At this point, students and the teacher do not have common understanding of what they are measuring: cluster size or droplet size	Previous proposed solution is to use one video, c.f. #282. #326, 329 J: Because it's just one video? One video takes a lot of effort…one second in each video is 60 fames. #328 V's counter: Take a few frames from each video. Because if you just take one video, then one person drop ((the droplets) then it's ((incomplete sentence)) #335, 341 J &K: It is possible that in one video, one frame has a lot of droplets but in the next frame, it collapses so there are no droplets. #346 V's counter: Don't choose the frame where it collapses. #347 K: Our five frames must be the biggest amount. #350 V's counter: Choose any five frames within the whole ((video)) #351, 353, 355 K: No, five frames in that ((incomplete sentence)). It's better than five seconds in that video which is different. It's not going to be fair because ((referring to video with J dropping the droplets)) if you're going to use five seconds in different positions ((points to different positions

		in video timeline)), it is not going to be very fair. ((K seems to equate one frame to one five second)). #361, 363 V's counter: It's more fair if we do from different things. Then you can show that even though there are differences in other variables…the droplet size still doesn't change. #364 J: No, now we're only changing one variable. We can't change another variable for this.
#365 T: What are we trying to do with this sampling anyway? What are we trying to find out?	What is the purpose of sampling video frames?	#366 J: The cluster size? #367 V: Show that there is not much difference in the droplet size. J realises her misunderstanding; K agrees with V.
No problematising instant as the discourse re-joins previous discourse based on what was problematised.	Should sampled frames come from one or multiple videos?	#373 J: What if one big droplet just dies in one frame and then in another frame there's tiny droplets? #374 V's counter: That's not our fault coz we're trying to find the difference in droplet size. If the droplet collapses, then so be it. Just take another frame with a lot of droplets. #380, 382 K's counter: Actually, I'm thinking about it, five frames per second there's not much difference…Because in five frames per second, in that five frames in one go, how many droplets will J actually drop? Not much. #384-387: V & K: Doing five frames of the same thing won't make much difference. Say, you're doing five droplets of the same duration when the result is almost the same, then what's the point of doing it? #390 K: So I think V was right. We should pick five frames in different times.
No problematising instant as the discourse re-joins previous discourse based on what was problematised.	How many frames to sample?	#390 K: So one video is 15 seconds right? #391, 395 V's counter: It's more like a full minute…or more. #394, 396, 398 K: Then we take the five best… at different intervals. Coz you can't pick the best five in like a five second interval.
#400 J: How do you pick the best?	How to decide "best" frames to sample?	#402-403: V & K: The most number of droplets in the video. #404 T: Why? #405 J: Because, more variation. #407 K: So if the other teacher asks, oh that variation is too…big. Then we can say that this is the biggest variation ((inaudible)) a frame. #408 V: So this is the most number. If even within the most number, there is not much difference, that means ((incomplete sentence)). #412 T: Is it logical, or not? Will you be convinced if someone said that to you? #413 K: Yeah #428 K: Because in the end, what we're doing for this thing is just to find, is just to put our assumption in a test in saying that, is it ((the droplets)) the same size, and then vary it. ((Unsure what K means by the second "it". Could refer to number of droplets or cluster size)).

To summarise, in the "validating assumption" segment, the first author (co-teacher) initially problematised the scientific soundness of A2's decision, asking A2 what their peers or other scientists might find problematic with their approach. She then requested A2 to provide evidence to support their assumption as valid or sound, which led to discussion of how A2 could determine droplet size range from video frames and how to sample the frames/clusters. The discourse segment also saw the first author clarifying with the students what they were trying to determine with the sampling (#365), as the lack of common understanding on the purpose of sampling became apparent from the students' persistent disagreements over whether the video frames/clusters should be sampled from within one video or across multiple video recordings (c.f. Table 2, #351, #353, #355 versus #361, #363). After the students reached a common understanding, they agreed on sampling frames from multiple videos, the number of frames to sample, and the criterion for selecting the fames to sample.

DISCUSSION

During the "measuring cluster size" segment (Table 1), students initially sustained the cluster size measurement problem by highlighting inadequacies of proposed solutions in relation to observed cluster behaviour in videos (instances at lines #14, #58, #65). That is, students tested the solutions on empirical data. Students then came up with hypothetical scenarios of cluster movement and data measurements (#87 and #113) to test the limits of proposed solutions. The group incorporated two factors for measuring cluster size and prioritised one factor, in order for the measurement to encompass the hypothetical scenarios. Next, Victoria challenged the necessity of the cluster diameter factor as a measure of cluster size if they were to prioritize the factor of number of droplets (#128). To keep both factors, Victoria wondered if they could "find the average of both" factors (#144), which Kang rejected as the factors measured different physical quantities (length versus amount) (#145, 147). Consequently, A2's discussion of the cluster size measurement problem led them to identify an assumption they had to make in their investigations: all the droplets were the same size (#148-151).

The group brought up the issue of their assumption to the first author (also the co-teacher), possibly to seek endorsement from the teacher. While the first author could have resolved A2's measurement problem by approving their assumption, she sustained the problem and upped the ante by problematising the scientific soundness of the group's measurement decision and the validity of their assumption (Table 2, lines #168, #208, #210). With the researcher's support, including redirecting students to the purpose of sampling video frames (#365) when a lack of common understanding of the purpose was noticed, A2 rose to the challenge. The group concluded they would measure variation in droplet sizes (using frames from multiple video recordings, with justification for why this is a better approach than using frames from a single recording) to justify their assumption that droplets have similar size.

CONCLUSION

The "cluster size" analysis presented in this paper suggests some useful instructional designs and moves for sustaining data problematisation. Inquiry instruction was designed to have students plan and carry out investigations and work with empirical data they collected, with limited teacher intervention until students have had opportunities to grapple with their data. Working with messy, real data meant students' initial proposed measurement might not always work, which was what A2 realized as do many scientists. Instructional moves within students' grasp for sustaining data problematisation include: testing (measurement) solutions using hypothetical scenarios, identifying the solution core by questioning necessity of all solution parts and considering synthesis of solutions, and identifying assumptions in solution. More challenging instructional moves that may require instructor's scaffolding include: problematising scientific soundness (e.g. validity and reliability) of (measurement) solutions and validity of assumptions, as well as redirecting students when lack of common understanding is detected (e.g. when disagreements persist). While these instructional design and moves are non-exhaustive, they suggest what students are capable of when given the opportunity to problematise data.

ACKNOWLEDGEMENT

We would like to thank the students and their teacher mentor for participating in the research study.

REFERENCES

Engle, R. A., & Conant, F. R. (2002). Guiding principles for fostering productive disciplinary engagement: Explaining an emergent argument in a community of learners classroom. *Cognition and Instruction*, *20*(4), 399–483.

Grandy, R., & Duschl, R. A. (2007). Reconsidering the character and role of inquiry in school science: Analysis of a conference. *Science & Education*, *16*(2), 141–166.

IYPT Problems. (n.d.). Retrieved October 30, 2017, from http://archive.iypt.org/problems/

Manz, E. (2018). Designing for and Analyzing Productive Uncertainty in Science Investigations. *Proceedings of the 14th International Conference of the Learning Sciences*, (July), 288–295.

Ong, Y. S. (2018). *Developing secondary school students' epistemic practices through student-centered critique in scientific inquiry*. The Pennsylvania State University. Available from ProQuest Dissertations & Theses A&I. (2082402442)

Phillips, A. M. L., Watkins, J., & Hammer, D. (2018). Beyond "asking questions": Problematizing as a disciplinary activity. *Journal of Research in Science Teaching*, *55*(7), 982–998.

Watkins, J., Hammer, D., Radoff, J., Jaber, L. Z., & Phillips, A. M. (2018). Positioning as not-understanding: The value of showing uncertainty for engaging in science. *Journal of Research in Science Teaching*, *55*(4), 573–599.

SCIENCE EDUCATION AS THINKING: THE BEAUTY OF SCIENTIFIC THINKING AND CRITICAL THINKING

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This communication studies two key cognitive competences in 21st-century education, namely, critical thinking and scientific thinking, which have different origins and traditions. Critical thinking is a construct created within the framework of cognitive psychology and has been cultivated especially in philosophy since the old times, whereas scientific thinking emerged from scientific practice in science education, mainly from the studies of history, philosophy, sociology, nature and processes of science (among many others). Due to their different research traditions, both concepts are expressed in specialized literature with different formulations, terminologies and dialectics. This communication explores the relationships between critical thinking and scientific thinking in order to elaborate a synthesis, connect both research programs and show their resemblance in order facilitate their understanding and implementation by science teachers who are not specialists in these issues. Finally, the applications and the implications of the resemblance for science education are discussed.

Keywords: Scientific competences, scientific thinking, critical thinking.

INTRODUCTION

Currently, several educational organizations and experts agree about the great value of thinking for 21st-century general education. Thus, critical thinking (hereafter CT) has become a centre of attention in mainstream education, as it is broadly considered important and functional for personal, social and work life (National Research Council, 2012). The European Union (2014) proposed seven key competences and some transversal skills to achieve key competencies: critical thinking, creativity, initiative, problem solving, risk assessment, decision making, communication and constructive management of emotions. The OECD's (2009) PISA skills and competencies for the 21st century involve three dimensions, which include skills such as research, problem solving, creativity, decision making, critical thinking responsibility and the ability to think independently. Furthermore, many prestigious educational experts suggest keys for deep learning that include critical thinking as a common issue; for instance, Fullan's 6 C competencies for deep learning include critical thinking, creativity, communication, collaboration, citizenship and character (Fullan & Scott, 2014).

On the other hand, scientific thinking (or scientific reasoning, as it is also labelled) emerged in science education. An extensive literature on history, philosophy, sociology and nature of science, socio-scientific issues, argumentation, meta-cognition, reflection, and some papers on processes of science often mention a set of cognitive, epistemic, procedural and value skills that are put into play in scientific practice. Further, some prefer the label scientific reasoning to refer to scientists' habits of mind (Kind 2013), yet this label may convey some reductionism of scientific thinking to logical thinking.

As CT consists of challenging beliefs from reflective analysis to clarify and distinguish mere opinions from propositions based on information and evidence, it directly connects with the very essence of scientific knowledge, often understood as the coordination of facts and theories to validate knowledge (Kuhn, 2002).

This study elaborates the concepts of CT and scientific thinking to unveil their resemblance; as a consequence, the claim that CT may be considered a cross-cutting concept for science education is discussed. Further, the lack of consensual conceptualisations for the two concepts leads to different formulations, terminologies and dialectics, which is especially misleading for teachers to achieve 21st-century educational competences. Hence, another aim seeks to contribute some clarification for the two concepts that provides clearer understanding for teachers and science teachers who are not specialists in these issues in order to teach them with quality. Moreover, a claim is made to consider CT a cross-cutting concept for both general and science education and, as a consequence, to discuss the contributions and implications of their role in science education.

Critical thinking

CT is the key tool of philosophy since its birth, yet its conceptual framework has been mainly developed within cognitive psychology along the 20th century, involving the so-called higher order thinking skills. The CT literature provides multiple definitions, each contributing to highlight some important aspects of critical thinking, yet this multiplicity suggests that scholars disagree about a consensus definition. Norris and Ennis' (1989) short definition is one of the most celebrated: "... reasonable thinking that is focused on deciding what to believe or do".

Beyond the lack of consensus on the definition, scholars agree that CT is composed of multiple skills, so that some scholars choose to define CT through the complex and diverse set of higher order skills that are put into play when thinking. For example, Fisher's (2009) extensive definition proposes the following skills for CT: identifying the key elements; identifying and evaluating assumptions and implicit values; clarifying and interpreting expressions and ideas; judging the acceptability and credibility of affirmations; evaluating different types of arguments; testing your own conclusions; producing arguments; appreciating and interpreting data and evidence; recognizing logical relationships between propositions; understanding and using language with clarity, precision and discrimination. Further, some controversies about the differential relevance of skills are still hotly debated, yet some scholars agree to distinguish between basic, process and dispositional (values) skills (Costa, 2001).

Several educational programs have been established and applied for teaching CT for decades (Costa, 2001). Most programs still remain empirically untested in terms of determining their actual impact and thinking achievements (Saiz, 2017). Indeed, efforts have been made over the years to assess the effects of such complex and elusive learning, and some assessment tools have come to light, but they are not without controversies (Norris & Ennis, 1989).

Scientific thinking

Kind (2013) traced back the history of scientific reasoning to conclude that it involves three types of knowledge (content, procedural and epistemic knowledge). Further, Kind and Osborne (2016) considered the lack of consensus about the meaning of scientific reasoning a failure and proposed a taxonomy that involves six styles of scientific reasoning: mathematical deduction, experimental exploration, hypothetical modelling, categorization and classification, probabilistic and statistical thinking and evolutionary accounts.

On the other hand, some scholars prefer the term scientific thinking to label the kind of thinking skills involved in scientific practice. This trend underlines scientific thinking as the intentional coordination of theory and evidence to seek, understand, interpret, represent and explain knowledge (Faye, 2014; Kuhn, 2002).

Further, an extensive science education literature on history, philosophy, sociology (socio-scientific issues), and nature of science, argumentation, meta-cognition, reflection, and some papers on the processes of science have contributed to the development of the skills and values involved in scientific practices to validate scientific knowledge, yet just a few explicitly use the concept of scientific thinking (hereafter SCFT) to refer to that wide multiform mind-set of scientists' skills and values involved in scientific practice. For instance, the Next Generation Science Standards (NGSS, 2013) propose for scientific practice the following skills, which constitute a kind of basic universal SCFT:

- asking questions and defining problems
- developing and using models
- planning and carrying out investigations
- analysing and interpreting data
- using mathematics and computational thinking
- constructing explanations and designing solutions
- engaging in argument from evidence
- obtaining, evaluating and communicating information

Erduran and Dagher's (2014) reconceptualization of the nature of science (NOS) presents a broader SCFT inventory when developing the two interactive NOS dimensions (cognitive-epistemic and social-institutional). The first one includes scientific practices, aims and values, scientific knowledge and methods and methodological rules, and the second one contains professional activities, scientific ethos, social certification, social values, and organisational, political, and financial aspects of science. In turn, each of them includes specific science skills and values (classification, observation, experimentation, epistemological tenets, institution networks, critical examination, theory choice, anomalies, peer evaluation, creativity, contributions from different persons, etc.). Similarly, Manassero-Mas and Vázquez-Alonso (2019) also proposed a broader collection of SCFT skills for scientific practice.

Some science education literature identifies the students' difficulties in learning nature of science and socio-scientific issues, and highlights some of the students' basic thinking errors, such as ignoring data and justifications, introducing personal opinions, making inadequate inferences and reinterpretations, jumping to conclusions as self-evident, not admitting evidence contrary to their ideas, inability to evaluate counter arguments and lack of basic epistemic knowledge, such as confusing facts and interpretations (García-Mila & Andersen, 2008; McDonald & McRobbie, 2012).

RESULTS

Scientific thinking

The literature on SCFT is summarized in a taxonomy that has been elaborated previously and involves ten broad aspects of SCFT (Vázquez-Alonso & Manassero-Mas, 2018). Seven SCFT aspects of the taxonomy have a predominantly epistemic orientation:

1. Observation
2. Categorization
3. Pattern recognition
4. Creation and verification of hypotheses
5. Control of variables
6. Models, metaphors and analogies
7. Coordination of explanations and evidence

The remaining three aspects of SCFT show a predominantly social orientation:

8. Elaboration of materials
9. Information and communication
10. Attitudes and values

The former ten aspects of SCFT are so broad that their epistemic or social dominant orientation is primary in each aspect, yet this dominance should not be interpreted as pure or exclusive in any of them. Furthermore, each aspect of SCFT can be broadly developed in a list of exemplary skills that contribute to characterize the aspects and help to provide much specific connection to science education curricula. The list highlights some significant skills associated with each aspect, though in any case, the list must not be taken as exhaustive or closed, as it still is open to scrutiny for enlarging or completing the depiction of each SCFT aspect.

The first aspect, observation, is likely the simplest aspect of SCFT, which involves all kinds of watching, collecting data, gathering information, describing, chronicling, etc. on the entities under observation.

The aspect categorization knowledgeably involves scrutiny skills such as defining, sorting, organizing, ordering, analysing, comparing, contrasting, etc. assumptions, concepts and problems concerning the entities under research.

Similarly, the categorization skills involve grouping similar data, quantifying measurements, discovering regularities, synthesizing and generalizing the empirical data.

The aspect about creation and verification of hypotheses embraces skills such as asking questions, identifying problems and assumptions, formulating hypotheses, planning and developing investigations, applying statistical analysis, using technology appropriately and applying mathematical and computational thinking.

The control of variables is likely the most representative aspect of the experimental character of many procedural scientific practices that involve highlighting surprising or contradictory data, posing practical problems, using logic, controlling the effects of multiple variables and attributing causality to events.

The coordination of explanations and evidence includes central skills: using tests, arguing and identifying evidence data, deducting, inferring, and abducting conclusions, issuing critical judgments, accepting and rejecting theories, validating knowledge, suggesting solutions or comparisons, and constructing coherent, valid and reliable explanations and theories.

The aspect models, metaphors and analogies involves creating models, analogies and theories, solving problems, making decisions, searching bases for knowledge, replicating theories, models and knowledge and simulating models and data.

The information and communication aspect is revealed in skills such as communicating and sharing knowledge, publishing discoveries, working cooperatively as a team, participating in congresses, discussing theories and solutions with colleagues, evaluating one's own and others' communications and assuming personal and social responsibilities.

The elaboration of materials aspect involves all kinds of skills that contribute to elaborating the tools needed to inform the scientific practice, such as exploring the literature and hypotheses, constructing tables, figures, diagrams and graphs, creating and imagining investigations and experiments, developing technologies, tackling scientific and social needs and problems and informing scientific policies.

The scientific attitudes and values involves acting ethically and legally, whilst cooperating and competing and being sensitive to relationships with society; further, thinking with correctness, integrity and impartiality, maintaining a sceptical and curious attitude, showing openness of mind, challenging knowledge with alternatives, evaluating assumptions, predicting consequences, and searching for new ideas and knowledge with creativity and imagination.

The former list of associated skills to SCFT develops each aspect of SCFT, yet their complexity does not allow claiming that any skill belongs exclusively to the assigned aspect. Thus, the list does not intend a correspondence between skills and aspects of SCFT to be univocal; instead, a skill may overlap in several aspects of SCFT. In spite of this overlapping, it is expected that the development of skills may contribute to orientate teaching and to relate SCFT to CT.

Critical thinking

A taxonomy of CT has been empirically elaborated from the skills included in 17 CT assessment tools (ranging from 1 to 88 skills), which are much less ambiguous than authors' definitions. The limited extension of this paper does not allow detailing the procedures, which consisted of identifying the assessment skills declared in each tool and quantifying the frequencies of the different CT skills to empirically synthesize the main components of the taxonomy. In order to overcome the difficulties of this analysis (different terminologies, unbalanced number and some grouping of skills presented in questionnaires), an interpretive analysis was applied to state the degree of equivalence between the different specification and wording of skills (categorical reasoning, deduction, drawing conclusions, etc.), to balance the contributions of the different instruments and to prioritize the grouped dimensions and categories (Vázquez-Alonso & Manassero-Mas, 2019).

The analysis produced the following list of categories in decreasing order of frequencies: communication, problem solving, reasoning, creativity, argumentation, decision making, clarification and precision of ideas, fallacies and errors, identification of assumptions, and evaluation. Taking into account the relations of similarity, overlapping or inclusion between some of these categories taken from the literature on CT, the suggested taxonomy for CT is formed by the following main four dimensions (Table 1):

• The dimension of creativity encompasses the set of cognitive actions and operations aimed at generating questions, ideas, conclusions, models, analysis and synthesis.

• The dimension of reasoning and argumentation encompasses the mental and cognitive operations aimed at justifying the validity of a conclusion.

• The dimension of complex processes (problem solving and decision making), encompasses the set of skills applied to find a solution for a problem or make the most appropriate decision.

• The evaluation and judgment dimension refers to the operations aimed at judging the quality and fairness of any element of one's own or others' thinking (information, assumptions, conclusions or consequences) or any thinking process or skill (justification, validity or reliability).

Table 1. A taxonomy of critical thinking, developing its main dimensions and categories.

CREATIVITY (generating ideas, conclusions)		
	Asking good questions	
	Observation (compare, classify)	
	Analysis and synthesis (parts-whole, analogies, models)	
REASONING AND ARGUMENTATION (justifying predictions, implications, conclusions)		
	Logical (deductive)	
	Empirical (explain with data, information, evidence)	
		Inductive (generalizations)
		Argumentation (abductive)
		Statistical (probabilistic)
	Fallacies and Errors	
COMPLEX PROCESSES		
	Decision making	
	Problem solving	
EVALUATION AND JUDGMENT (assessment of the thinking quality)		
	Intellectual standards (clarity, accuracy, relevance, ...)	
	Reasoning (quality assessment of reasons and arguments)	
	Actions (judging solutions, decisions, consequences, ...)	
	Credibility of sources	
	Identifying assumptions	
	Communication (clarification of meanings)	
	Meta-cognition (evaluating one's own thinking)	
		Self-regulation and self-reflection
		Attitudes and affects (dispositions)

Each dimension develops as sub-dimensions and categories to accommodate the multiple CT skills arising from the analysis. For example, the development of the dimension of reasoning and argumentation includes all the mental operations involved in the justification of conclusions, which encompass logical-deductive thinking, empirical thinking (which justifies conclusions with facts and evidence), statistical-probabilistic reasoning, and a special section for the errors of thinking, that is, the well-known fallacies of reasoning.

A key implicit idea in this theoretical framework states that CT is the foundational construct, thus, it has the highest hierarchical level in the framework; consequently, this construct must be reserved for labelling the global construct. Moreover, the subsequent levels of the taxonomy depict the set of lower level categories of thinking skills thus included in CT. Broadly speaking, creativity skills might be considered the lowest level category of the taxonomy, whilst evaluating and judging might be considered the highest one.

Indeed, the taxonomy does not advocate that the different categories are totally disjointed or different from each other; on the contrary, as they all are kinds of human thinking, the different categories may share some elements and be related to each other. Of course, the more complex the category, the more elements it encompasses of other categories; for instance, the category "thinking standards" is normative and applicable to any thinking skill, and the complex "problem solving" may certainly include elements of creativity and reasoning.

A synthesis: the relationship between critical and scientific thinking

It is common sense that CT is a human competence, which, in the case of its application to scientific practice, becomes an essential part of SCFT, although described under the nomenclature of scientific practice. To justify this claim, the comparison between the CT taxonomy and the aspects and skills of SCFT was elaborated, and its results are presented herein (Table 2). The aspects of SCFT and the dimensions of CT have been qualitatively compared, seeking to identify mutual correspondences between the categories of the two constructs, through the best fit among their contents. The results of this comparison of contents show each category of CT and its corresponding aspects of SCFT in the same row.

Table 2. Relationships between critical thinking and scientific thinking operationalized through the correspondence between critical thinking dimensions and categories and the aspects of scientific thinking.

Critical Thinking (DIMENSIONS / Categories)	**Scientific Thinking** (Aspects)
CREATIVITY	
Asking good questions	4 Creation and verification of hypotheses 10 Attitudes and values
Observation	1 Observation
Analysis and synthesis	2 Categorization 3 Recognition of patterns 5 Control of variables 8 Models, metaphors and analogies
REASONING AND ARGUMENTATION	
Logical	5 Control of variables 7 Coordination of explanations and evidence
Empirical • Inductive • Argumentation • Statistics	 4 Creation and verification of hypotheses 5 Control of variables 7 Coordination of explanations and evidence
Fallacies and Errors	5 Control of variables
COMPLEX PROCESSES	
Decision making	6 Models, metaphors and analogies
Problem solving	7 Coordination of explanations and evidence 8 Elaboration of materials
EVALUATION AND JUDGMENT	
Reasoning	7 Coordination of explanations and evidence

	9 Information and communication
Actions	9 Information and communication
Credibility of sources	8 Elaboration of materials
Identifying assumptions	10 Attitudes and values
Standards	10 Attitudes and values
Communication	8 Elaboration of materials
	9 Information and communication
Meta-cognition	
• Self-regulation and self-reflection	9 Information and communication
	10 Attitudes and values
• Attitudes and affects	10 Attitudes and values

Some aspects of SCFT are assigned to several different categories of CT, and conversely, some categories of CT share several aspects of SCFT. This means that the correspondences between SCFT and CT are not isomorphic, as the best-fit-content does not imply that all the skills of the SCFT aspect accurately fit all the skills within the corresponding category of CT (and conversely). It just means that most of both CT and SCFT contents correspond with each other.

The SCFT aspect #7, coordination of explanations and evidence, is the most repeated aspect over the categories of CT, as seven categories share common contents with it. The SCFT aspects, #9, information and communication, and #10, attitudes and values, also spread across many CT categories, especially across the categories of evaluation and judgment. Conversely, the categories of CT that unite many aspects of SCFT are decision making, problem solving and analysis and synthesis.

DISCUSSION AND CONCLUSIONS

This paper focus on empirically unveiling the skills and dispositions common to CT and SCFT to make them understandable for science education, to overcome their pursuit in separate research fields and their meta-knowledge nature that makes them different from any other school curriculum contents. SCFT and its relationships to the higher order skills have been claimed necessary to achieve learning of epistemic issues taught in science education (such as socio-scientific issues). The literature results also show that there are additional, important and surprisingly coincidental similarities between the two constructs, such as the approaches to teaching methodology and assessment instruments. These new potential similarities deserve future analysis, which may contribute to strengthen the resemblance and the foundational nature of thinking for science education (Swartz, Costa, Beyer, Reagan & Kallick, 2008).

The results of the comparison elaborated herein show an extraordinary resemblance of SCFT-CT that allows closing the theoretical gap between two apparently different research traditions and bringing closer thinking-based teaching and science learning. It is likely that the similarity between CT and SCFT lies in their common qualities of being human thinking and the common meta-knowledge feature that they both share.

Additional differences also stem from the analysis, though most are not in conflict as they differ on qualitative emphasis. For instance, credibility of sources or fallacies are quite important for CT, yet scarcely relevant to SCFT due to the scientists' social accreditation; conversely, the control of variables is an extremely important skill in science and hardly practised in CT.

Within this approach, thinking may be deemed a more appropriate label to designate SCFT than reasoning, as its skills exceed the six reasoning styles suggested by Kind and Osborne (2016); in fact, according to the taxonomy, the six reasoning styles relate partially to the aspects of SCFT 2, 3, 4, 5, 7 and 8. Thus, reasoning styles are just a subset of CT that relates to the dimension of reasoning and argumentation, and the CT-SCFT model accounts for the six reasoning styles as a particular case of the model, and extends it with additional SCFT skills.

The interpretation of the relationships among CT and SCFT skills can contribute to improve both science education and general education through their coordinated, explicit and reflective teaching. The findings may contribute to realize the potential of science education to improve students' thinking skills, and vice-versa, the students' thinking skills may contribute to improve deep learning in science. The latter is plainly advocated by some science education literature suggesting that mastering higher order skills (CT in our terms) is a key condition to successfully develop the activities (debating, choosing, deciding, etc.) leading to deep learning in science (i.e., epistemic learning of socio-scientific issues, Simonneaux 2014). The former may be exemplified by Kuhn's (1993) proposal, demanding an enlargement of specific argumentation issues to involve broader CT skills (as reflected in the CT taxonomy).

Lastly, the point here is not about choosing critical or scientific labels for teaching thinking skills, but the clear understanding that most of them are conceptually equivalent. The clarification of the similarity between critical and scientific thinking through their corresponding taxonomies and relationships benefits both general and science teaching by making both constructs understandable for teachers. It benefits general teaching because learning of thinking skills is not only improved from the thinking-based programs, but also from science education teaching scientific skills. Conversely, CT skills, usually advocated by general education, also benefits and improves science education, as they too are SCFT skills.

ACKNOWLEDGEMENT

Project EDU2015-64642-R (AEI/FEDER, UE) funded by the Spanish State Research Agency and the European Regional Development Fund.

REFERENCES

Costa A. L. (Ed.) (2001). *Developing minds: A resource book for teaching thinking* (pp. 44-46). Alexandria, VA: ASCD.

Erduran, S., & Dagher, Z. R. (2014). *Reconceptualizing the nature of science for science education, scientific knowledge, practices and other family categories*. Dordrecht, Holland: Springer.

European Union (2014). *Key competence development in school education in Europe. KeyCoNet's review of the literature: A summary*. 2014. http://keyconet.eun.org (consulted 12/12/2018).

Faye, J. (2014). *The nature of scientific thinking. On interpretation, explanation and understanding*. London: Palgrave MacMillan UK.

Fisher, A. (2009). *Critical thinking. An introduction*. Cambridge, UK: Cambridge University Press.

Fullan, M., & Scott, G. (2014). *Education PLUS.* Seattle, WA: Collaborative Impact SPC.

García-Mila, M., & Andersen, C. (2008). Cognitive foundations of learning argumentation. In S. Erduran & M. P. Jiménez-Aleixandre (Eds.), *Argumentation in science education: Perspectives from classroom-based research* (pp. 29-45). New York: Springer.

Kind, P. M. (2013). Establishing assessment scales using a novel disciplinary rationale for scientific reasoning. *Journal of Research in Science Teaching,* 50(5), 530-560.

Kind, P., & Osborne, J. (2016). Styles of Scientific Reasoning: A cultural rationale for science education? *Science Education*, 101, 8-31.

Kuhn, D. (1993). Science as argument: Implications for teaching and learning scientific thinking. *Science Education,* 77(3), 319-337.

Kuhn, D. (2002). What is scientific thinking and how does it develop? In U. Goswami (Ed.), *Blackwell Handbook of childhood cognitive development* (pp. 371-393). Oxford, UK: Blackwell Publishing.

Manassero-Mas, M. A., & Vázquez-Alonso, A. (2019). Conceptualización y taxonomía para estructurar los conocimientos acerca de la ciencia [Conceptualization and taxonomy to structure knowledge about science]. *Revista Eureka sobre Enseñanza y Divulgación de las Ciencias*, 16(3), 3104.

McDonald, C. V., & McRobbie, C. J. (2012). Utilising argumentation to teach nature of science. In B. J. Fraser, K. G. Tobin & C. J. McRobbie (Eds.), *Second international handbook of science education* (pp. 969-986). Dordrecht, the Netherlands: Springer.

National Research Council (2012). *Education for life and Work: Developing transferable knowledge and skills in the 21st century*. Washington, DC: The National Academies Press.

NGSS Lead States (2013). *Next generation science standards: For states, by states*. Washington, DC: The National Academies Press.

Norris, S. P., & Ennis, R.H. (1989). *Evaluating critical thinking*. Pacific Grove: Midwest Publications.

OECD, Organisation for Economic Co-operation and Development (2009). *Working paper 21st century skills and competences for new millennium learners in OECD countries*. (EDU WP n. 41).

Saiz, C. (2017). *Pensamiento crítico y cambio* [Critical thinking and change]. Madrid: Pirámide.

Simonneaux, L. (2014). From promoting the techno-sciences to activism – A variety of objectives involved in the teaching of SSIs. In L. Bencze & S. Alsop (Eds.), *Activist science and technology education* (pp. 99-112). Dordrecht, the Netherlands: Springer.

Swartz, R. J., Costa, A. L., Beyer, B. K., Reagan R., & Kallick, B. (2008). Thinking-based learning. promoting quality student achievement in the 21st century. New York: Teachers College Press, Columbia University.

Vázquez-Alonso, Á., & Manassero-Mas, M. A. (2018). Más allá de la comprensión científica: educación científica para desarrollar el pensamiento [Beyond scientific understanding: Science education to develop thinking]. *Revista Electrónica de Enseñanza de las Ciencias*, 17(2), 309-336.

Vázquez-Alonso, Á., & Manassero-Mas, M. A. (2019). Taxonomía de las destrezas de pensamiento: una herramienta clave para la alfabetización científica [Taxonomy of thinking skills: A key tool for scientific literacy]. In M. D. Maciel & E. Albrecht (Org.), Ciência, Tecnologia & Sociedade: Ensino, Pesquisa e Formação [Science, Technology & Society: Teaching, Research and Training] (pp. 17-38) Sao Paulo: UNICSUL.

HOW PRIMARY SCHOOL STUDENTS EXPLAIN SCIENTIFIC PHENOMENA

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Teachers have the task of supporting and evaluating their students in developing their explanatory skills. Although children are asked to construct explanations from the first grade. Nevertheless, there is no hint of a description of the requirements they have to fulfill in order to explain or a general definition of what a student´s explanation should look like. If we want to evaluate students' skills, we need a basis that allows us to asses theses skills. This kind of basis is missing in early science education. The following qualitative quasi-longitudinale interview study attempts to understand how primary school students explain scientific phenomena orally and how their explanations change from 1st to 4th grade. Using a sample of 126 students, oral student explanations at the selected phenomenon state of aggregation of water are videotaped and prepared for a qualitative content analysis using a deductive derived category system. The validation study led to a further survey to examine the influence of a hand puppet as an addressee on the quality of the explanation. The results of the two preliminary studies are presented in the following article.

Keywords: Explanation Construction, Primary School, Language of Science

INTRODUCTION

‚Why is the snowman melting?' ‚What happens to the water in the puddle?' The fascination of scientific phenomena accompanies us from our childhood. This does not change the fact that understanding and explaining phenomena is a complex challenge. A challenge we have to face at school from the very first grade. Students´explanations are firmly anchored in the curriculum of early science education. For example, students' textbooks require a high variety of explanations. This reflects the anchoring of explanatory skills as a component of one of the central aims of early science education. The children are expected to develop scientific literacy and in doing so, learn to construct and discuss their explanations about scientific phenomena (Möller et al., 2014). Thereby, explaining is understood as a discursive practice for knowledge construction (Prediger et al., 2016). When clarifying and structuring one's own knowledge to construct an explanation, possible gaps in knowledge and problems of understanding can be uncovered and become the starting point for a new learning process (Webb, 1989). This shows the substantial importance of explaining not only for school learning but also for lifelong learning. Under consideration that the students are asked for explanations from first grade on, when the development of their writing skills just started and the classroom interaction bases on oral communication mostly, it is clear that we should focus on oral explanation skills for a first look. If we want to support the further development of the students' explanatory skills specifically, we must assess the current state of their abilities first. But in order to evaluate student explanations or assess their quality, a basis is needed, that tells us what a good student

explanation should look like. The problem is that this basis does not yet exist, especially not for primary science education. Neither there is a generally accepted definition of explaining nor a description of criteria or requirements which must be fulfilled by the students to build an adequate explanation. Filling this gap is one of the purposes of our study.

THEORETICAL BACKGROUND

First of all, the missing consensus of a definition of explaining makes it necessary to clarify our understanding of a student‘s explanation which is bases on often-used definitions in language and science educational research (Klein, 2016; Osborn & Patterson, 2011; Morek, Heller, & Quasthoff, 2017).

> *An explanation is the product of an interactive process of knowledge transfer between two or more actors, using descriptions and combining different parts of knowledge to generate new knowledge. In this process, it is possible to use argumentative elements too.*

Additionally, the variety of explanations by using the *explanation typology* of Klein (2016) is taken into account. Within the framework of this typology, the facts to be explained (explanandum) are devided into *Explaining-What*, *Explaining-How*, and *Explaining-Why*. *Explaining-What* is represented by questions for words, terms or meanings of representations or a theoretical concept like *"What are the states of aggregation?"*. In order to explain *'What'* the explainer uses declarative knowledge resources to support the recipient in understanding the explanandum or to enable him to construct a mental model of the terms, representations or theoretical concepts to be explained.

In contrast, *Explaining-How* focusses on procedural knowledge. The explainer wants to enable the recipient to do certain actions independently or to use scientific methods. This kind of explanatory process is initiated by questions such as *"How can you change the states of aggregation of water?"*. An essential feature of this explanation type is the sequencing and adherence into a logical order.

Explaining-Why shows the greatest similarity with the common understanding of a scientific explanation to clarify the occurrence of a scientific phenomenon. Thereby a necessary clarification of the available knowledge and the targeted selection and linking these components of knowledge or arguments is needed. This reorganizing thinking process of selecting suitable facts can be understood as a part of conditional knowledge. This type of explanation is represented by questions like *"Why can you see your breath in winter?"*. (Klein, 2016; 2017)

The three types of explanations show an increasing level of abstraction from *Explaining-How* to *Explaining-Why*. At the same time, they refer to further important requirements in student‘s explanation like the kind of interpretation the students show in explaining the phenomenon.

This leads us to the category *'scientific understanding'*. This category describes more then the decision if the explanation is right or wrong. It makes statements about the knowledge source the students use to explain. The teacher or evaluator also gets an impression of how the student interprets the phenomenon. For example, from a scientific point of view, it is wrong if the students explain that the ice cubes disappear when they melt, but if we consider that the students are referring to their direct observations, it is a quite correct statement. That's not yet an interpretation of the phenomenon. In addition to the scientifically-conclusive interpretation that ice melts under the influence of heat and pressure, the young students use different forms of analogies to interpret the phenomenon. Some kinds of interpretation attribute characteristics such as a will and emotions of the inanimate influence factor heat. This leads to explanations such as "If the heat goes up on the ice, then the heat and the cold do not like each other and the ice cubes go away." Hagstedt and Spreckelsen (1986) call this kind of understanding a logogenic or animistic interpretation.

Under the consideration that explaining is a discursive practice for knowledge construction (Prediger et al., 2016) we must bear in mind that oral expressions are usually fleeting and tend to use everyday language. For this reason, it is useful to look at the linguistic quality (*language*) of the explanations in terms of the completeness, length, structure**,** and activ or passiv construction of the statements.
At the same time, discursivity refers to a possible influence of the addressee on the quality and scope of the explanation. The confirmation of the importance of orientation and consideration of the recipient of the explanatory process is supported by the research work of Kulgemeyer and Peters (2016). In Webbs research (2015) also points out, that the initiation of explanatory processes is triggered and influenced by the recipient's questions significantly. It can, therefore, be assumed that *recipient orientation or interaction* is another important facet of the analysis of explanations.
Using the example of game instructions, which is a part of explaining-how, Röhner (2009) was able to record in her longitudinal study that the logical *structure* of the explanation and its *completeness* increases from the first to the fourth grade. At the same time, it is one of the few studies which focus on early explanatory skills. Most other studies on student explanations focus on secondary school like the study of Sandoval (2005). Her research underlines the importance of structure for the quality of high school student explanations and argumentations (Sandoval, 2005). This overview of research supports the impression that the research on students' explanations and explanatory skills of primary school students is low. Therefore, the following study strives to answer the questions:

1. How do primary school students explain scientific phenomena orally?
2. What is the difference between oral explanatory skills from 1st to 4th grade?

METHOD

A quasi longitudinale qualitative interview study trys to answer these questions. The study is videotaped and in order to take into account the discursive character of the explanatory process and to get an overview of the improvement of the explanatory skills from the first grade on, the focus is on the oral explanations. In order to ensure the comparability of the content of the explanations, the phenomenon of the states of aggregation of water has been selected because this topic is anchored in the curriculum of early science education and can be presented in various complexities so we can use the examples in all four grades. The setting includes three selected examples of this scientific phenomenon (see fig.1-3):

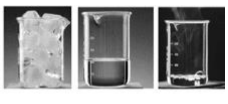

Figure 1 State of Aggregation of Water

Figure 3 Function of a Steamboat

Figure 2 Evaporation of Water on a Black Board

These phenomena were represented to the students in short video sequences. The following oral explanation process of the primary school students between one student and a recipient was videotaped in an interview situation. The recorded explanations with a duration of three to five minutes then were transcribed and prepared for qualitative content analysis according to Mayring (2014). In the center of the qualitative content analysis is the category system, which is deductively derived in a first step and includes the six main categories as shown in fig 4.This category system is tested in a pilot study with a sample of 57 primary school students' explanations distributed over the four grades.

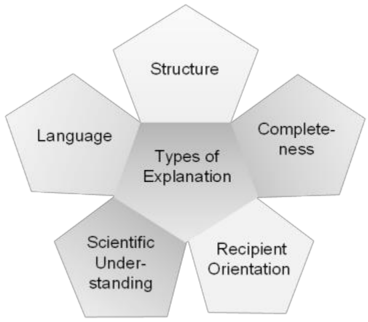

Figure 4 Deductive Category System

The following results relate to the pilot study (validation of the category system) and its impact on the process and the evaluation of the main study. The results of the pilot study will also demonstrate the necessity of a further survey to check the influence of a change of addressee between real person and hand puppet on the explanatory quality. These results will also be part of the following report.

RESULTS

The purpose of the pilot study was to prove the validation and reliability of the deductive derived category system and the feasibility of the main study. The use of the category system to analyse the piloting data has shown that the selected main categories can be covered in the explanations. However, the first intercoder reliability of $\kappa = 0.43$ showed the necessity of a further differentiation of the definitions and feature descriptions. The revision of the category system resulted in an intercoder reliability of $\kappa = 0.85$. The analysis also provided initial insights into the characteristics of the main categories or the individual facets of the students' explanatory skills. For the purposes of clarity, we decided to divide the sample into two parts. The part *Explaining in School Entrance Phase* includes the explanations of the first and second graders and the group *Explaining in School Exit Phase* covers the third and fourth-grade students.

The analysis has shown that the students from the school entrance phase prefers the type Explaining-What as a first try to clarify the understanding of the phenomenon to be explained. In doing so they mainly use declarative knowledge and also show a strong influence by their direct observations. Looking at the external or structural construction of the explanation, students´statements tend to have no or medium coherence. Therefore, they are only partially able to link and relate their statements to each other. This is also reflected in the fact that simple sentences are used usually in the formulation of their explanations.
In contrast, the students from the school exit phase often use the type Explaining-Why to answer the question *"Can you explain this to me?"*. Their explanations refer to nomological interpretation and the use of conditional knowledge. The predominant use of related sentences is reflected in the high coherence up to complete coherence of their statements.
At first look, the comparison of the two sub-samples reveals a development in the individual facets of the students' skills to explain. However, this development is not reflected in the main category completeness of an explanation. No student in the sample has been able to explain the

presented phenomenon state of aggregation of water (solid, liquid, gaseous) completly. Most of them omitted the gaseous phase of the water, regardless of the grade.

However, a particularly important aspect turned out to be the recipient orientation. First of all, only a few hints of recipient orientation has been detected in the analysis. These few moments, however, had a decisive influence on the explanatory process. It turned out that the interaction between the explainer and the addressee partly led to the termination of the explanatory process. Due to the authority gap between the young student and the adult interviewer, the students partly stopped the explanatory process under the assumption that the recipient has no knowledge deficit and already knows the answer. The necessity of making an explanation is questioned by the student. In order to solve the problem and to enable the student to continue the explanatory process to be able to show the whole spectrum of his explanatory skills, a hand puppet instead of the adult interviewer as a direct interaction partner was used in a second pilot-study. A communicative-supporting effect of the hand puppet is assumed for interviews with children (Vogl, 2015). The interaction with the hand puppet should lead to a reduction of the authority gap and thus to a more relaxed atmosphere of conversation, which stimulates the verbal and cognitive abilities of the children (Vogl, 2015). In contrast, the hand puppet can also tempt to play and have a distracting effect on the young student. Older children might also feel that they are not taken seriously in the interview situation (Vogl, 2015). In order to clarify these uncertainties, we conducted another survey with 24 students from the school entrance and exit phase. The survey procedure in itself was unchanged - only the addressee was replaced. The results show, that the students of all grades accept the hand puppet as an interaction partner. There were no longer cases of early termination or interruption of the explanation process due to the difference in authority between student and interviewer. On the direct question of how they felt about the conversation with the hand puppet, the older children gavepositive feedback also. None of the participants found the interaction strange or even silly. Overall, the children were able to get into the explanation process quicker by using the hand puppet and that fewer impulses and questions from the interviewer were necessary.

IMPLICATIONS AND OUTLOOK

The presented results led to the decision to use the hand puppet also in the main survey as the interaction partner. The main study was done in the summer of 2019. Oral explanations of the three selected phenomenon examples were collected from a total of 126 primary school students over the four grades. This sample is made up of at least 30 students of each grade from at least 2 different schools and 3 different classes. The data is currently being evaluated. First impressions point to the existence of different explanatory profiles, some of which are independent of the age of the students. Further analysis will show whether this impression can be confirmed. Ultimately, the results can be used not only as a basis for establishing an evaluation for oral explanations by students in primary school but equally as a basis for developing interventions. In addition, the findings can be used to further develop differentiated textbook tasks by making the requirements of the explanations transparent.

REFERENCES

Hagstedt, Herbert; Spreckelsen, Kay (1986): Wie Kinder physikalische Phänomenen begegnen [How children encounter physical phenomena]. In: Sachunterricht und Mathematik in der Primarstufe [Sachunterricht and Mathematics in primary school] 14, pp. 318–323.

Klein, J. (2016). Erklären-Was, Erklären-Wie, Erklären-Warum. Typologie und Komplexität zentraler Akte der Welterschließung. [Explain-what, Explain-how, Explain-why. Typology and Complexity of central activities in discovering the world] In: Vogt, R. (Ed.). (2016). Erklären.[Explain] Tübingen: Stauffenburg Verlag.

Klein, J. (2017). Beginnende Argumentier- und Erklär-Kompetenz im Vorschulalter (1,9 - 3,0) Vorformen und Topik. [Initial argumentation and explanatory competence in preschool age (1,9-3,0) Early forms and topics] In Meißner, I., & Wyss, E. L. (Ed.). Stauffenburg Linguistik: Band 93. Begründen - Erklären - Argumentieren. Konzepte und Modellierungen in der Angewandten Linguistik [Justify-Explain-Argue. Concepts and Modellings in Applied Linguistics] pp. 65–88. Tübingen: Stauffenburg Verlag.

Kulgemeyer, C., & Peters, C., H. (2016). Exploring the explaining quality of physics online explanatory videos. European Journal of Physics, 37, (6)

Mayring, P. (2014). Qualitative Content Analysis. Theoretical Foundation, Basic Procedures and Software Solution. Klagenfurt: Beltz.

Möller, K., Kleickmann, T., & Sodian, B. (2014). Naturwissenschaftlich-technischer Lernbereich [Scientific-technical learning area]. In Einsiedler, W. (Ed.). Handbuch Grundschulpädagogik und Grundschuldidaktik [Handbook primary-school pedagogy and primary-school didactics] pp. 527–535. Bad Heilbrunn, Stuttgart: Klinkhardt; UTB.

Morek, M., Quasthoff, U., & Heller, V. (2017). Erklären und Argumentieren. Modellierungen und empirische Befunde zu Strukturen und Varianzen. [Explaining and arguing. Modelling and empirical findings] In: Wyss, E. L., Meißner, I. (Ed.). Begründen – Erklären – Argumentieren. Konzepte und Modellierungen in der Angewandten Linguistik. [Justify-Explain-Argue. Concepts and Modellings in Applied Linguistics] Tübingen: Stauffenburg. pp. 11- 46

Osborne, J. F., & Patterson, A. (2011). Scientific argument and explanation: A necessary distinction? Science Education, 95 (4), 627- 638.

Röhner, C. (2009). Abschlussbericht: Projekt: Sprachförderung von Migrantenkindern im Kontext frühen naturwissenschaftlich-technischen Lernens [Final report: Project: Language support for migrant children in the context of scientific-technical learning].pdf

Prediger, S.; Erath, K.; Quasthoff, U.; Heller, V. & Vogeler, A. (2016). Befähigung zur Teilhabe an Unterrichtsdiskursen: Die Rolle von Diskurskompetenz. [Empowerment to participate in Educational Discourses: The Role of Discourse Competences] In: Menthe, D; Höttecke, T; Zabka, M.; Hammann, M. & Rothgangel (Hrsg). Befähigung zu gesellschaftlicher Teilhabe. Beiträge der fachdidaktischen Forschung. [Empowerment to participate in Society. Contributions from Didactic Research] Münster: Waxmann.

Sandoval, William A.; Millwood, Kelli A. (2005): The Quality of Students´Use of Evidence in Written Scientific Explanations. In: Cognition and Instruction 23 (1), S. 23–55. Online verfügbar unter http://www.jstor.org/stable/3233896, zuletzt geprüft am 08.08.2017.

Webb, N. M. (2015): Peer interaction and learning in small groups. In: International Journal of Educational Research 13 (1), S. 21–39.

Vogl, S. (2015): Interviews mit Kindern [Interviews with children]. Eine praxisorientierte Einführung [A practice orientated Introduction] Weinheim & Basel: Beltz Juventa.

SOCIOSCIENTIFIC ARGUMENTATION: TOULMIN'S ARGUMENT PATTERN FOR TEACHING AND LEARNING OF BIODIVERSITY AND ITS CONSERVATION

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Argumentation and discourse have become central elements of science education. In this framework, biodiversity turns out to be a complex concept, with its conservation being recognised as a socio-scientific issue (SSI) that helps to develop students' scientific and environmental literacy. To explore teacher's and students' argumentative discourse, we developed a SSI-based teaching and learning sequence about the use of Toulmin's Argument Pattern (TAP) to make decisions on context-based biodiversity issues. This research, of a sociocultural nature, uses educational discourse analysis with qualitative (conversational analysis) and mixed methods (sociocultural discourse analysis). After having dialogued with our research registers, we report on students' appropriation of scientific argumentative practices, incorporating TAP to everyday reasoning and school science. We have identified several obstacles in teaching and learning of TAP, mainly in relation to terminology (meanings and usage of "rebuttals" and "warrants"), students' habituation to stereotyped strategies of school culture (showing apathy towards group discussions, evaluation of knowledge claims and the recognition of the need to look for rebuttals), and students' reliance on their own epistemic abilities (as sufficient per se *to evaluate facts and justify claims). Related to this, teacher's most frequent dialogical support moves were 'theoretical knowledge activation', 'activity regulation' and 'knowledge legitimation'. Implications arise on the articulation of ecological knowledge and epistemic thinking, and how to support and orchestrate their articulation in the context of SSI-based science teaching.*

Keywords: Classroom Discourse, Socioscientific Issues, Context-based learning

INTRODUCTION

The evaluation of knowledge through the use of scientific evidence (argumentation) is a significant scientific practice, together with inquiry and the construction of explanations and models (Crujeiras Pérez & Jiménez Aleixandre, 2015). Arguments concerning the appropriateness of experimental design, the interpretation of evidence, and the validity of knowledge claims are central to the everyday discourse of scientists (Erduran, Simon, & Osborne, 2004). Over the past few decades numerous studies have focused on the analysis of argumentation, which have highlighted the importance of discourse in the acquisition of scientific knowledge and students' conceptual understanding (Erduran et al., 2004). In most definitions, argumentation is understood as a social rationally-guided activity, which is primarily comprised of utterances (speech acts). This is why, from a sociocultural perspective, discourse and argumentation have a central role in science education.

Science education scholars of the argumentation strand have typically worked on the basis of a conceptual distinction between argumentation as a process and arguments as the products that can be identified from the process. For decades, Toulmin's Argument Pattern (TAP) (Toulmin, 1958, cited in Evagorou & Osborne, 2013) has been a central analytical framework, which refers to argument as the set of claims, data, warrants, and backings that contribute to the content of an argument. However, Toulmin's model does not properly help to distinguish an analyst between the elements (claim, warrant and so on), especially in dialogic argumentative sequences, since discursive aspects become lost when translating them to TAP elements (Nielsen, 2013). Also, many researchers have relied on other frameworks of argumentation theory such as Pragmadialetics and Linguistics (Franco & Munford, 2018). However, TAP still is a main theoretical structure in arranging arguments for decision-making issues and inquiry-based teaching and learning (Bernat, Ferrandis, & Gómez, 2019; Crujeiras Pérez & Jiménez Aleixandre, 2015; Ratz & Motokane, 2016). Further, it has not been addressed how secondary-school students use TAP for the construction of arguments and the evaluation of biodiversity-related claims when TAP is part of the content that is taught. In agreement with Evagorou and Osborne (2013), although we used Toulmin's model in our study, we also view argumentation as the social construction of knowledge in which the learners are expected to share ideas, question assumptions and restructure their existing knowledge schemata based on the interactions in their groups.

Biological diversity plays an important role in ecosystem functioning, providing essential benefits to people and their well-being. Despite the utmost importance of biodiversity for sustainable development, it is declining at unprecedented rates. Biodiversity has thus been recognized as educational priority at all educational levels, and it has been proposed that people should be empowered to act in ways that protect and conserve biodiversity (Bermudez & Lindemann-Matthies, in press). For this to happen, Biology teaching should consider biodiversity protection to be a socioscientific issue (SSI) because of its intricate links to individual and societal decisions (Lee, Grace, Rietdijk, & Lui, 2019). Decision-making teaching about SSIs often include group discussion and cooperative learning, strategic training in decision-making strategies, transactional argumentation and the discussion of strategies for widening discussion perspectives (Lee et al., 2019).

Current research on children's reasoning about biodiversity generally focuses on the acquisition of scientific definitions, plants and animals names, or on students' conceptual understanding in different learning environments (e.g., Almeida, García Fernández, & Strecht-Ribeiro, in press; Bermudez, Díaz, & De Longhi, 2018; Kontkanen, Kärkkäinen, Dillon, Hartikainen-Ahia, & Åhlberg, 2016; Lee et al., 2019; Pérez Mesa, 2019). Related to this, Yli-Panula, Jeronen, Lemmetty and Pauna (2018) have recently surveyed current instructional methods in biology that promote biodiversity teaching and learning, and revealed that the most used teaching methods were hands-on instruction, experiential learning and teacher presentations, with role plays, debates and study trips being the least used ones. In spite of this, decision-making about SSIs is an important means to develop and deepen students' understanding of ecological knowledge through data analysis and construction of evidence-based arguments (Lee et al., 2019).

We use this framework as a way of explore teacher's and students' argumentative discourse in a SSI-based teaching and learning sequence about biodiversity conservation issues.

METHODS

A teaching-learning sequence (TLS) was designed and implemented in the 5th course (32 students aged 16-17) of a state secondary school in a small town in the Province of Córdoba, Argentina. All students came from families of medium to low socioeconomic status. The underlying goal of the TLS was to facilitate students' meaning and decision-making in an argumentative context about current SSIs. The design and execution were carried out jointly by the first and third author. The latest is the regular teacher of the group of students for the subject "Ecology", and has 15 years of experience in secondary schools. The first author was the research team's primary liaison with the teacher and class, designing lessons and coteaching. The second author helped with field notes and with the analysis of classroom discourse transcripts.

The TLS tackled argumentation practices in biodiversity-related SSIs, which were contextualised to current environmental tensions in the Province of Córdoba, in 5 out of 9 lessons (80 min/lesson). In the first session, biodiversity alternate frameworks were identified by the teacher by showing slides with images of plants, animals and other biodiversity expressions at different organisational levels. In lesson 2 students read a short document that narrated the evolution of the conceptualisation of biodiversity and presented its current political and scientific definitions. Our school reference scientific model of biodiversity was an adaptation of the conceptualisation put forward by the Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES, *www.ipbes.net*). This Panel has further specified the meaning of biodiversity as occurring on three organizational levels -genetic, species, and ecosystems (Convention on Biological Diversity, *https://www.cbd.int/*)- to include more components, such as species evenness, species composition, functional composition, and landscape units. A fieldwork to an urban natural park was undertaken in lesson 3, where native plants and animals were perceived and identified with the help of a dichotomous key. In return to the classroom (lesson 4), students discussed about a newspaper article about the conflicts arising on the use of exotic species for native forest reforestation and worked in groups in order to propose a solution to a decision-making task. Afterwards, students re-described their understanding when they had to recognise the species and explain the components of biodiversity, in terms of our reference model, as the slide presentation of lesson 1 was shown again. Lessons 5 to 9 addressed scientific argumentation using TAP framework. First, transposed context-based scientific evidence of biological diversity was used for discussing about its protection (native forests shortage, invasive alien species threat and the implicated ecosystem processes). Then, students in small groups had to identify and use scientific evidences provided by the teaching team in order to take a position over and make a decision about biodiversity conservation in Córdoba. With the purpose of deepening biodiversity understanding and making arguments more complex, new scientific evidence -contextualized to agricultural expansion- were offered to the students after their thoughts and everyday experiences were retrieved. After students had elaborated progressively more complex TAPs, they had to write a letter to the governor and the local media to express their concerns and recommendations about the recent approval of a law and another draft law on native forest protection and countryside forestation. Lessons 5 to 9 are the analytical units of the current paper.

Our research has a sociocultural nature and focuses on argumentative practices in terms of TAP elements. We use educational discourse analysis with qualitative (conversational analysis – CA-) and mixed methods (sociocultural discourse analysis -SDA), according to Mercer (2010). Recursive analytical categories were identified by CA and their reports are illustrated by commented selected extracts of transcribed talk. After SDA, we coded teacher's utterances (questions and statements) during the teaching of TAP following an interpretative perspective, whereby categories of teacher's purpose discursive moves were developed and refined, using a bottom-up approach, through an iterative process (Bansal, 2018).

RESULTS AND DISCUSSION

TAP for evaluating knowledge claims and elaborating arguments

TAP elements are often used by researchers to categorize students' arguments (Evagorou & Osborne, 2013; Nielsen, 2013) but they are less frequently taught to students with the purpose of discussing and making decisions about biological conservation. In the sequence of next dialogue (extracted from lesson 5), it is shown how students used TAP knowledge to produce an argument sequence about experiences relevant to their own contexts. This was considered to be an indicator of students' understanding in terms of the appropriation of community practices that sustain scientific discourse. References: T = teacher, S = Student (Arabic numbers are used to differentiate them, e.g. S1), numbers before S and T indicate the talk turn within the same lesson.

197 T: This form of argumentation helps us not to say something unfounded. Generally, we reach a conclusion without thinking about the backing that supports it, then we are opposing conclusions that are not related to any evidence, no warrants. Am I clear?

198 S1: No.

199 S2: I can come to the conclusion from data, let's give an example, I say that Melisa stole my cell phone, but I do not have any evidence that she actually stole it… [I can't make such claim]. That's what it means.

200 T: Perfect! What it would be an evidence or the warrants to support that claim?

201 S2: For example, that Melisa had done the same thing in the past and someone had seen her.

202 T: The data would be 'my cell phone was stolen', the warrants would be 'since Melisa has previously stole my phone…" Then I can search for backings to support my claim that she had stolen it. For example, something that has to do with human behaviour that indicates that in general people who already stole once tend to do it more than once, since there is a pattern of repeated behaviours. I mean, not because I invented it but as a scientific evidence supports my claim.

203 S1: Oh! Right, I get it.

204 T: Unless…, a rebuttal is an exception. Unless…

205 S2: Unless I had lost it.

206 S3: Unless Melisa hadn't come that day.

207 T: Great! Now we can write down what we have said.

Obstacles to and scepticism toward argumentation practices

We have identified several obstacles in teaching and learning of TAP for biological conservation. In some situations, it seems that difficulties in task completion arise from the ways in which students use words with very different meanings from those assigned in the scientific community (Reigosa & Jiménez Aleixandre, 2007). For instance, the term "reserve" in Spanish is valid for both "rebuttal" and "a protected area for wildlife" meanings, with the latter being more significant for the students in the context of our activity. Because of this, after the following dialogue, that took place on lesson 5, the teacher started using synonyms of "reserve", such as "counter-argument", "exceptions" and "refutation".

172 T: What does "rebuttal" ["*reserva*" in Spanish] mean?
173 S1: Something that is taken care of, that is maintained.
174 S2: Something that retains…
175 S2: A water reserve, for instance.
176 T: But in this context... [5 seconds, no answer]
177 T: We are talking about argumentation, what is argumentation, then?
178 S1: Something that is talked about?
179 S4: Rebuttals ["*reservas*" in Spanish] are exceptions.
180 S5: Is it something that is being discussed? [...]
185 T: We seek to conclude on something, and based on that, take decisions. I asked you what we can do in the fields there are constantly flooded... Thus, using theory we will seek to reach a conclusion, but based on scientifically validated evidence. that's why we have been talking about what researchers have found in their study of water infiltration, to develop our backing. Then, what would be to argue for us? Coming to conclusions using scientific evidence, that implies discussing what justifications and theoretical framework we will use to come to an agreement. For example, which are your warrants and backings in order to say whether you're going to log or not? One can take different positions according to the theoretical framework and thus reach different conclusions.

Another issue was identified when addressing "warrants", which are the statements that relate evidence and conclusions. When justifying, students should use rules or principles to link available data to the conclusion and make use of laws or a set of scientific knowledge to support their reasoning (Toulmin, 1958). However, in our study, students replicated data or redescribed backings instead of justifying their claims. This is in agreement with Sanmartí (2008), who points out that when justifying a phenomenon, students usually write a tautology, or refer to little relevant reasons. Terminology also imposed obstacles to assignment completion since a literal translation of "warrants" into Spanish is "*garantías*", which have a strong legal connotation associated with rental agreements. Moreover, at school, justifying is usually used as a synonym to the fact of arguing (Custodio, Márquez, & Sanmartí, 2015), and then, some students had difficulty in perceiving when we were talking about the whole argument pattern (TAP) or about the warrants.

Third, students' habituation to stereotyped strategies of school culture was an obstacle to the teaching and learning of argumentation as a scientific practice. According to Reigosa & Jiménez Aleixandre (2007), in stereotyped images about teaching and learning, roles are clearly defined and characterized by the teacher giving instructions and the students following them. This was evident in our study as a generalized apathy towards group discussions and the evaluation of knowledge claims, which posed difficulties in evidence selection to support a conclusion, an expansion of the zone of proximal development (ZPD) in student-student interaction, and in the recognition of the need to look for rebuttals. Therefore, most students did not spontaneously participate in whole-class discussions, remain sceptical about knowledge construction and waited for the teacher to "provide legitimate school knowledge". Moreover, only some students in the social interaction within small groups benefited from a given intervention of the teacher, then limiting their collaborative and active knowledge-construction (Reigosa & Jiménez Aleixandre, 2007). As a consequence, the teacher spent significant time in whole-class discussions in lessons 6 and 7 in order to re-contextualise prior small-group interactions.

Fourth, the fact that people tend to rely recklessly on assessments that are based on everyday experiences or common-sense reasoning may be an obstacle to expanding their initial views. This obstacle may influence learning when students are likely to believe that their own epistemic abilities are sufficient *per se* to evaluate facts, the truthfulness of statements and justify claims (Scharrer, Bromme, Britt, & Stadtler, 2012). We found examples of this obstacle when students clung to ideas or observations, without questioning them from a broader framework, in the context of discussing with the teacher and their counterparts (e.g., *"I always saw it that way"*, *"in the country there are cows, always"*, etc.). We consider the third and fourth obstacles to be related to *epistemic thinking* and traditional school science, which emphasises the need for students to shift towards a *multiplist* perspective according to which the source of knowledge is in the self and knowledge is multiple, subjective, uncertain, and justified by personal preferences and judgments (Barzilai & Eshet-Alkalai, 2015). Epistemic thinking is a multi-faceted construct that includes cognitive-level epistemic processes and strategies as well as metacognitive knowledge, skills, and experiences related to the nature of knowledge and to knowing strategies and processes.

Decision-making based SSI argumentation: the conservation of biological diversity

Epistemic practices were linked to TAP when students had to evaluate scientific evidences in order to make decisions about biodiversity conservation. After small-group discussions, through which students had to answer open-ended questions regarding SSIs, students produced argument patterns as the one shown in Figure 1. Initially, students faced difficulties in interpreting scientific evidences and identifying TAP elements, but eventually managed to elaborate complex arguments, which was supported by teacher's epistemic moves (Ratz & Motokane, 2016). This is in agreement with Lee et al. (2019), who provided evidence to the impact of cultural exchange on students' own and others' views on broadening their perspectives (ZPDs, Reigosa & Jiménez Aleixandre, 2007) and stimulating their critical reasoning. Also, students had to write letters to the governor and the local media as a homework assignment in order to express their concerns and recommendations about two draft laws on native forest status and countryside reforestation (see Methods). Some students, even who previously had had little class participation, got involved with the task and produced proper arguments by incorporating scientific knowledge, as the one shown in Figure 2. Therefore, as stated by Lee et al. (2019), we found that issues that lead students to informed decision-making could be used as a context, with more background scientific information provided, to deepen students' understanding of ecological knowledge through data analysis and construction of evidence-based arguments.

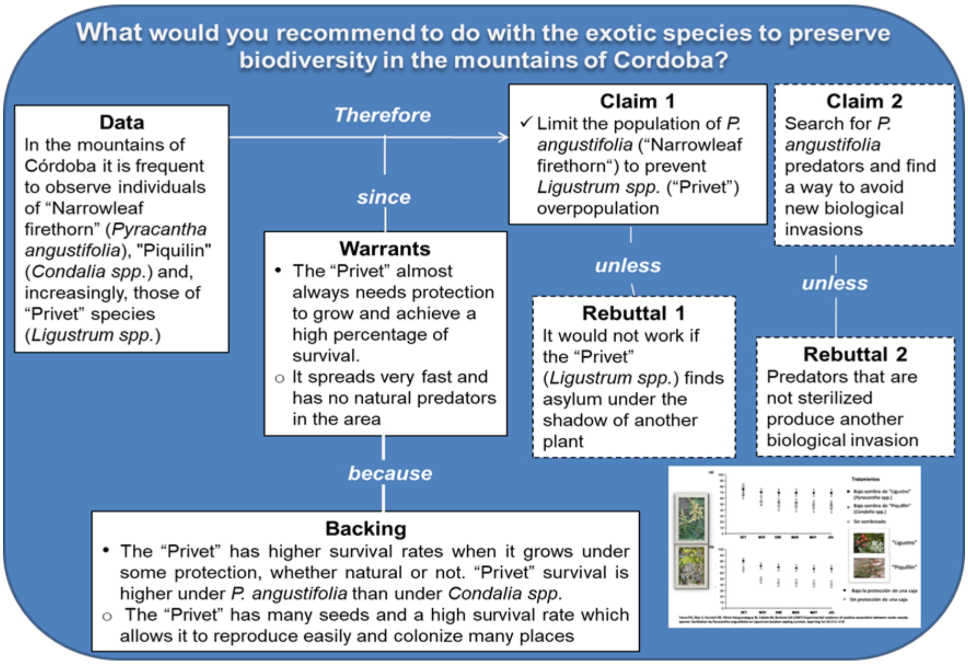

Figure 1. Students' Toulmin's Argument Pattern elaborated for decision making about SSIs after evaluating scientific evidences. References: Closed circle = based on given scientific evidence. Open circle = based on other evidence. Solid and dotted line: argument elements requested and not requested in the assignment, respectively.

Dear Editor,

We are writing to inform you about environmental issues that affect the native forests of Cordoba. Through our investigations we have discovered that the rate of forest loss has been 19,354ha/year between 1979 and 2010, due to an increase in cultural vegetation, mainly monocultures, that has caused the loss of soil and its fertility. Also, wild fires and overgrazing has led to the clogging of water bodies, the solvation of river basins and flooding, since deforestation impedes water absorption.

The loss will continue to increase since, according to agroforestry law, only 2% of the area of the farmlands must be reforested. Also, the agricultural frontier is going to expand due to changes in the native forest areas subject to agricultural activities (draft law).

Therefore, the solution we propose is to modify the agroforestry law by increasing the forested area and favouring native species with seeds or that agricultural activities are avoided in areas with native forests.

We hope this letter reaches the public and becomes aware of the importance of our native forest.

Students of 5th course

Figure 2. A letter written by a group of students in order to express their concerns regarding decision-making about biodiversity issues.

Teacher's discursive moves to support the teaching of TAP

The findings corresponding to the teacher's support provided to guide students during TAP teaching and learning are presented in Table 1 (lesson 6 and 7), where the types of strategies identified are summarized, expressed in percentages of teacher's talk turns and illustrated with examples. Supports by the teacher has the function of scaffolding, that helps learners to carry out tasks that they would not be able to achieve alone, and to enable the development of a higher level of autonomous competence (Reigosa & Jiménez-Aleixandre, 2007). In the current study, we found that the most prominent categories of teacher's support were 'theoretical knowledge activation', 'activity regulation' and 'knowledge legitimation' (Table 1). These supports could be related to the development of an open-ended activity (Crujeiras Pérez & Jiménez Aleixandre, 2015), and to the above-mentioned obstacles in teaching and learning of TAP, and suggests that students do not participate in science-classroom discourse themselves. Rather, in the current study, the teacher provided specific opportunities for students' engagement, which is in accordance with Bansal's (2018) findings. Related to this, we agree with Scott, Mortimer and Aguiar (2006) regarding school scientific dialogue that entails the teacher to act as a thinking thread by opening up conversational space to diverse views, and hence, leading to dialogic interactions. Although the 'reflection on the validity of an argument' and the teacher's request for students' reflection were less represented in teacher's discursive moves (2% and 4%, respectively), these categories could better characterise dialogic argumentation in general, and the evaluation of knowledge claims in particular. Future teachers' dialogic orchestration of classroom interaction, as well as science education research on this topic, should provide insight into dialogic and epistemic discursive moves on other classroom settings, with better school argumentative backgrounds (Bansal, 2018; Lehesvuori et al., 2019; Ratz & Motokane, 2016).

Categories of teacher's scaffolding strategies (frequencies, %)		**Examples**
Theoretical knowledge (29)	Activation (24)	What would pigmentation be? Is it chlorophyll? Why do you think it is important for chlorophyll to break down?
	Contribution (5)	By shrubland we understand a configuration called "Romerillal"; they are bushes that one can find in the "Altas Cumbres" mountains
Reflection on the validity of an argument (2)	Universality (1)	We could say exotic species in general
	Singularity (1)	A rebuttal may also be, for example, that what we have found only applies for the studied species, not for all of them. I can't generalize that it works for all exotic species. Each one has its own leaf feature
Request for reflection on… (4)	the validity of an argument (1)	How would one be able to prove if the following year those hectares were lost or not?
	the validity of the theoretical knowledge used (2)	Why is important to know if the plant is perennial or deciduous for land fertilization?
	the elements of the argument (TAP) (2)	The warrant... if I'm using the theoretical framework that we just said, the warrant has to provide a link between the data and the claim, and are strengthened by the backings
Activity regulation (46)	Regulation of the interpretation of an assignment (19)	What was the problem in the assignment?
	Contribution of the interpretation of non-textual data (11)	This is a satellite photo, what we see is how a closed forest and a cultivated area look like… and thus, it's possible to model this feature and see how it changes
	Request for interpretation of non-textual data (14)	What does the y axis say?
	Request for reflection on an assignment completion (1)	What have you done to answer this question?
	Contribution of process for assignment completion (2)	That is the process to be done, to analyse how big are the bars and what do they represent

Knowledge legitimation (18)	Validation (16)	Good, it's a rebuttal of the conclusion
	Correction (2)	The "espinillo" is not typical of the Chaco-Serrano forests, but it's commonly found in the region called "Espinal"
Clues (1)	Clues that suggest a specific response (1)	Are you sure that that is the problem?

Table 1. Dialogic supports provided by the teacher to guide students during TAP teaching and learning.

In order to make some concluding remarks, we would like to highlight that argumentation and socio-scientific issues, such as biodiversity conservation, is a plausible strategy to promote relational and contextualized scientific practices, even in unprivileged environments. We acknowledge that the case study of a single teacher and TLS has limitations in terms of generalisation. However, we showed how students were able to use TAP in order to evaluate the acceptance of claims, integrate scientific evidence and make decisions about biodiversity conservation. Argument-based instruction research should explore the articulation of knowledge and epistemic thinking, and how to support and articulate them in the context of argumentative-based science teaching. Last, SSI-based instruction has helped students to challenge commonly held assumptions about biodiversity and ecosystem functioning, and to overcome mental obstacles in a way to empower their decision-making.

ACKNOWLEDGEMENT

Special thanks to Universidad Nacional de Córdoba, Secretaría de Ciencia y Tecnología (project codes 92830720150100024CB and 33620190100028CB), and Agencia Nacional de Promoción Científica y Tecnológica de Argentina, FONCYT (project code PICT-2015-1903), and ESERA (European Science Education Research Association, 2019 Fellowships) for financial support.

REFERENCES

Almeida, A., García Fernández, B., & Strecht-Ribeiro, O. (in press). Children's knowledge and contact with native fauna: a comparative study between Portugal and Spain. *Journal of Biological Education*, 1-16. doi: *10.1080/00219266.2018.1538017*

Bansal, G. (2018). Teacher discursive moves: conceptualising a schema of dialogic discourse in science classrooms. *International Journal of Science Education*, *40*, 1891-1912. doi: *10.1080/09500693.2018.1514543*

Barzilai, S., & Eshet-Alkalai, Y. (2015). The role of epistemic perspectives in comprehension of multiple author viewpoints. *Learning and Instruction*, *36*, 86-103. doi: *10.1016/j.learninstruc.2014.12.003*

Bermudez, G.M.A., & Lindemann-Matthies, P. (in press). "What Matters Is Species Richness"—High school students' understanding of the components of biodiversity. *Research in Science Education*, 1-29. doi: *10.1007/s11165-018-9767-y*

Bermudez, G.M.A., Díaz, S., & De Longhi, A.L. (2018). Native plant naming by high-school students of different socioeconomic status: implications for botany education. *International Journal of Science Education*, *40*, 46-66. doi: *10.1080/09500693.2017.1397297*

Bernat, F.X.M., Ferrandis, I.G., & Gómez, J.G. (2019). Competencias para mejorar la argumentación y la toma de decisiones sobre conservación de la biodiversidad. *Enseñanza de las Ciencias, 37*, 55-70. doi: *10.5565/rev/ensciencias.2323*

Crujeiras Pérez, B., & Jiménez Aleixandre, M.P. (2015). Desafíos planteados por las actividades abiertas de indagación en el laboratorio: articulación de conocimientos teóricos y prácticos en las prácticas científicas [Challenges posed by open inquiry tasks in the laboratory: articulation of theoretical and practical knowledge in scientific practices]. *Enseñanza de las Ciencias*, *33*, 63-84. doi: *10.5565/rev/ensciencias.1469*

Custodio, E., Márquez, C., & Sanmartí, N. (2015). Aprender a justificar científicamente a partir del estudio del origen de los seres vivos [Learning to justify scientifically by studying the origin of living beings]. *Enseñanza de las Ciencias*, *33*, 133-155. *10.5565/rev/ensciencias.1316*

Erduran, S., Simon, S., & Osborne, J. (2004). TAPping into argumentation: Developments in the application of Toulmin's argument pattern for studying science discourse. *Science Education*, *88*, 915-933. doi: *10.1002/sce.20012*

Evagorou, M., & Osborne, J. (2013). Exploring young students' collaborative argumentation within a socioscientific issue. *Journal of Research in Science Teaching*, *50*, 209-237. doi: *10.1002/tea.21076*

Franco, L.G., & Munford, D. (2018). A análise de interações discursivas em aulas de ciências: ampliando perspectivas metodológicas na pesquisa em Argumentação [The analysis of discursive interactions in science lessons: broadening methodological perspectives in argumentation research]. *Educação em Revista*, *34*, e18295. doi: *10.1590/0102-4698182956*

Kontkanen, J., Kärkkäinen, S., Dillon, P., Hartikainen-Ahia, A., & Åhlberg, M. (2016). Collaborative processes in species identification using an internet-based taxonomic resource. *International Journal of Science Education*, *38*, 96-115. doi: *10.1080/09500693.2015.1129469*

Lee, Y. C., Grace, M., Rietdijk, W., & Lui, Y. C. (2019). A cross-cultural, cross-age, and cross-gender study of Hong Kong and UK secondary students' decision making about a biological conservation issue. *International Journal of Science Education*, 41, 2696-2715. doi: *10.1080/09500693.2019.1693662*

Lehesvuori, S., Hähkiöniemi, M., Viiri, J., Nieminen, P., Jokiranta, K., & Hiltunen, J. (2019). Teacher orchestration of classroom interaction in science: exploring dialogic and authoritative passages in whole-class discussions. *International Journal of Science Education*, 41, 2557-2578. doi: *10.1080/09500693.2019.1689586*

Mercer, N. (2010). The analysis of classroom talk: Methods and methodologies. *British Journal of Educational Psychology*, *80*, 1-14. doi: *10.1348/000709909X479853*

Nielsen, J.A. (2013). Dialectical features of students’ argumentation: A critical review of argumentation studies in science education. *Research in Science Education*, *43*(1), 371-393. doi: *10.1007/s11165-011-9266-x*

Pérez Mesa, M.R. (2019). Concepciones de biodiversidad y prácticas de cuidado de la vida desde una perspectiva cultural. *Tecné Episteme y Didaxis: TED*, 45, 17-34. *https://revistas.pedagogica.edu.co/index.php/TED*

Ratz, S. V. S., & Motokane, M. T. (2016). A construção dos dados de argumentos em uma Sequência Didática Investigativa em Ecologia [The construction of the data of arguments in an Investigative Didactic Sequence in Ecology]. *Ciencia & Educação*, *22*(4), 951-973. doi: *10.1590/1516-731320160040008*

Reigosa, C., & Jiménez Aleixandre, M.P. (2007). Scaffolded problem-solving in the physics and chemistry laboratory: difficulties hindering students’ assumption of responsibility. *International Journal of Science Education*, *29*, 307-329. doi: *10.1080/09500690600702454*

Sanmartí, N. (2008). Escribir para aprender ciencias [Write to learn science]. *Aula de Innovación Educativa*, *175*, 29-32. *https://www.grao.com/es/aula-de-innovacion-educativa*

Scharrer, L., Bromme, R., Britt, M. A., & Stadtler, M. (2012). The seduction of easiness: How science depictions influence laypeople’s reliance on their own evaluation of scientific information. *Learning and Instruction*, *22*, 231-243. doi: *10.1016/j.learninstruc.2011.11.004*

Scott, P.H., Mortimer, E.F., & Aguiar, O.G. (2006). The tension between authoritative and dialogic discourse: A fundamental characteristic of meaning making interactions in high school science lessons. *Science Education, 90*, 605–631. doi: *10.1002/sce.20131*

Toulmin, S. (1958). *The uses of argument.* Cambridge: University Press.

Yli-Panula, E., Jeronen, E., Lemmetty, P., & Pauna, A. (2018). Teaching methods in biology promoting biodiversity education. *Sustainability*, *10*, 3812. doi: *10.3390/su10103812*

IDENTIFICATION OF EVIDENCE BY ENGINEERING UNDERGRADUATES AND PRE-SERVICE SCIENCE TEACHERS IN AN ARGUMENTATION ACTIVITY

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Scientific argumentation is considered as one of the general competencies that engineering students must achieve. This paper analyses the capacity to identify evidence in an argumentation activity on characteristics of materials, developed with 46 engineering undergraduates of the second year of the Degree in Industrial Technologies Engineering and 81 pre-service science teachers of the University of Malaga (Malaga, Spain). These pre-service science teachers studied a Master's Degree in Secondary Education and were classified for this study in two groups depending on whether or not their previous degree was related to the knowledge necessary to solve the activity. The activity proposes to argue the choice of a bicycle according to the material of manufacture (steel or aluminium), focusing this paper on the analysis of the evidence shown in their arguments. A number of evidence, their type, their quality in terms of the level of adequacy and precision, and the inclusion or not of personal ideas, were considered as dimensions. The results show that engineering undergraduates are capable of providing arguments with more evidence and of different types (economic, physical-chemical and mechanical) as opposed to pre-service science teachers. On the contrary, pre-service teachers offer arguments with a better quality of evidence than undergraduates. Pre-service science teachers from degrees unrelated to the activity used a significant number of personal ideas when arguing. These results highlight the need to continue training both undergraduates and pre-service teachers so that they can argue in their profession in the best possible way.

Keywords: Initial Teacher Education (Pre-service), evidence-based approaches, decision making.

INTRODUCTION

The promotion of reasoning and argumentation skills constitutes an important role in the competencies that undergraduates must acquire (Andrews et al., 2006; Mercier & Sperber, 2011). Hence, university education has an inescapable responsibility in promoting these skills (Mouraz et al., 2014).

In the field of engineering, argumentative skills are of great importance not only because they allow them to support in a reasoned way an idea in the resolution of a problem, but also since they allow engineers to justify which is the best of their proposals according to the requirements of the client and the current regulations (De Castro, Torres & Candelo, 2015).

Thus, learning to argue is essential to persuade the interlocutor about the engineer's position on a problem or about the solution to that problem (Jonassen, & Kim, 2010). Also, the development of the argumentation in engineers is considered as one of the general competencies that every undergraduate of the Degree in Industrial Technologies Engineering must achieve (Ministry of Education and Science, 2007).

However, Holvikivi (2007) established that one of the problems that engineers face is not the mathematical reasoning for the resolution of problems in their discipline, but the adequate use and ability of language structures to express formal reasoning about the solution of a disciplinary problem. Several studies support this difficulty (Escudeiro, Barata, & Lobo, 2011; Marco-Galindo, Macau-Nadal, Nussbaum & Schraw, 2007; & Pastor-Collado, 2010) and have detected essential mistakes in the communication skills of engineering students.

Argumentation is one of the relevant scientific practices in science education and consists of being able to evaluate statements based on evidence. It implies recognizing that scientific conclusions and statements must be justified, that is, supported by evidence (Jiménez-Aleixandre, 2010).

The argumentation can be raised in the teaching-learning process concerning any problem, either exclusively scientific/technological or socio-scientific. In order to design and evaluate argumentation activities, it is important to have an adequate model understanding the argumentation. In this effort, the Toulmin model (2003) and the Jiménez-Aleixandre simplification (2010) stand out to facilitate the understanding of the essential elements of a good argument: evidence, justifications, and conclusions. This study aims to analyse the capacity to identify evidence in an argumentation activity proposed to engineering undergraduates and pre-service science teachers.

In short, from initial training, it is, therefore, necessary to place greater emphasis on preparing students in scientific argumentation in order to achieve an important impact on the outcome of their learning in the sciences (Yalvac, Smith, Troy & Hirsch, 2007).

METHOD

A total of 127 students from the University of Malaga (Malaga, Spain) participated in this study during the academic year 2018/19, divided into three groups:

- Undergraduates (UG) of the second year of the Degree in Industrial Technologies Engineering (N = 46, 37 men and 9 women),
- Pre-service science teachers from similar degrees (SD) with the necessary knowledge to solve the activity (engineering and chemical sciences) (N = 37, 24 men and 13 women), and,
- Pre-service science teachers from other scientific degrees not related to the knowledge (NSD) (N = 44, 21 men and 23 women).

SD and NSD were studying a Master's Degree in Secondary Education Teaching at the University of Malaga.

The participants answered an argumentation activity included in a broader questionnaire, as a previous step for the design of an argumentation training programme with students from the Industrial Engineering School of the University of Malaga. The statement of the activity was:

"You are going to buy a bicycle, and you have to choose the material for its frame. If the options are between a steel or aluminium frame (Figure 1), indicate which one you would choose and reasonably justify why you choose that frame concerning the other".

Figure 1. Steel (option A) and aluminium (option B) frame bicycle

The responses of the participants were analysed according to the three elements of an argument (evidence, justification, and conclusions), focusing this paper on the identification of evidence. Three dimensions were considered in the analysis:

(1) Evidence number.

(2) Type of evidence provided: economic, physical-chemical (density, interaction with the environment, etc.) and mechanical (tenacity, elasticity, production/repair properties, etc.).

(3) Its quality in terms of the level of adequacy and precision to scientific-technological knowledge.

The inclusion or not of personal ideas was also considered as another dimension.

A rubric (Table 1) was used for the analysis (Table 2), which was established by consensus among the researchers (authors of the paper), adding the necessary levels to address the range of responses offered by the participants adequately.

The following are some responses given by participants in order to illustrate how the analysis was carried out:

***"Option A, since even if the bicycle weighs more it is more resistant"* (NSD03).**

The response of this pre-service science teacher presents two pieces of evidence (weight and mechanical resistance of the bicycle) (level L2 for evidence number), which correspond to two types of evidence (physical-chemical and mechanical) (level L4 for

evidence type). According to the evidence quality, these pieces of evidence are appropriately, but one of them (resistant) is an imprecise evidence (level L2 for evidence quality). This response does not present any personal ideas.

Table 1. Rubric generated for the analysis of the evidence identified by students

<table>
<tr><td colspan="6">Evidence Number</td></tr>
<tr><td>L0: No evidence</td><td>L1: One piece of evidence</td><td>L2: Two pieces of evidence</td><td>L3: Three pieces of evidence</td><td>L4: Four pieces of evidence</td><td>L5: Five pieces of evidence</td></tr>
<tr><td colspan="6">Evidence Type</td></tr>
<tr><td>L0: No evidence</td><td>L1: Economic</td><td>L2: Physical-chemical</td><td>L3: Mechanical</td><td>L4: Two different types</td><td>L5: Three different types</td></tr>
<tr><td colspan="6">Evidence Quality</td></tr>
<tr><td>L0: Inappropriate</td><td>L1: Some inappropriate</td><td>L2: Appropriate but imprecise</td><td colspan="2">L3: All appropriate and some imprecise</td><td>L4: All appropriate and precise</td></tr>
<tr><td colspan="6">Personal Ideas (qualities, use, appearance, preference, personal budget)</td></tr>
<tr><td colspan="3">No</td><td colspan="3">Yes</td></tr>
</table>

"Option B, because this bicycle is lighter, does not rust and is cheaper than the other bicycle" **(UG21).**

The response of this undergraduate presents three pieces of evidence (weight, corrosion resistance and price of the bicycle) (level L3 for evidence number), which correspond to two different types of evidence (economic and physical-chemical) (L4 for evidence type). However, the quality of the evidence was categorized in the level L1 since the property price was indicated inappropriately (a bicycle with a steel frame is cheaper than one with an aluminium frame). This response does not present any personal ideas.

"Option B. Bicycle with aluminium frame. I would choose the aluminium frame since it is a tougher and lighter bicycle. It is also nicer to the touch and the eye. Moreover, it does not rust easily although it is a little more expensive to repair the frame" **(SD31).**

The response of this pre-service science teacher presents five pieces of evidence (weight, mechanical resistance, corrosion resistance, price and mechanical aspects) (level L5 for evidence number) that correspond to three different types of evidence (economic, physical-chemical and mechanical) (L5 for evidence type). These pieces of evidence are appropriate, but some are not precise (the participant mentions that it is a robust bicycle but any specifications are given) (L3 for evidence quality). He emphasizes its touch and showiness as a personal idea.

The Kruskal-Wallis test was used to study possible statistically significant differences between the groups, using the Mann-Whitney U test to detect the group that produces the differences in each case and the possible differences between sexes.

RESULTS

The percentages of responses in each group and dimension are shown in Tables 2 and 3. Responses at level 0 of the rubric were not found in none of the dimensions.

Table 2. Percentage of responses of each group for the dimensions evidence number and evidence type.

	Evidence Number					Evidence Type				
	L1	L2	L3	L4	L5	L1	L2	L3	L4	L5
UG	39.1	30.4	23.9	4.3	2.2	4.3	39.1	8.7	32.6	15.2
SD	67.6	18.9	13.5	0.0	0.0	2.7	70.3	0.0	24.3	2.7
NSD	75.0	22.7	2.3	0.0	0.0	2.3	77.3	0.0	20.5	0.0

Table 3. Percentage of responses of each group for the dimensions evidence quality and personal ideas.

	Evidence Quality				Personal Ideas	
	L1	L2	L3	L4	No	Yes
UG	17.4	8.7	28.3	45.7	67.4	32.6
SD	5.4	2.7	13.5	78.4	70.3	29.7
NSD	0.0	6.8	6.8	86.4	54.5	45.5

It can be seen that UG offers a higher number of pieces of evidence (mean value 2.00) compared to pre-service science teachers (mean SD: 1.46; mean NSD: 1.27).

Likewise, UG was the group with the best results regarding the type of evidence, on the one hand since it was the only group that identified the three types of evidence (SD and NSD did not use mechanical evidence), and on the other hand, because they argued with a greater number of different types.

However, the best results in the quality of evidence were offered by SD (mean value: 3.65) and NSD (mean: 3.80) versus UG (mean: 3.02).

NSD was the group that used the most personal ideas when arguing.

The Kruskal-Wallis test showed that there were significant differences in at least two groups for the number, type and quality of evidence, but not for personal ideas.

The Mann-Whitney U test indicated statistically significant differences between UG and SD for the variables number of evidence ($Z = -2.638$; $p = 0.008$), type ($Z = -2.399$; $p = 0.016$) and quality ($Z = -3.019$; $p = 0.003$), but not for personal ideas ($Z = -0.279$; $p = 0.780$). For UG and NSD the same significant differences were found (evidence number: $Z = -3.866$, $p = 0.000$; type: $Z = -3.215$, $p = 0.001$; quality: $Z = -4.043$, $p = 0.000$; personal ideas: $Z = -1.234$; $p = 0.214$). The Mann-Whitney U test indicated that there were no significant differences between the SD and NSD groups.

No significant gender differences were found in the UG and SD groups, although there were within NSD, regarding evidence quality ($Z = -2.720$; $p = 0.007$) and personal ideas ($Z = -2.125$; $p = 0.034$), in both cases in favour of women.

CONCLUSIONS

The results show that knowledge may influence some aspects of the capacity to use evidence, in this study in terms of the quantity and types of evidence used, but not the evidence quality. The absence of such knowledge may be related to the use of personal ideas rather than evidence in the arguments offered.

On the other hand, the results obtained show the need to train both undergraduates and pre-service science teachers on scientific argumentation. In this second case, bearing in mind that they will be the future technology/science secondary teachers, who will, in turn, have to train their students in argumentation.

ACKNOWLEDGEMENTS

This work was supported by the Spanish government through its 2017 research call [EDU2017-82197-P, R&D Project].

REFERENCES

Andrews, R., Bilbro, R., Mitchell, S., Peake, K., Prior, P., Robinson, A., See, B. H & Torgerson, C. (2006). *Argumentative skills in first year undergraduates: a pilot study*. York: The Higher Education Academy.

De Castro, A. E., Torres, L. & Candelo, J. (2015). Argumentación en ingeniería: un estudio en dos universidades colombianas. Conference paper in II Congreso Internacional de Innovación Educativa.

Escudeiro, N., Barata, A. & Lobo, C. (2011). Enhancing students team work and communication skills in international settings. *Proceedings of 2011 International Conference on Information Technology Based Higher Education and Training* (ITHET 2011) (pp. 57-64). Izmir, Turkey: Institute of Electrical and Electronics Engineers (IEEE).

Holvikivi, J. (2007). Logical reasoning ability in engineering students: a case study. *IEEE Transactions on Education, 50*(4), 367-372.

Jiménez-Aleixandre, M. P. (2010). *10 ideas clave. Competencias en argumentación y uso de pruebas* (Vol. 12). Barcelona (Spain): Graó.

Jonassen, D. H. & Kim, B. (2010). Arguing to learn and learning to argue: design justifications and guidelines. *Educational Technology Research and Development, 4*(58), 439-457.

Marco-Galindo, M. J., Macau-Nadal, R. & Pastor-Collado, J. A. (2010). Learning written communicative skills in UOC engineering curricula: A virtual university initiative and its future development. *Proceedings of 2010 IEEE Transforming Engineering Education: Creating Interdisciplinary Skills for Complex Global Environments* (pp. 1-15). Dublin, Ireland: Institute of Electrical and Electronics Engineers (IEEE).

Mercier, H. & Sperber, D. (2011). Why do humans reason? Arguments for an argumentative theory. *Behavioral and Brain Sciences*, *34*, 57-11.

Ministry of Education and Science (2007). *Real Decreto 1393/2007, de 29 de octubre, por el que se establece la ordenación de las enseñanzas universitarias oficiales.* BOE num. 260, de 30 de octubre.

Mouraz, A., Leite, C., Trindade, R., Martins, J. M., Faustino, A. M. & Villate, J. (2014). Argumentative skills in higher education: A comparative approach. *Journal of Education & Human Development*, *3*(1), 279-299.

Nussbaum, E. M., & Schraw, G. (2007). Promoting argument-counterargument integration in students' writing. *The Journal of Experimental Education, 76*(1), 59-92.

Toulmin, S. E. (1958). *The uses of argument* (2003, 3rd ed.). Cambridge: Cambridge University Press.

Yalvac, B., Smith, H.D., Troy, J.B. & Hirsch, P. (2007). Promoting advanced writing skills in an upper-level engineering class. *Journal of Engineering Education*, 117-128.

THE PRODUCTION OF LITERARY INSCRIPTIONS BY STUDENTS OF HIGHER EDUCATION IN THE HEALTH AREA WHEN CONDUCTING AN IMMUNOLOGY INQUIRY-BASED LEARNING ACTIVITY

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The aim was to analyze the production of literary inscriptions in the form of drawings and argumentative writings by groups of students of higher education when they carried out an inquiry-based learning activity with the subject of immunology. The analyzes showed that the students produce literary inscriptions in the form of drawings and arguments in the proposed inquiry-based learning activity, however, there is more production of graphic inscriptions and arguments referring to the drawings when the groups of students were not previously exposed to other graphic and schematic literary inscriptions in basic biology classes before the application of the activity.

Keywords: Inquiry-based learning in Biology, inquiry-based learning in Immunology, literary inscriptions in science education

INTRODUCTION

In one of the objectives of science education, proposed by Hodson (2014), "students learn to do science" and inquiry-based learning activity is an important active learning methodology that makes it possible to reach this learning objective. By executing this methodology students can collect data and interpret them using the logic of science and thus producing the meanings of reality by means of the so-called, primarily by Latour & Woolgar, 1979, literary inscriptions. Literary inscriptions can be defined as the material resources that can be used by scientists to materialize, learn the object or phenomenon studied from a given reality, for example, writings, annotations, arguments, photographs, explanations, diverse designs. The study of the production of literary inscriptions is of interest in the science education and it is up to the teacher the mediation of the construction of knowledge in class using inscriptions.

Inquiry-based learning activity is an active learning methodology [MAA] are possible to be developed by teachers through problematizing objectives that encourage students to develop in a critical and autonomous way about given content, ultimately stimulating their curiosity. (Borges, Alencar 2014; Oliveira, 2014; Moreno 2016,) For Gewhr et al. (2016) MAAs need to be organized based on appropriate pedagogical strategies: concept maps, peer instruction and the verbalization and observation strategy. However, Berbel (2011) shows that for such results to be effective, it is necessary to understand, choose and interest students in face of new learning.

Active Learning Methodologies are the representation of the activity of scientists, in which the production of evidence occurs in two different ways. In the first, through “hands on” activities, which are carried out experimental laboratory practices in the construction of primary data, to solve important problems for the group of students, as in Silva (2011). In the second, they are “hands off” activities in which secondary data related to a problem situation are offered, which are solved only through arguments with other literary inscriptions. In this way, the process of scientific enculturation takes place, appropriating scientific cultural tools, their criteria for the production, communication and evaluation of scientific knowledge (Deboer, 2006; Munford e Lima, 2007; Bybee, 2006; Driver et al, 1999; Kuhn, 1993; Duschl, Osborne, 2002).

The argument only exists when there is a case for direct affirmative. For this, three minimum elements related to Toulmin's (2006) argumentative pattern are necessary: the data show it, the conclusion, has its merit established through the guarantee, which justifies and links the data to the conclusion. It is necessary to understand the dynamism of this model, as the conclusion is provisional, given its relationship with other more convincing elements, which are supported by direct evidence, specialized literature, together with the qualifiers of each dependent field. Only from the points above is it possible to classify, evaluate and criticize an argument.

The development of scientific reasoning occurs in two ways. The first of the primary data, which students build through experimentation and the collection of evidence of reality. The second of the secondary data is collected by others and presented in different ways- graphs, tables, schemes. The former are important for students to understand the source of the data, while the latter are understood as authoritarian, as they are possible to be manipulated in order to identify patterns. In this way, the second is able to generate a greater number of arguments than the first, but which are of worse quality, as they are more distant from the scientific knowledge established by the literature (Kelly, Druker, Chen, 1998; Hug, McNeill, 2008).

The quality of the arguments depends on an appropriate set of scientific knowledge present in the data and its justifications. In order for these to have these characteristics, it is necessary to apply scientific theories relevant to each of these specific problems. The construction of this theory takes place by reasoning during the process of building evidence and models. These are especially important on the molecular scale as in the astronomical macroscopic, because they are strongly abstract in nature, due to their evidences, they are not perceptible to the average daily vision. However, the more distant this is from a theme, the lesser the student's participation, being necessary for the teacher to be a mediator between the spheres of everyday life and the scientific knowledge of abstract models, through socio-scientific activities and contents (Hogan, Maglienti, 2001; Sandoval, 2005; Osborne, 2007; Erduran, Duschl, 2004; Berland, Reiser, 2009; Bottcher, Meisert, 2010; Jiménez-Aleixandre, Puig Mauriz, 2010; Chiaro and Leitão, 2005).One of the literary inscriptions present in the sciences is drawing, both in articles and in teaching, in the form of graphs constructed using a table of collected data, diagrams from microscopic photos and in an isometric representational form of agents and phenomena and phylogenetic trees. The use of drawing in teaching serves for students to deepen their knowledge, communicate it and be able to be evaluated by the teacher. With drawing it is possible to overcome the limitations of teaching centered only on passive listening and writing, stimulating investigative teaching and student curiosity (Quillin, Thomas, 2015; Ainsworth, Prain and Tytler; 2011). For Vygotsky (1989) the drawings represent a preliminary stage of writing, not representing what is seen, but what is known. Therefore, the aforementioned author suggests that the drawing has the same origin as the written language, and, with the development of writing, the drawing is configured as other ways of representing what is written, such as, for example, a graphic description.

Here, our proposal of investigative activity, went in two directions to analyse the work with the literary inscriptions, drawings and writings, by the groups of students of heath area course during an immunology inquiry-based learning activity. In a first, the literary inscriptions as graphic designs and schemes were presented and analysed with the students; and in the second moment, the literary inscriptions of the same nature were produced by the students themselves. And also, the production of literary inscriptions in the form of arguments in both situations. The “inquiry work movement” by student groups with these literary inscriptions in classes sequence was our focus of analysis. How did the students move in the two ways situations proposed that mobilized the construction of students' knowledge in biology classes?

METHODOLOGY

The immunology inquiry-based learning activity*:* the inquiry-based learning activity is used with adaptations from the proposal described in Manzoni-de-Almeida et al., (2016). Briefly, the inquiry-based activity consists in the creation of the narrative that begins with problem situation and a question in which a researcher, interested in accomplishing a treatment of a chronic illness with stem-cells, studies to treat a mouse with chronic disease with these stem-cells. However, before performing the treatment it is necessary to identify in which of the samples of bone marrow cells collected from a healthy mouse there is only the presence of stem cells and not other types of already differentiated cells. To solve this question, and to find out which of the samples are undifferentiated cells, the groups of high education students receive raw results from experiments performed by the laboratory techniques Polymerase Chain Reaction (PCR), Northern blot and flow cytometry. In all these spaces the students can write and draw about the immunology case in the inquiry-based activity.

Data collection: the data were collected in the classes of bases of biological cell, taught in the first year of undergraduate courses in the health area. For the purpose of this study, the application of the activity was structured in two forms: “Situation 1” and “Situation 2”. In 1 the groups of students performed in the first class the analysis of graphs and images.

The images consisted of 13 simplified diagrams of B lymphocyte maturation; there were also 2-column plots illustrating the gene expression of the RAG and Actin gene. Each group of students received the same 13 diagrams of cell differentiation of B lymphocytes, but their 2-column graphs changed, some received graphs illustrating the gene activation of RAG and Actin from stem cells, others from pre-B cells and others from mature B; later in the second class they carried out the inquiry-based learning activity with theme of Immunology, described above.

In 2 the groups of students first, carried out the inquiry-based learning activity, later in the second class, carried out graphs and images analyses. In both situations, students were divided into groups to carry out activities (17 students divided into 3 groups in 1; and 13 students divided into 3 groups in 2; Total 6 hours/class for each class; held twice). The students read and signed the Free Consent Term (TLC) (Protocol CEP: 0985/2015).

Data analysis: literary inscriptions produced was the analysis of: 1) the presence of drawings produced and classified in graphic design, schematic design or free artistic design (adapted from Quillin & Thomas, 2015); and 2) was the analysis of production of arguments in the Toulmin standard (2006).

RESULTS, DISCUSSION AND CONCLUSION

The analyzes of the selected data set showed that the student groups produced literary inscriptions in the form of writings and drawings by carrying out the inquiry-based learning activity only in Situation 2 (Figure 1, example). In Situation 1 the groups of students produced only written literary inscriptions of arguments. The analysis of the material produced by the groups of students showed the development of drawings classified as diagram and graph, with 9 drawings in graphical format (5 graphic designs in each application of didactic activity) and 1 schematic drawing in Situation 2. However, in the analysis of the material of Situation 1, the presence of drawings classified as schema and graphs was not detected.

Most of the graphics produced were in accordance with the raw data, with the RAG and actin gene expression bars. However, instead of making just one column for each one, using the raw data experiments, they made one for each one. Which led some students to create the time graph? Both cases were not appropriate with the literature. Such results are consistent with Fernandes and Morais (2011), as there is a lack of mathematical literacy in the construction of graphs, as well as reading and understanding of them.

The analysis of the writings produced by the student groups in the reports showed that in both situations there were written arguments produced according to the Toulmin standard. The analysis of these writings showed a total of 49 arguments in Situation 1, divided in the detection of 28 and 21 arguments in each application of the didactic activity. In the analysis of Situation 2 the presence of 29 arguments was detected, being the detection of 16 and 13 arguments in each application of the activity. The texts produced in Situation 1 are short arguments and little related to the empirical data of the inquiry-based learning activity investigative activity, but linked to argue, “schematize” the design, the phenomenon exposed. However, the arguments related to Situation 2 are directly derived and referenced from the graphic designs constructed by the students themselves.

In both situations the arguments were short and with little theoretical depth in the reported area of the activity. We believe that this occurrence is due to little familiarity with the theoretical subject, since the studied classes are located in the first semester of the health course, which corroborates with Hug, McNeill (2008), as well as Chiaro and Leitão (2005), because secondary data were offered which can be manipulated and trends can be seen. However, without prior knowledge of immunology, a topic unfamiliar to students, there was a misunderstanding in the graphic data of gene expression, considering those of 1.5 RAG as mature B lymphocyte, which was from the trunk. The arguments written in both situations were slightly longer and close to the literature when describing the maturation of B lymphocyte.

Table 1: **Written and image expression of the construction of knowledge by the groups of students performing the inquiry-based learning activity in the classes with basic biology knowledge in the courses of the health area**

		Situation 1		**Situation 2**	
		1	2	1	2
Number of drawings produced	Graphics	0	0	5	5
	Schemes	0	0	0	1
Number of arguments produced		28	21	16	13

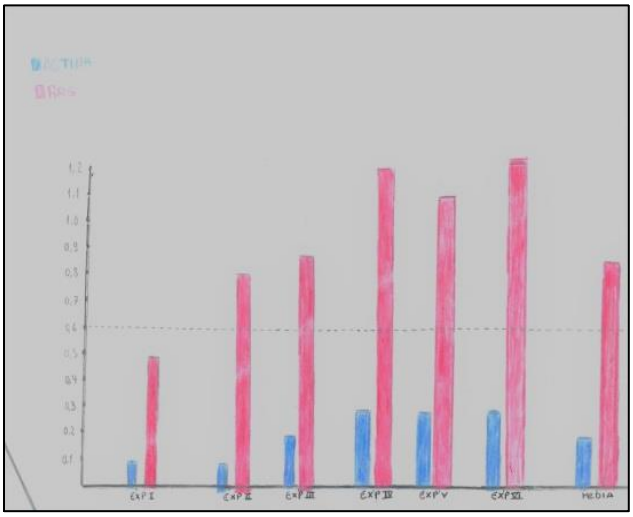

Figura 1 Exemple Graph Situation 2

This suggests that student groups in this Situation 1 did not contextualize the graphical format of literary inscription as a social practice linked to the construction of meaning to understand the proposed biological phenomenon. As the phenomenon is already given, deciphered in graphs and diagrams, the movement of student groups was only to "explain" it by the written verbal language, the arguments, which present the greatest total number in this sequence. The option of presenting the drawings in schematic and graphic form in Situation 1 suggests that the design in science teaching as a way of representing reality and as a communication strategy as proposed by Ainsworth, Prain & Tytler (2011) reinforces the role of the drawing as an active learning tool because the student explores, coordinates and justifies his understanding in science. Bowen et al., (1999), noticed that the construction and better use of students with the graphic design is more positive from the construction of the graphs by the students themselves when developing the situation research since the meaning of the graphic drawings passes knowledge and experiences with social practices, also social practices of science, which are directly associated with the composition of the inscriptions. However, the inverse phenomenon, the work with the ready literary inscriptions can bring difficulties of interpretation by the students, since, the students first have to realize an effort of understanding of the biological phenomenon from the drawing and later to realize the work of deconstruction of the understanding transmitted by the literary inscription for the construction of the biological meaning proposed by the data (Bowen & Roth, 2002; Roth, 2013). This discussion also suggests that the phenomenon of the absence of the production of inscriptions in the format of drawings in Situation 1 also by the non-"appropriation" of social practices and scientific in the construction of analyzes of literary inscriptions.

In conclusion, the work of the teacher in the classroom with the most diverse nature of literary inscriptions in inquiry-based learning activity can provide several creative aspects of scientific expression for students; and immunological inquiry-based learning activities, such as the one studied, can provide the production and interpretation of a diversity of important literary inscriptions related to the objectives of scientific literacy in the training of science teachers, biology (in particular Immunology) and the insertion of students undergraduate programs in the areas of biological sciences and health in scientific culture for the development and training of researchers in the natural sciences.

REFERENCES

Ainsworth, S., Prain, V, Tytler, R (2011). Drawing to learn in science. *Science Education. 2011, 33 (333)*, 1096-1097
.

Berbel, N.A.N (2011). As metodologias ativas e a promoção da autonomia de estudantes. Semina: Ciências Sociais e Humanas, Londrina, v. 32, n. 1, p. 2540.

Berland, L.K, Reiser, B.J. (2009). Making Sense of Argumentation and Explanation. Science Education, v. 93, n. 1, p. 26-55.

Borges, T.S., Alencar, G. (2014) Metodologias ativas na promoção da formação crítica do estudante: o uso das metodologias ativas como recurso didático na formação crítica do estudante do ensino superior. Cairu em Revista; n° 04, p. 119-143.

Bottcher, F., Meisert, A. (2010). Argumentation in Science Education: A Model-based Framework. Science & Education, v. 20, n. 2, p. 103-140.

Bowen, G.M., Owen, G.M., Roth, W.M. & McGinn, M.K (1999). Interpretations of graphs by university biology students and practicing scientists: Toward a social practice view of scientific representation practices. *Journal of Research in Science Teaching*, *36(9)*, 1020-1043.

Bowen, G.M. & Roth, W.M (2002). Why students may not learn to interpret scientific inscriptions. *Research in science education.32(3)*, 303-327.

Bybee, R. W. (2006). Scientific Inquiry and Science Teaching. In L. B. Flick, & N. G. Lederman (Eds.), Scientific Inquiry and Nature of Science: Implications for Teaching, Learning and Teacher Education (pp. 1-14). Dordrecht: Springer.

Chiaro, S., Leitão, S.(2005) O papel do professor na construção discursiva da argumentação em sala de aula. Psicologia: Reflexão e Crítica, v. 18, n. 3, p. 350-357,2005

Deboer, G.(2006). Historical perspectives on inquiry teaching in schools. IN: FLICK, L.D., LEDERMAN, N. G. Scientific inquiry and nature of science: Implications for teaching, learning and teacher education. Netherlands: Springer, p. IX-XVIII.

Driver, R., Asoko, H.; Leach, J, Mortimer, E., Scott, P.(1999). Construindo conhecimento científico na sala de aula. Química nova na escola, n.9, p. 31-40.

Erduran, S., Duschl, R. (2004). Interdisciplinary Characterizations of Models and the Nature of Chemical Knowledge in the Classroom. Studies in Science Education, v. 40, p. 105-138.

Fernandes, J.A; Morais C.(2011) Leitura e Interpretação de gráficos estatísticos por alunos do 9º. ano de escolaridade. Educ. Matem. Pesq., São Paulo. 13(1): 95-115.

Gwhr, D, Strohschoen, A. A.G., Marchi, M.I, Martins, S.N, Schuck, R.J (2016). Metodologias ativas de ensino e de aprendizagem: Uma abordagem de iniciação à pesquisa. Revista Ensino & Pesquisa, v.14, n.01, p.225-246.

Hogan, K, Maglienti, M.(2001). Comparing the epistemological underpinnings of students' and scientists' reasoning about conclusions. Journal of Research in Science Teaching, v. 38, n. 6, p. 663-687.

Hodson, D. (2014) Learning science, learning about science, doing science: different goals demand different learning methods Int. *J. Sci. Educ. 36*, 2534–53.

Hug, B., McNeill, K.L. (2008). Does data type influence classroom conversations? International Journal of Science Education, v. 30, n. 13, p. 1725-1751.

Jiménez-Aleixandre, M.P; Puig Mauriz, B.(2010). Argumentación y evaluación de explicaciones causales en ciencias: el caso de la inteligencia. Alambique, v. 63, p. 1118, Kelly, G.J, Druker, S., Chen, C. (1998). Student's reasoning about electricity: combining performance assessments with argumentation analysis. International Journal of Science Education, v. 20, n. 7, p. 849-871.

Kuhn, D.(1993) Science as Argument: Implications for Teaching and Learning Science Thinking. Science Education, v. 77, n. 3, p. 319-337.

Latour, B. & Woolgar, S. (1979). *Laboratory life: The Construction of Scientific Facts.* Princeton University Press New Jersey.

Moreno, M. A. (2016)Concepções de professores de biologia, física e química sobre a aprendizagem baseada em problemas (ABP). Revista Hipótese, Itapetininga, v. 2, n.1, p. 104-117, 2016.

Munford, D., LIMA, M.E.C.C.(2007). Ensinar ciências por investigação: em quê estamos de acordo? Revista Ensaio. V 7, n.1.

Oliveira, L.P.L.(2014) Metodologia de projetos: da segmentação de conteúdos a um ensino contextualizado e integrado à vida.. Planaltina – DF,p.1-15, 2014.

Osborne, J.(2007). Towards a more social pedagogy in science education: the role of argumentation. Revista Brasileira de Pesquisa em Educação em Ciências, v. 7, n. 1, p. 1-17.

Quillin, K & Thomas, S. (2015). Drawing to learn: A framework for using drawings to promote model-based reasoning in biology. *CBE-Life Science Education. 14(1)*, 1-16.

Sandoval, W.A. (2005). Understanding Student's Pratical Epistemolgies and Their Influence on Learning Through Inquiry. Science Education, v. 89, n. 4, p. 634-656.

Silva, F.A.R.(2011) O Ensino de Ciências por investigação na educação superior: um ambiente para o estudo da aprendizagem científica. Tese. Universidade Federal de Minas Gerais. Belo Horizonte.

Toulmin, S.E (2006). *Os usos do argumento*. 2. Ed. São Paulo: Martins Fontes.

Vygotsky, L.S. (1989). *A formação sicial da mente*. 3ª ed. São Paulo, Martins Fontes.

THE CONTROVERSIAL ASPECT OF THE SOCIOSCIENTIFIC ISSUE AS A DISCURSIVE CONSTRUCTION OF THE TEACHER

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The Socioscientific Issues (SSI) movement is a contemporary part of the Science-Technology-Society-Environment (STSE) approach in Science Education which aims to study controversial issues of scientific and social interest widely disseminated by the media in order to promote students' development. We aim to illustrate and discuss how the controversial character related to an SSI is the result of a discursive construction performed by teacher and students in the classroom. An episode extracted from a didactic sequence applied by a Chemistry teacher in a Brazilian public school is presented and analysed. In the episode, conflicting points of view about the pollution of a stream are explored in order to transform this issue into a controversy. The structure of the interaction was described in terms of triadic Initiation-Response-Feedback patterns and the discursive move performed in the classroom was characterized as a displacement of mental context shared between the teacher and the students.

Keywords: Socio-scientific issues, classroom discourse, context-based learning.

INTRODUCTION AND THEORETICAL BACKGROUND

Promoting citizens' scientific education goes beyond understanding the scientific concepts that explain the phenomena observed in nature, since the main purpose of studying Science in school is not only to deal with its conceptual contents, but also the methods used by researchers, aspects of the nature of this knowledge and its implications in other spheres such as Society, Politics, Economy and Environment.

In this sense, for nearly five decades or so, the STSE (Science-Technology-Society-Environment) approach has been configured as a strategy for promoting the relationship between scientific knowledge and different areas in which it is involved. As dictated by Pedretti and Nazir (2011), there is no single possible approach when thinking about developing STSE proposals in education, however, all of them converge to the fact that it is necessary to raise awareness of the studies regarding the articulation between scientific production and technological and social demands.

The authors (*idem*) suggest a classification of STSE teaching proposals into different variations according to teaching resources and emphasized purposes, and, more specifically, the study of socioscientific issues (SSI) aiming at the development of values in students, the understanding of the nature of Science (NOS) and the awakening of conscience about socio-political-environmental action. Pérez and Lozano (2013) signal that since the beginning of the 21st century, the STSE movement has undergone a reconfiguration towards the study of SSI and has become a way of effecting the STSE relationship in the classroom. Therefore, an Academia's concern is studying and understanding the nature of these issues and ways of integrating them as didactical proposals in the classroom.

Socioscientific issues in Science Education

SSI can be considered as controversial issues about scientific knowledge that present implications for different areas, such as society, economy, politics and environment. The controversial aspect of an SSI often leads to wide media coverage, which presents the issue for the population and influences divisions of opinion because most of them are involved in studies that are still under development (Ratcliffe & Grace, 2003; Pérez and Lozano, 2013). Examples of SSI are climate change and global warming, nuclear threats, genetically modified organisms planting and consumption, marijuana decriminalization, and animal experimentation.

Since these questions are related to the population's experience and lead to a division of opinions and consequent discussion, working with SSI in the classroom can promote benefits for the development of students in the cognitive sense, by learning scientific concepts, and also in the moral sense, by the acquisition of values and value judgments, fostering of critical thinking and promotion of argumentation (Zeidler, Sadler, Simmon & Howes, 2005; Zeidler & Nichols, 2009).

Considering these characteristics, Pérez (2014) indicates that teacher's planning capacity is essential when bringing SSI in the classroom, once dealing with a controversy creates a necessity for the teacher to articulate knowledge of different areas, mediate discussions and expression from different points of view brought by students, and structure teaching sequences in order to create a learning context (Zeidler & Lewis, 2003) faithful to the commitment of cognitive and moral development of students. Thus, it becomes target of research how the teacher creates and sustains this SSI-influenced context in the classroom.

Socioscientific issues as teaching contexts

Before exploring how SSI can generate a teaching context, it is important to keep in mind a clear understanding of what "context" means. For this definition, we rely on the notion proposed by Edwards and Mercer (1987), who argue that in a learning environment there are three kinds of shared contexts by teacher and students and act as elements of meaning making. They are the situational context, relative to the material environment of the actions; the linguistic context, related to the progress and content of the classroom discourse, and the mental context, related to the ideas evoked and shared in the social plan of the classroom. Giordan (2013) points out that the engine of meaning processes in the classroom is the displacement of contexts over time, what Edwards and Mercer (1987) call "continuity", which means that a previously experienced situational or linguistic context later becomes a mental one that is reclaimed in the classroom by the teacher or the students to proceed with the development of their ideas.

Combining this definition with the SSI approach, we argue that it functions as structuring issue of classroom teaching proposals, which acts as a mental context that is constantly recovered by the teacher and, therefore, reconfigures itself over time, anchoring scientific concepts and subsidizing the formation of opinions by the students. In other words, in order to become an effective teaching resource, the teacher needs to pose a question at the beginning of a teaching sequence, which is constantly revisited for its solution or discussion. This means that, to recover a lived context, the teacher uses the discourse, mainly mediated by the speech, to effect the contextual displacement. Thus, the proposition of the triggering question that serves as guide to the classroom activities, that is, the construction of the context, is a discursive phenomenon and, therefore, keeps in itself the characteristics of the SSI used for the creation of the teaching proposal.

In this sense, since there is a controversy involved in an SSI, we aim to study the discursive characteristics, in terms of structure, function and content of the utterances related to the construction of the controversial aspect of an SSI in the classroom by a Chemistry teacher. More specifically, we aim to demonstrate how she and two students involved in a discursive interaction mobilize the displacement of contexts to understand a controversy related to the pollution of an aquatic environment.

RESEARCH SCENARIO AND METHODOLOGY

The data presented in the next section is taken from the development phase of a didactic sequence (DS) entitled “Do you know what is in the water of the Pirajussara stream?”, developed and applied by a Chemistry teacher to high school students in a public high school in the city of Embu das Artes (Brazil). The main goals of this DS were to determine the quality parameters of a water sample (such as color, turbidity, pH and salinity) of the Pirajussara stream, a water source located in São Paulo (Brazil), and to discuss the origins and possible solutions for the pollution suffered by this stream since the 1960s.

Data were collected through audio-visual record of the lessons, using two digital cameras positioned in the background and in front of the recording environments, and four digital recorders to capture the voices of the teacher and students. After recording, the multilevel mapping of the lesson was performed for data selection. This methodology (Silva-Neto, 2016) is based on the segmentation, at different levels, of the DS lessons taking as reference the teaching activities as structuring units of each lesson. Thus, the first level of analysis corresponds to each of the lessons; the second level, to the teaching episodes, which are defined as moments of the lessons in which the teacher presents specific purposes with the class, and the third level, to the discursive sequences, that is, the discourse units that make up each episode.

An episode whose discursive sequences corresponded to the construction of the controversial aspect related to Pirajussara’s water pollution was selected for analysis, as will be explained later. For the analysis, we used the frameworks developed by Mehan (1979) and Mortimer and Scott (2003) for the characterization of classroom discourse. The first author points out that there is a triadic pattern in teacher-student interactions consisting of an Initiation (I), usually posed by the teacher, followed by a student's Response (R), which is subjected to an Evaluation (E) by the teacher. The other ones add that the third turn of interaction does not necessarily work as an evaluation, thus, sometimes it fulfills the role of providing a Feedback (F) to the students’ responses, when the teacher elicits more information from them. Another type of utterance that can be observed in the interaction patterns of classroom discourse is characterized by Silva and Mortimer (2010) as a Synthesis (S) of the interaction. It is usually seen after an evaluation turn, and is used by the teacher either to summarize the ideas that have been discussed or to close the interaction. With these considerations in hand, it is then possible to present the found results.

RESULTS AND DISCUSSION

The selected episode occurred in the last lesson of the DS, in which after gathering the results of the analysis of the quality parameters collected over the other six lessons that made up the sequence, the teacher and the students discussed and solved the initially proposed question, in this case, the water potability of the Pirajussara stream.

After the evaluation of the parameters and the conclusion that the water could not be consumed due to the results obtained, a discussion started about the possibility of cleaning the stream, as can be observed in the transcript below:

Table 1. Transcription of the episode of controversy construction related to the SSI. St = Speech turn; Sp = Speaker (T = Teacher, Sn = Student n); IP = Interaction Pattern (I = Initiation, R = Response, F = Feedback, S = Synthesis of the interaction).

St	Sp	Transcription	IP
1	S1	- Teacher, is there any place where people enter to clean it?	I
2	S2	- No! This is why it is so dirty; nobody goes there to clean it.	R
3	T	- Oh! However, whoever goes there to clean it, whoever does the maintenance, they go equipped, and they wear overalls, gloves, and security glasses. They are ready to do it; they won't enter there, isn't it?	R
4	S2	- But, teacher, if there was anyone to clean it, the river wouldn't be like that, would it?	F
5	T	- But why do we need to clean it?	I
6	S2	- Because it is very dirty! It is mixing sewage with the river spring water.	R
7	T	- But should the sewage be there?	F
8	S1	- No!	R
9	S2	- What?	R
10	T	- The sewage… Is it in the right place, then, if it is mixed with the river spring water?	F
11	S2	- No!	R
12	T	- So if it were in the right place, do you agree with me that we wouldn't need to clean it?	F
13	S2	- Yes.	R
14	T	- If everything were in its own place...	S

In turn 1, student S1 initiates the interaction with a movement of subversion of the interaction pattern, providing an initiation to the teacher about the places where the stream water was cleaned by professionals. In 2, she is answered by student S2, who denies the existence of such places claiming that it was the fact that there were no people to clean the stream that implied the current situation of the polluted environment.

S2 was referring to people in general in her answer, however, we can infer that S1 was asking about the existence of professionals to perform the cleaning of the stream. Thus these people come into direct contact with the water, a fact that was understood by the teacher. S1 was answered in turn 3, when the teacher states that professionals enter the stream properly equipped, hence not having direct contact with the polluted water. Then, in turn 4, student S2 evaluates the teacher's response, putting her disagreement on the fact that if the stream were cleaned by professionals, it would not be polluted.

In order to regain the discourse authority, the teacher directs student S2 an initiation in 5, asking her why the stream water should be cleaned, and receiving the answer that it was dirty because the spring water of the stream was mixing with the sewage discharged by the residences. Again, the teacher asks if the presence of sewage in the water is appropriate and S1 responds negatively, whereas S2 asks the teacher to repeat her initiation. After the teacher does it, S2 responds negatively. In turn 12, the teacher once again puts her authority by asking S2 rhetorically about the need to clean the water if the sewage was not contaminating it, receiving a student's agreement response and concluding the interaction in 14 with a synthesis in the form of the expression "If everything were in its own place ...".

We can infer from the description of the utterances that made up the episode above that the structure of the interaction developed by the teacher and students S1 and S2 occurred in three phases. Between turns 1 and 4 we observed a subversion of the interaction, since the initiation turn was performed by S1, who received answers from both the teacher and student S2, and the teacher's response was submitted to an evaluation by the second student. Between turns 5 and 12 we saw an extended I-R-F-R-F-R-F sequence, in which the teacher regains her classroom authority to guide the students to a single point of view. Finally, in turns 13 and 14, we have the completion of the interaction with a synthesis from the teacher, which pointed to the desired conclusion.

It is in terms of the contents that circulated in the utterances that we identified the creation of a controversy in the classroom. First, we must be clear about what a controversy means. Usually, when we think of an SSI-related controversy we refer to a polemical issue. Nevertheless, Pirajussara's pollution itself does not present a polemical side that causes a sharp division of opinion among people. We argue that the controversy dealt with in this interaction fragment is due to the difference of points of view presented by student S1 and student S2 regarding the solution for the problem of stream pollution, and by the teacher and student S2 regarding the origin of such a problem.

When student S1 brings to the classroom her doubt about the existence of professionals who clean the already polluted stream, she states a possibility of solution for the problem, once she points the need to clean a dirty environment. However, student S2 brings another demand, in this case, that if there were people to clean the stream it would not be in such a situation. To work with such divergence, the teacher chooses not to deal with the solution demand proposed by S1 by simply explaining to her that the professionals who clean the stream enter such an environment appropriately equipped.

However, due to S2's opposition to the teacher's explanation, the teacher takes a different path in which she chooses to deal with the source of the problem. The demand brought by student S2 is that the stream is polluted because the water from its spring is being mixed with the sewage content from the residences. Thus, the teacher conducts the second part of the interaction in order to convince the students that even before thinking about the possibility of cleaning the stream, one must think about the source of its pollution, that is, the lack of access to sanitation system. This information is implicit in the teacher's synthesis utterance, where “If everything were in its place ...”, can actually be interpreted as: if the population living around the stream were assisted with basic sanitation policies, the sewage produced would be destined for the correct location rather than the stream.

CONCLUSIONS

We could identify that the controversial aspect related to the SSI that underpinned the DS was the opposition between demands related to the pollution of the Pirajussara stream: on the one hand, the need to clean an already polluted environment, and on the other one, the need to stop the sewage discharge into the water. The teacher discursively explored this opposition in order to convince the students that even before thinking about the solution for the problem, one must think of its real source. To do so, from a subversion of interaction promoted by S1, the teacher regains her authority and develops a series of I-R-F triads to reach the desired point of view.

Returning to the idea of contextual creation based on an SSI, the construction of the controversy observed in the described episode was made possible by a series of contextual displacements (Edwards & Mercer, 1987) performed by the teacher and the students. S1, by bringing its doubt about the professionals, brings to the classroom an external context to the one that was already being studied, that is, the results of the analyses performed in the previous six lessons. To oppose the idea brought by S1, S2 makes another displacement when she brings to the classroom the memory of the dirty stream image, visualized by the class when they visited the stream mouth to collect a water sample. Finally, to convince the students to reflect on the origin of the pollution, also the teacher makes a contextual displacement by bringing to the classroom the discussion about the need for basic sanitation policies, an aspect that had been worked with the class in the first lesson of the DS, in the synthesis utterance.

This result makes ground for one last consideration. As stated earlier, SSI function as a context in which the teacher develops a narrative in the classroom, which, even linear, does not necessarily need to be fully presented at the beginning of a sequence of lessons. The fact that the controversy was revealed only in the last lesson does not indicate that this aspect was missing in the first class. On the contrary, it highlights the potentiality of using SSI as structuring elements of teaching proposals, given the teacher and students’ ability to recover the context that was initially proposed to develop the scientific knowledge in the classroom.

To summarize, we state as a contribution the existence of problematization movement, which occurs using an SSI as the basis for the construction of a DS, and occurs in a discursive way by the recovery of contexts over time. We also propose as further research the study of the discursive characteristics of the problematization movement throughout the lessons of a DS. In doing so it will be possible to identify not only the structure and function of the utterances related to the issue construction, but also the dynamics of contextual displacements that make an SSI an instrument of meaning making in the classroom.

ACKNOWLEDGEMENT

We acknowledge the Coodernação de Aperfeiçoamento de Pessoal de Ensino Superior (CAPES, Brazil) and the Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq, Brazil) for funding the research, and the Chemistry teacher who participated in the development of the DS.

REFERENCES

Edwards, D., & Mercer, N. (1987) *Common knowledge. The development of understanding in the classroom.* London: Methuen.

Giordan, M. (2013) *Computadores e Linguagens nas Aulas de Ciências.* 2nd ed. Ijuí: Unijuí.

Mehan, H. (1979) *Learning lessons. Social organization in the classroom.* Cambridge: Harvard University Press.

Mortimer, E. F., & Scott, P. H. ***Meaning making in secondary Science classrooms.*** 1st ed. Philadelphia: Open University Press.

Pedretti, E., & Nazir, J. (2011) Currents in STSE Education: Mapping a complex field, 40 years on. *Science Education, 95*(4), 601 – 626. doi: 10.1002/sce.20435.

Pérez, L. F. M., & Lozano, D. L. P. (2013) La emergencia de las cuestiones sociocientíficas en el enfoque CTSA. *Góndola, enseñanza y aprendizaje de las ciencias, 8*(1), 23 – 35. doi: 10.14483/23464712.5021.

Pérez, L. F. M. Cuestiones sociocientíficas en la formación de profesores de ciencias: aportes y desafíos. ***Revista Tecné, Episteme y Didaxis TED***, *36*, 77 – 94. doi: 10.17227/01213814.36ted77.94.

Ratcliffe, M., & Grace, M. (2003) *Science education for citizenship. Teaching socio-scientific issues.* Maidenhead: Open University Press.

Silva, A. C. T., & Mortimer, E. F. (2010) Caracterizando estratégias enunciativas em uma sala de aula de Química: aspectos teóricos e metodológicos em direção à configuração de um gênero do discurso. *Investigações em Ensino de Ciências*, *15*(1), 121 – 153. ISSN: 1518-8795.

Silva-Neto, A. B. (2016) *Multimodalidade e produção de significados sobre representação estrutural química: aportes metodológicos para a análise gestual na sala de aula.* (Master dissertation) Retrieved from http://www.teses.usp.br/teses/disponiveis/81/81132/tde-29032017-171514/pt-br.php.

Zeidler, D. L., & Lewis, J. (2003) Unifying themes in moral reasoning on socioscientific issues and discourse. In: Zeidler, D. L. (ed). *The role of moral reasoning on socioscientific issues and discourse in Science Education.* Dordrecht: Kluwer Academic Publishers, 289 – 306.

Zeidler, D. L., Sadler, T. D., Simmons, M. L., & Howes, E. V. (2005) Beyond STS: A research-based framework for socioscientific issues education, *Science Education, 89*(3), 357 – 377. doi: 10.1002/sce.20048.

Zeidler, D. L., & Nichols, B. H. (2009) Socioscientific issues: Theory and practice. *Journal of Elementary Science Education, 21*(2), 49 – 58. doi: 10.1007/BF03173684.

ARGUMENTATION IN THE CHEMISTRY TEACHING: ANALYSIS OF DISCURSIVE INTERACTIONS AND VERBAL ACTIONS

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The central role of argumentation in science is producing the debate among people because the argument is directly connected with the learning process to provide the appropriation of scientific discourse, and in order to be a window onto the epistemic work of science. Therefore, the problem question in this study is to *identify which are the verbal actions used by students that favor the formation of scientific arguments in an activity with controversial issues? Thus, argumentation in dialogical model was used to identify verbal actions of six undergraduate students of the Chemistry Course. Data was collected by recording the debate between the two groups of students (a lawyer and two witnesses) and it was analyzed with a model which establishes relationships between the verbal actions performed in the pragmatic, argumentative and epistemic plans with the enunciative strategies. The results show that the initiations of metaprocess and process type favor the argumentation because they demand a higher level of students' reflection and engagement that trigger epistemic operations of low and higher cognition such as definition, classification, explanation and generalization.*

Keywords: Argumentation, verbal actions, enunciative strategies.

INTRODUCTION

The argumentation studies came to be established when a distinction was made between two aspects: (1) the study of logic, which was taken to be the disembedded rules for producing correct inferences from given premises and (2) the study of how people in specific situations actually reason from premises to conclusions (Driver, Newton & Osborne, 2000). Thus, the central role of argumentation in science is producing the debate among people, because the argument is directly connected with the learning process to provide the appropriation of scientific discourse, and in order to be a window onto the epistemic work of science (Erduran, 2006; Kelly & Takao, 2002; Zohar & Nemet, 2002).

Therefore it is important to develop argumentative activities in science classroom because they can be highly beneficial for students to advance scientific knowledge, learn how to identify and evaluate scientific arguments, as well as to learn how to craft them. Hence, in this study, the following problem question is guided: what are the verbal actions used by students favor the formation of scientific arguments in an activity with controversial issues?

Theoretical background: the dialogical model of argumentation

The argumentation in dialogical model is defined as a linguistic activity that propitiates debatable or controversial ideas, being the enunciation placed in the background of the dialogue. For Plantin (2005, p. 63-4), dialogical argumentation "is triggered when a point of view is questioned in answer to the same question" or some fact or conjuncture to be analyzed. Thus, it is this statement that puts itself in doubt in the argumentation in dialogical model, establishing a triple situation divided into Proponent, Opponent and Third Party (Plantin, 2005).

It is understood as Proponent the one who manifests an opinion contrary to an initial statement, and this opinion is dominant. The Opponent is the one who opposes the proposer, and finally, the Third Party is the speaker who does not identify with either of the two discourses, opposing the proponent and the opponent, transforming this opposition into a question (Plantin, 2005).

Summing up, the discourse construction in this model can be considered as follows: the question generates the argument and the argument generates the conclusion, that is, the answer to the question. Thus, "argumentation can be seen as a way of constructing answers to questions that organizes a discursive conflict" (Plantin, 2005, p. 70). Besides that:

> In such a situation, all semiotic elements articulated around this question have argumentative value. In particular, the justifications can be accompanied by a series of concrete actions, co-oriented by the speeches and aiming to make the positions defended sensitive (Plantin, 2005, p. 65).

Based on these ideas it is possible to identify verbal actions that favor and construct the argumentation through three distinct planes: the pragmatic, the argumentative and the epistemic.

The pragmatic plan is based on discursive actions that create the necessary conditions for the argumentation to effectively establish itself. Verbal actions, in this plan, derive from a plausible topic of discussion, making the argument appear in the eyes of students as an appropriate method for managing these differences (Leitão, 2011). The same author also highlights actions that can be seen as an invitation to argument such as challenging others to formulate their points of view, asking for justification for points of view, placing the student in the position of opponent, presenting arguments to negotiate, resolve different points of view and encourage the student to respond to con arguments. Dialoguing with the ideas of Plantin (2005), it is the moment of the Proponent and Opponent to opine against or in favor of the presented statement (the debatable subject).

In the argumentative plan the verbal action aims to generate and sustain the argumentation by defining operations as definition/justification of points of view and negotiation of divergences. Here, it focuses on how participants practice or encourage others to implement defining operations (Chiaro & Leitão, 2005). The actions included in this category are described by Leitão (2011) as formulation and evaluation of arguments, doubts, objections, con arguments and answers to the objections considered. It is the moment that the arguments of the Proponent and Opponent become conflicting and aim to analyze the initial statement. Here the Third Party has the role of fostering arguability from new questions or statements.

The epistemic plan is related to verbal actions that directly mobilize knowledge, that is, they bring to the discussion information such as relevant concepts and definitions to the domain of knowledge (Leitão, 2011; Chiaro & Leitão, 2005). This epistemic dimension is related to the possibility created in the argumentation of construction and transformation of concepts and development of common reasoning of the domain of knowledge to which such concepts refer. Some examples of actions for this category are: the presentation of contents as concepts and definitions on the subject, demonstration of some procedure, ways of reasoning and observations based on documentary sources or by experimentation and verification of students' points of view (Leitão, 2011). Broadly speaking, they are the answers to the initial questions (or statements).

That is the reason why the argumentation is discussed as a "social and discursive activity that is carried out by the justification of opposing points of view and considerations" (Chiaro & Leitão, 2005, p. 350) in order to promote changes in conceptions/representations of the participants on the topic discussed. Interest in the relationship between argumentation and knowledge-building processes has generated studies that seek to understand the characteristic role that argumentation plays in educational processes and how it can be productively implemented in teaching-learning situations (Leitão, 2011).

RESEARCH PATH AND ANALYTICAL FRAMEWORK

This work is a qualitative research where six undergraduate Chemistry Course students participated. An activity based in investigative case about a discursive conflict was elaborated through a simulated jury on nucleophilic substitution and elimination reactions. The case technique was intimate debate that is known "as structured debate or constructive debate. It is a powerful method for dealing with case topics that involve controversy" (Herreid & DeRei, 2007, p.10).

The activity was developed in 9 (nine) consecutive classes of 50 (fifty) minutes, totaling 9 classroom meetings. In the first class, the case was delivered to the students and read aloud by the teacher, who then opened for clarification on the case and the activity.

The case served as a problematization for the classroom discussion about nucleophilic substitution and elimination reactions, discussing the properties of each one, the advantages and limitations, as well as the laboratory conditions that favor each reaction. This discussion was conducted until the eighth meeting and in the last meeting the simulated jury was performed.

Data collection was done by recording the debate between the two groups of students (a lawyer and two witnesses), which was later transcribed in its entirety. A model of analysis was created (Table 1) which establishes relationships between the verbal actions performed in the pragmatic, argumentative and epistemic plans with the enunciative strategies (Silva & Mortimer, 2010) to identify the argumentative structures that benefited the argumentativeness about the theme and, therefore, which favored the students' arguments.

Table 1. Model of the data analysis.

Model of analysis	
Plans	**Related Enunciative Strategies**
Pragmatic	*Types of Initiations* - Choice: requesting a yes or no type answer. - Product: requiring a name or a fact. - Process: demanding an opinion or interpretation of who is answering. - Metaprocess: demanding a construction of ideas and major reflection.

Argumentative	*Intentions* - Creating a problem: mobilize the student's intellectual and emotional form in the initial development of the scientific story. - Exploring the student's visions: identify and explore the students visions about specific ideas and phenomenon related to the theme. - Keeping the narrative: provide comments about the scientific story to help develop the theme and its relationship. - Introducing and developing the scientific story: make available the scientific ideas in social plan in the classroom.
Epistemic	*Epistemic Operations* There are a set of categories related to the cognitive activities of knowledge construction that are classified as: description, explanation, generalization, classification, comparison etc.

The interactions and verbal actions allow the analysis of the interventions through activities related to the investigative cases, especially when the method is the intimate debate, because it allows the discussion among the students establishing relationships between the students' points of view in scientific terms and the reasons that justify them.

RESULTS AND DISCUSSION

Table 2 presents the main strategies of verbal actions used by the lawyer and witnesses during one of the episode of the debate:

Table 2. Main verbal actions and enunciative strategies presented in the debate.

Episode 2 – Lawyer Questions of the group 1 to the witnesses of the group 2	
Pragmatic plan/initiations	Identified from the type of questions made by the lawyer during the debate. Some examples are: - Challenging the students to formulate viewpoints (*Initiation of metaprocess*) - Requesting justifications (*Initiation of process*) - Requiring the opponents to reexamine their points of view (*Initiation of metaprocess*) - Examining the point of view of who is asking (*Initiation of metaprocess*) - Demanding students' answer to con arguments (*Initiation of process*)
Argumentative plan/intentions	Identified from the enunciations that sustain the argumentation among the students as: - Searching the students' opinion (*Intention of exploring the student's visions*) - Doing juxtapositions of ideas (*Intention keeping the narrative*) - Presenting points of view (*Intention of keeping the narrative*) - Formulating an alternative points of view (*Intention of introducing and developing the scientific story*) - Realizing objections (*Intention of creating a problem*)
Epistemic plan/epistemic operation	Identified from the type of speech content used by the students during the debate. The main epistemic operation is: explanation, classification, description and comparison.

Below, one part of this debate is exhibited among the students about the inversion of configuration in unimolecular nucleophilic substitution reactions:

> *Lawyer:* So the substitution reactions I think according to the literature says that all and (pause) undergo inversion, right teacher?
> *Teacher:* Yes.

Lawyer: I even wondered if it was all Sn2 reactions undergo inversion.
Teacher: Inversion in configuration.
Lawyer: That, inversion in configuration.
Teacher: Inversion can happen, it happens. But that does not mean it will generate your enantiomer.
Lawyer: That's it! I wanted to "like". Because in Sn2 reactions because in the book I think it speaks.
Witnesses 1: Always speak.
Lawyer: That's all, I even thought that inversion of configuration occurs.

In this interaction, the student-lawyer questions the teacher for a process initiation in a content discourse regarding the inversion in configuration that occurs in bimolecular nucleophilic substitution reactions. This action presents itself as a pragmatic plan, because the question invites the teacher to examine the conceptual domain on the subject of the questioner, and thus creates the possibility of disagreement or not about the subject (Chiaro & Leitão, 2005).

Through the interaction, the teacher introduces and develops the scientific story, providing the scientific ideas about the inversion of configuration in this type of reaction, contributing to the student's formulation of the question. Mendes and Santos (2013) present in their results that a positive evaluation and request for clarification from the teacher are strategies for the discourse direction, which is similar in this first round in an argumentative plan.

Then the "lawyer" makes a question from the metaprocess initiation which requires knowledge, reflection and justification of the witnesses about the inversion of the configuration content, keeping the verbal action on a pragmatic plan:

Lawyer: Why does the inversion of configuration occur?
Witnesses 2: Because of the conformation of the intermediate state. And how it will attack here to form the desired product it...
Witnesses 1: And to form the desired product, then it needs the inversion.
Witnesses 2: This group will cause a... a probability in this group in the case this hydrogen and in this brome and then it will reverse to another side, it will pass everything here, and this will be the conformation.
Witnesses 1: It must occur in order to obtain the desired product.

Both witnesses answer presenting justifications and reasons based in the product formation with the goal of keeping the narrative. In the epistemic plan, the students try to explain the inversion of the configuration by supporting the desired product, but this strategy only allows describing one of the causes of inversion. Thus, the epistemic operation observed to approach the description still requires a conceptual evolution to the total domain of the addressed scientific content (Vargas, 2010).

SOME CONSIDERATIONS

The role of the lawyer was an important factor of argumentation because as a proponent, it always began with a question to the witnesses. In addition, the initiations of metaprocess and process type favor the argumentation because they demand a higher level of students' reflection and engagement.

Regarding the argumentative plan, different types of verbal actions stood out. In this episode there were statements involving juxtapositions of ideas, presentation of points of view, search for the opinion of colleagues, formulation of an alternative point of view, objections and others. Throughout this episode, the intention is to maintain the narrative with the purpose of helping colleagues to follow the conceptual development.

In relation to the epistemic plan, the description and classification were the categories more used, but the explanation and generalization categories were also used, and that triggers epistemic operations of low and higher cognition. However, the planned activity required from the student's specific speeches about the content that required the previous study and from this the construction of the scientific knowledge through its arguments.

Therefore, the differential of this work was to apply the analysis model developed for discursive analysis to identify what kind of enunciative interactions/strategies and verbal actions in argumentative situations favored learning. The identification and analysis of these statements contribute to present how the scientific chemical knowledge is appropriated by the students during argumentation activities, allowing the evaluation of the learning process in the course of the construction of their arguments.

ACKNOWLEDGEMENT

CAPES for financial aid and all participants.

REFERENCE

Chiaro, S., & Leitão, S. (2005). O papel do professor na construção discursiva da argumentação em sala de aula. *Psicologia: reflexão e crítica*, 18, 350–357.

Driver, R., Newton, P., & Osborne, J. (2000). Establishing the norms of scientific argumentation in classrooms. *Science Education*, 84, 287–312.

Erduran, S. (2006). Promoting ideas, evidence and argument in initial teacher training. *School Science Review*, 87, 45–50.

Herreid, C. F., & DeRei, K. (2007). Intimate debate technique: medicinal use of Marijuana. *National Science Teachers Association*, 4, 10–13.

Kelly, G. J., & Takao, A. (2002). Epistemic levels in argument: An analysis of university oceanography students' use of evidence in writing. *Science Education*, 86, 314–342.

Mendes, M., & Santos, W. (2012). Argumentação em discussões sociocientíficas em aulas de química: ainda se tem muito para argumentar. In *Encontro Nacional de Ensino de Química: 16.* (pp. 1–12). Salvador: Universidade Federal da Bahia.

Leitão, S. (2011). O lugar da argumentação na construção do conhecimento em sala de aula. In: Leitão, S., & Damianovic, M. C. (Eds.). *Argumentação na escola*: o conhecimento em construção. Campinas: Pontes, 2011, p.13-46.

Plantin, C. (2005). *L'argumentation. Histoire, théories et perspectives*. Paris: Presses Universitaires de France.

Silva, A. C. T., & Mortimer, E. F. (2010). Caracterizando estratégias enunciativas em uma sala de aula de química: Aspectos teóricos e metodológicos em direção à configuração de um gênero do discurso. *Investigações em Ensino de Ciência*, 1, 121–153.

Vargas, G. C. (2010). *Argumentação em sala de aula: um estudo sobre a aprendizagem na interação entre pares*. (Doctoral Dissertation, Federal University of Pernambuco, Brazil. Retrieved from https://repositorio.ufpe.br/bitstream/123456789/8584/1/arquivo871_1.pdf.

Zohar, A., & Nemet, F. (2002). Fostering students' knowledge and argumentation skills through dilemmas in human genetics. *Journal of Research in Science Teaching*, 39, 35–62.

PRE-SERVICE TEACHER'S DISCURSIVE MOVES GUIDING WORK WITH EVIDENCE

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The use of scientific evidence in argumentation is not a trivial pursuit and teachers should have an important role in promoting this practice. Framed in researches about biology classroom argumentation, the purpose of this study is to identify and characterize the discursive moves of a pre-service biology teacher that are related to students' work with evidence. For this, we analysed transcriptions of teacher-students' interactions during inquiry classes into an ecological problem. The data analysis led to identification of the following moves: requires evidence identification, requires clarification, requires claim defence, requires evidence reconsideration, and requires explanation. The results suggest a relationship between the discursive moves identified and the students' construction of more specific evidences, reconsideration of excluded evidence and use of evidence in the defence of an explanation. No metacognitive moves were identified.

Keywords: evidence, argumentation, science education.

INTRODUCTION

Evidence-based argumentation is a type of scientific discourse and a powerful tool in classroom contexts, especially when considering enhancing scientific literacy an important component of science education (Driver, Newton, & Osborne, 2000). Jiménez-Aleixandre (2010) propose that evidence-based argumentation may support students in the development of critical thinking, scientific practices and also ways of learn how to learn.

However, the use of evidence in argumentation is not a trivial pursuit. Several studies have pointed out that students often face difficulties that includes, for example: (a) interpreting evidence, identifying which are relevant to the problem (McNeill & Krajcik, 2007); (b) use sufficient evidence and (c) explain why the selected data can be used as evidence to support their claims (Sandoval & Millwood, 2005). Bravo, Puig, and Jiménez-Aleixandre (2009) described that the use of evidence involves competences on two dimensions: practical, including the use of evidence in different contexts and the operations associated within this performance and metacognitive, that is, the understanding about the nature of evidence, its function and criteria for evaluating.

In addition, teachers have faced different challenges in supporting this scientific practice. One of them refers to the need of moving away from an instruction centered on the transmission of knowledge to an instruction based on student construction of knowledge, understanding the importance of providing opportunities and support for students to raise and test hypotheses, position for and against and also use evidence in constructing explanations (Driver et al., 2000).

Thus, this study aims to identify and characterise a pre-service teacher's discursive moves that are related to high school students' work with evidence. In other words, we seek to comprehend the types of teacher' moves that may help students work with evidence during an inquiry activity.

METHODS

Participants

The participants are a pre-service teacher and five high school students (all girls, from 14 to 15 years old). These students share a low socioeconomic background and attend the same public-school classroom in a small city in the State of São Paulo, Brazil. At the time of the data collection, the pre-service teacher was attending the last period of Biology Teaching course at the University of São Paulo.

Data collection and analysis procedures

Data were collected during inquiry classes designed by the researches under the 'predict-observe-explain' framework (see Erduran, 2006), which provides a context for students' engagement in argumentation. In these classes, students were supposed to think and solve a problem around why the abundance of two plant species was different in two forests with similar abiotic conditions. To do this, they tested predation and competition hypotheses while examining provided data. In order to explain the phenomenon, students should be able to integrate predation and competition concepts into a single causal explanation, understanding that high predation rates of strong competitors can allow other species to establish. Table 1 summarises the inquiry activity proposed to the students, highlighting the evidence available in the instructional material.

Table 1. Summary of the inquiry activity.

Step	Tasks	Evidence Available
Predict	1. Identifying the differences between two forests and hypothesising several causes of these differences.	Map showing abundance and distribution of two plant species in each forest. Table showing these abundances.
	2. Establishing the seed predation as causal account.	Theoretical data - Text describing the life cycle of insect seed predators and the damage they cause to seeds.
Observe-Explain	3. Evaluating whether the predation hypothesis is able to explain the problem.	Field data - Table showing predation rates of the two plant species in each forest.

Predict	4. Establishing the plant competition as causal account.	Theoretical data - Text describing ecological conditions usually associated with plant competition and its negative effects on plant development.
Observe-Explain	5. Evaluating whether the competition hypothesis is able to explain the problem.	Laboratory data - Table showing seedings growth of the two species cultivated under different experimental conditions.

Framed in qualitative methods, this paper reports a case study (Yin, 2003). The classes, comprising 3 hours of video-audio recording, were transcribed and the participants' turns of speeches were labelled as PT for pre-service teacher and S1 up to S5 for students, in order to preserve anonymity. All turns with evidence mentions were selected. Although only the pre-service teacher's turns of speeches have been coded in this study, the analysis took into account the discursive interactions to understand each evidence work developed before and after teacher's interventions. The codification was done by both authors independently and all incongruences were then discussed and resolved. Categories' validity was established by comparing, discussing and refining interpretations in groups of experts.

FINDINGS

The transcriptions analysis allowed the identification of five typical discursive moves: (i) requiring evidence identification, (ii) requiring clarification, (iii) requiring claim defence, (iv) requiring evidence reconsideration and (v) requiring explanation.

When asking for evidence identification, the pre-service teacher gave direction to the students' data analysis, allowing them to select relevant data in solving the problem (Table 1).

Table 1. Excerpt illustrating the discursive move of requiring data identification.

Turn	Speaker	Talk and action	Discursive Move
853	PT	What is happening in forest B?	Requiring evidence identification
854	S2	It is being predated	

When asking for clarification of what had been said, the pre-service teacher commonly allowed students to discriminate better what they wanted to refer to, making data reference more specific. For example, in the excerpt bellow, a student stated that the seeds were being predated. After pre-service teacher's intervention, the student could specify the species she was talking about (species 1), as well as made explicit the comparison between data (the predation rate in forest A and B) (Table 2).

Table 2. Excerpt illustrating the discursive move of requiring clarification.

Turn	Speaker	Talk and action	Discursive Move
854	S2	It is being predated	
855	PT	Which one?	Requiring clarification
856	S2	The seeds of species 1 are being more predated in forest B than in A	

The pre-service teacher promoted the use of evidence by requiring claims defence. In the excerpt, the students present evidence to support their claims after pre-service teacher's intervention, who questions how the students can affirm that the predation is the answer to the problem at that moment (Table 3).

Table 3. Excerpt illustrating the discursive move of requiring data use.

Turn	Speaker	Talk and action	Discursive Move
551	S1	Predation can explain species 1	
552	PT	But what do you have to claim that the predation explains the abundance of the species 1?	Requiring claim defence
553	S2	It is because the species 1 are being more predated in forest B than in A	
554	S1	And that is why they are in a low abundance in forest B	

The pre-service teacher helped students to review their claims by requiring evidence reconsideration. In the excerpt bellow, a student presented a possible explanation for the phenomenon by discounting relevant evidence that could contradict her proposal. This student considers an insignificant difference between predation rates of different species in the same forest and disregards the comparison of predation rates between forests. In the next turn, the teacher highlighted the evidence discounted.

This discursive move was important to promote a step forward conceptual understanding. After this intervention, in turn 675, for the first time, a student suggested an explanation integrating predation and competition concepts (Table 4).

Table 4. Excerpt illustrating the discursive move of requiring evidence reconsideration.

Turn	Speaker	Talk and action	Discursive Move
673	S1	The species 1 is less abundant in forest B because it is more predated in this forest than in	

		the forest A. In forest B, the species 2 is less predated than the species 1, so the species 2 should be in a higher abundance than species 1, but both species have the same abundance because they compete	
674	PT	But if species 2 is more predated in forest B than in A, why does it have a high abundance in forest B?	Requiring evidence reconsideration
675	S2	In forest B, if the species 1 is being more predated than in forest A, it is not so strong anymore, is it?	

Additionally, the pre-service teacher conducted students to use evidence from theoretical bases, and also lead to the construction of an evidence-based explanation by requiring explanation. In the excerpt bellow, when questioning the relationship established between data (*i.e*, high predation rates leads to low abundance of plants) the pre-service teacher allows the student to make explicit her reasoning by appealing to the theoretical data available in the instructional material (*i.e.*, the beetle life cycle) (Table 5).

Table 5. Excerpt illustrating the discursive move of requiring explanation that allowed the use of theoretical data.

Turn	Speaker	Talk and action	Discursive Move
770	S3	In forest B, if there was more predation it would have less abundance of plants	
771	PT	Why? What happens when a plant is predated?	Requiring explanation
772	S3	Because the beetle larva eats the embryo and the seed does not germinate	

In the next excerpt, questioning the students, the pre-service teacher guides the construction of a final explanation supported by evidence. In turn 855, the pre-service teacher asks the students what causes the plants abundance observed. Then, one student identifies the predation of species 1 as the cause of the phenomenon. In the next turn, the teacher asks the students to explain what the predation causes in species interactions and, in turn 859, enable the students to explain the relationship between predation and competition ecological interactions, which makes explicit the cause and effect relationship between data (Table 6).

Table 6. Excerpt illustrating teacher's leading the construction of an explanation to phenomenon by requiring explanation.

Turn	Speaker	Talk and action	Discursive Move
855	PT	We know there are factors acting differently in each forest. What is happening in forest B that results in the pattern observed?	Requiring explanation
856	S2	It is the fact that the species 1 is more predated in forest B than in A	
857	PT	That is right. So, what happens to the interaction between the species 1 and 2?	Requiring explanation
858	S2	Because species 1 is being more predated, species 2 can have an advantage to increase its number	
859	PT	Even the species 1 being the strongest one?	Requiring explanation
860	S1	Yes. The strongest one is being more predated in forest B, so the species 2, which is the weakest, has its number increased	

CONCLUSION AND IMPLICATIONS

Each discursive move identified is showed to be related with students' comprehension, selection, and use of specific evidence to defend and review claims. The pre-service teacher's approach, such as guiding evidence identification or providing hints about what to include in reasoning are similar to the ones discussed by Gotwals, Songer, & Bullard (2012) in a scaffolded writing task.

All moves of the pre-service teacher could be classified as promoting a 'practice of use' dimension of evidence. We did not identify any discursive move related to the promotion of a 'metacognitive' dimension, such as encouraging students to think about the nature of evidence, also considered important to students' critical thinking development (Bravo et al., 2009). These results may be a reflection of the teachers' training itself, since discussions of a metacognitive nature are rarely proposed.

We emphasise the importance of studies that investigate how science teachers can support evidence-based argumentation. Studies that focus on pre-service teachers can provide insights into the relationship between current teacher education and classroom performance for the promotion of this facet of scientific discourse and give us directions to improve it.

ACKNOWLEDGEMENT

This research was supported by the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior - Brasil (CAPES) - Finance Code 001.

REFERENCES

Bravo, B., Puig, B., & Jiménez-Aleixandre, M. P. (2009). Competencias en el uso de pruebas en argumentación. *Educación Química*, *20*(2), 137–142.

Driver, R., Newton, P., & Osborne, J. (2000). Establishing the norms of scientific argumentation. *Science Education*, *84*, 287–312.

Erduran, S. (2006). Promoting ideas, evidence and argument in initial science teacher training. *School Science Review*, *87*, 45–50.

Gotwals, A. W., Songer, N. B., & Bullard, L. (2012). Assessing students' progressing abilities to construct scientific explanations. In A C. Alonzo & A. W. Gotwals (Eds.), *Learning progressions in science: Current challenges and future directions* (pp.183-210). Rotterdam: Sense Publishers.

Jiménez-Aleixandre, M. P. *10 ideas claves: competencias en argumentación y uso de pruebas*. Barcelona: Graó.

McNeill, K. L., & Krajcik, J. (2007). Middle school students' use of appropriate and inappropriate evidence in writing scientific explanations. In: M. Lovett and P. Shah (Eds.). *Thinking with Data* (pp. 233-265). Mahwah, NJ: Lawrence Erlbaum Associates.

Sandoval, W. A., & Millwood K. (2005). The quality of student's use of evidence in written scientific explanation. *Cognition & Instruction*, *23*(1), 23–55.

Yin, R. K. (2003). *Case Study Research: Design and Methods*. Thousand Oaks, CA: Sage Publications.

PART 8: STRAND 8

Scientific Literacy and Socio-scientific Issues

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CONTENTS

STRAND 8: INTRODUCTION

SCIENTIFIC LITERACY AND SOCIO-SCIENTIFIC ISSUES

The "post-truth" era and the growing realization of the global sustainability crises are both refocusing research and practice in science education worldwide. Abilities for scientific argumentation and contributing to value-based change have been emphasized more and more as important aims of school science. These developments underline and give new considerations to the ESERA Strand 8: Scientific Literacy and Socio-scientific Issues.

Socio-scientific issues (SSI's) have already gained ground in science curricula worldwide and proven successful in rendering science education more relevant for tackling the emerging sustainability issues. According to the research in the field, SSI's can make science learning relevant to students, promote critical thinking and value-laden dialogue, and elaborate the nature of science and the complex connections between science, technology, society and environment. New interpretations of scientific literacy (SL) have also emerged: 'Vision III' stresses that science education should prepare students not only to understand the role of science and informed decision-making in the society but also to question the societal choices and values on the basis of ethical consideration and take action to bring about desirable change. Both domains of the strand, SSI and SL, seem to provide crucial and desirable aspects for creating a responsible and reflective society. At the same time, both domains concern a wide spectrum of human life – from everyday situations to difficulties in making important decisions (that for some may resemble the Trolley problem). SSI's and SL call for an interdisciplinary approach from researchers due to the fact that they deal with moral and ethical questions and values.

The eleven papers from Strand 8 in this proceedings capture the diversity of topics and research approaches within the field of SSI's and SL. Both new and already established orientations to SSI's and SL are manifested in the following papers.

The first two papers focus on informal and nonformal science learning venues, which provide crucially important settings for fostering scientific literacy and sustainability education. Annika Roskam, Kai Bliesmer and Michael Komorek analyse the educational offerings for climate change education provided by out-of-school learning venues. Research on citizen science projects, providing adults with opportunities to work with scientists and vice versa, have remained under-theorised and therefore Till Bruckermann and colleagues propose a heuristic model for designing and evaluating citizen science projects.

The strand 8 contribution includes three papers focusing on SSI-related matters in pre-service primary school teacher education. Athanasia Kokolaki and Dimitris Stavrou employed SSI and Nature of Science approaches in primary school teacher training to negotiate aspects of the EU concept of Responsible Research and Innovation. The paper by Lida Desikou, Athina Koutsianou and Anastassios Emvalotis focuses on how teacher students' epistemic cognition influences how they deal with a SSI. Thirdly, Southern European pre-service teachers' opinions about circus with animals were investigated by António Almeida, Beatriz García Fernández and Penelope Papadopoulou.

School-industry collaboration and the development working-life skills are, also, increasingly important issues for SSI-based education. Prospective teachers' perceptions of the various benefits of collaboration between schools and industry were mapped in Špela Hrast's and Vesna Ferk Savec's questionnaire study. The paper by Luisa López-Banet, Cristina Ruiz González and Enrique Ayuso Fernández surveyed the biotechnology knowledge of Spanish students at the end of their secondary education. Tomotaka Kuroda addressed educational needs posed by working life by conducting a comparative study in Japan and the Republic of Malawi on higher education students' views of the abilities associated with STEM communities.

Finally, three papers investigated students' SSI-related views. To lay the groundwork for SSI-based instruction, Sayuri Tokura and colleagues investigated Japanese primary school students' abilities to recognise and consider other people's diverse cognitive and emotional viewpoints. In the research project reported by Laurence Schmitz and Christiane S. Reiners, an educational tool called "decision diary" was evaluated in supporting students' abilities to identify situations for everyday decision-making. Finally, Bruna Herculano da Silva Bezerra and Edenia Maria Ribeiro do Amaral present a study on how students apply their common sense and scientific knowledge when discussing SSI's in various contexts.

Antti Laherto & Eliza Rybska

CLIMATE CHANGE AND THE PHYSICAL DYNAMICS OF COAST, WADDEN SEA AND OCEAN AS TOPICS FOR EXTRACURRICULAR LEARNING

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To illustrate the effects of climate change on coastal areas for learners of every age, a large number of out-of-school learning venues in Germany have emerged in recent years. However, empirical studies have shown that their educational offerings focus on biological content. Because physics is mostly absent, the operators of the out-of-school learning venues fail to demonstrate the intertwining of the dynamics of inanimate and animate nature. Thus, they are unable to address the effects of climate change consistently. Here the present research and development project comes in, which uses the Model of Educational Reconstruction (Duit, Gropengießer, Kattmann, Komorek & Parchmann, 2012) as a theoretical framework. In collaboration with cooperation partners whose out-of-school learning venues attract millions of people each year, new exhibits, guided tours, and learning materials on physical dynamics in the context of coastal areas are being developed (development share). The resulting learning formats are integrated into their existing educational offerings after an empirical examination of their effectiveness (research share). Research and development efforts are thus closely interlinked in this project, which is funded by the German Federal Environmental Foundation DBU.

Keywords: Non-formal Learning, Conceptual Understanding, Qualitative Methods

INTRODUCTION

Coastal areas are characterised by extremely high dynamics and are particularly sensitive to the effects of climate change. However, many learners are unaware of this and usually think in terms of linear cause-and-effect relationships and are generally of the opinion that a cause generates a locally and temporally immediate effect. But the coast and the climate are complex systems whose nonlinear behaviour is often difficult to intuitively understand (Jacobeit, 2007). To illustrate the peculiarities of the complex coastal system and its interaction with climatic changes, a high double-digit number of educational institutions have emerged on the coast of Germany, which use exhibitions, student laboratories, and guided tours as learning formats. They benefit from the large tourist crowds in the coastal regions of Germany, attracting millions of visitors each year.

EMPIRICAL EXAMINATION OF EDUCATIONAL OFFERINGS

Due to many people visiting these out-of-school learning venues, an empirical study was conducted with the operators there. The Model of Educational Reconstruction (Duit et al., 2012) serves as the theoretical framework of the empirical investigation. Two areas are of interest: On the one hand, it is examined how the operators create their educational offerings and who is involved in their development. On the other hand, it is investigated to what extent physical contents are addressed in the context of inanimate coastal dynamics. The following two research questions had to be answered:

(i) How do the out-of-school learning venues create educational offerings, and who is involved in the development?

(ii) To what extent are physical aspects addressed in their educational offerings?

Methods

To answer the research questions, structured guideline interviews with those responsible for the respective educational offerings were conducted. Overall, operators from 11 different learning venues were surveyed. All interviews were evaluated using qualitative content analysis (Mayring, 2014). The interview guide was comprised of questions that already based on a deductively generated system of main categories. The utterances of the interviewees were condensed, assigned to the system of main categories and then subcategories were created inductively. The generated system of main and sub-categories was finally interpreted to answer the research questions.

Results

(i) In only a few cases, science education researchers are involved in the development of educational offerings. The operators of the out-of-school learning venues usually design the educational offerings and ultimately implement it themselves. Most of the operators are without any pedagogical background. Often, they are scientists in the fields of biology or environmental sciences. In the development of exhibitions, the operators only cooperate with advertising agencies to effectively stage their planned exhibits.

(ii) The operators strongly emphasise the importance of physical aspects in understanding climate change and its impact on coastal regions. However, since the operators doubt that physical content could produce a similar level of fascination and interest, the physical view in the offerings is not as strongly emphasised as the biological one. Only as much physics as necessary and as little as possible is integrated into the offerings. In a non-representative analysis (Piplak & Ostendorf, 2018), ten national park houses were examined to what extent physical exhibits can be found there and on which topics. It was also investigated to what extent these exhibits permit interactions by the visitors and whether the information provided is needed for a further understanding of the exhibits. Fig. 1 summarizes the central results. In addition to the lower potential for fascination, many of the interviewees regard the physical content as very complicated since they believe it is oriented primarily to mathematics. Also, in some institutions, there is the idea that addressing physical content means a high expenditure on equipment and a heavy financial burden. For details, see Fig. 2, Fig. 3.

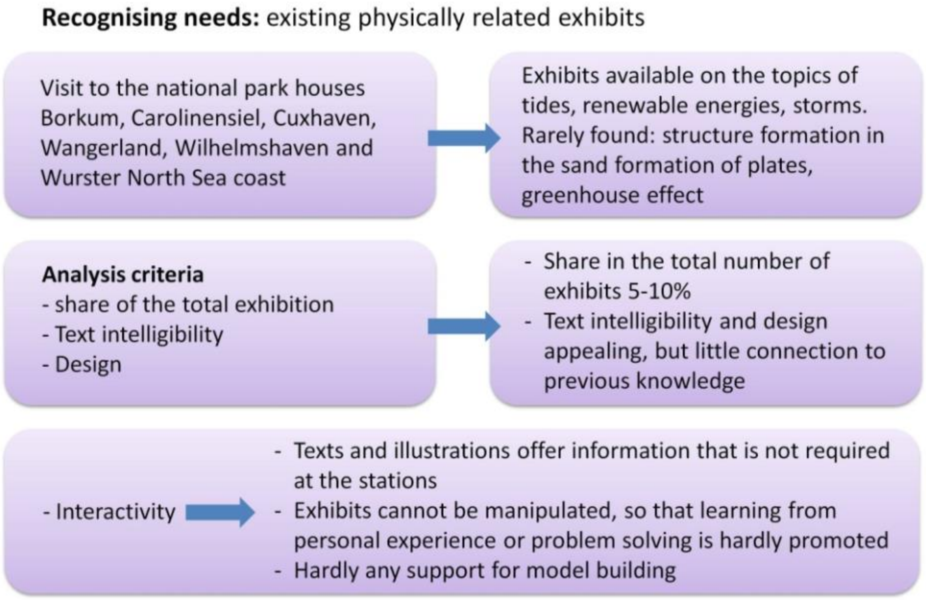

Figure 1. Analysis of national park houses for proportions and type of their physical exhibits

Discussion

The results of the empirical study show that the out-of-school learning venues on the coast represent a very suitable research and development field for science education researchers. Since the support of science education researchers rarely occurs, there is an opportunity to bring together skills from many different areas and to exploit synergies. The operators of the institutions, in their role as scientists, work together with advertising agencies and science education researchers to develop new exhibits and other learning opportunities, thereby eliminating the one-sided focus on biological content in existing educational offerings. Especially science education researchers with a specialisation on the field of physics are in demand for further development of the educational offerings because the operators of the institutions are usually neither physicists nor science education researchers. Besides, the study shows that some "misconceptions" prevail among operators as they feel that the integration of physical content is expensive, complicated, and overwhelms the visitors. Discussions with the operators of the facilities showed that they are very interested in cooperation with science education researchers. Therefore, some of them have become cooperation partners, which is particularly pleasing, as their institutions record a total number of more than one million visitors every year.

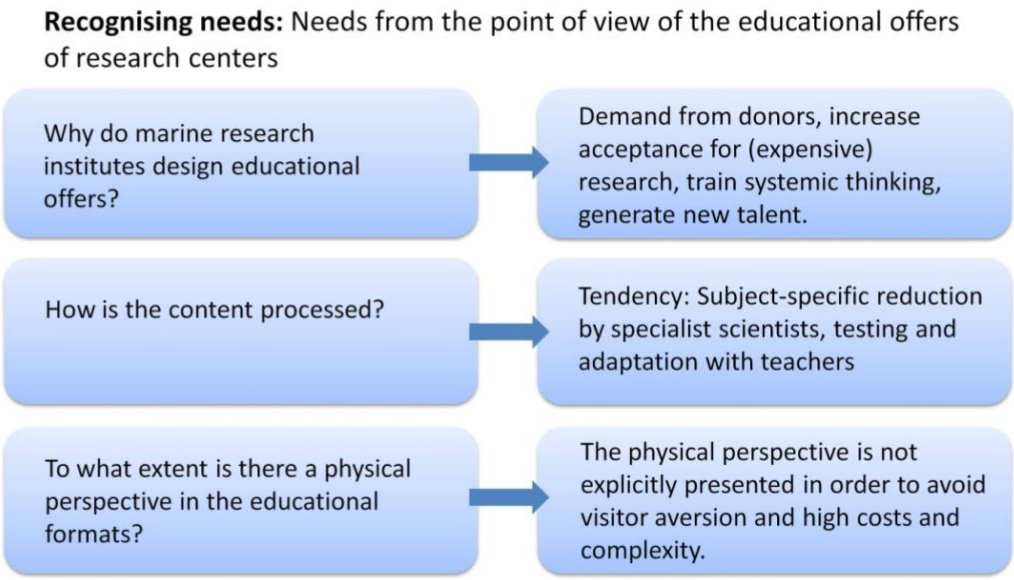

Figure 2. Expressed needs of those responsible for marine research institutes

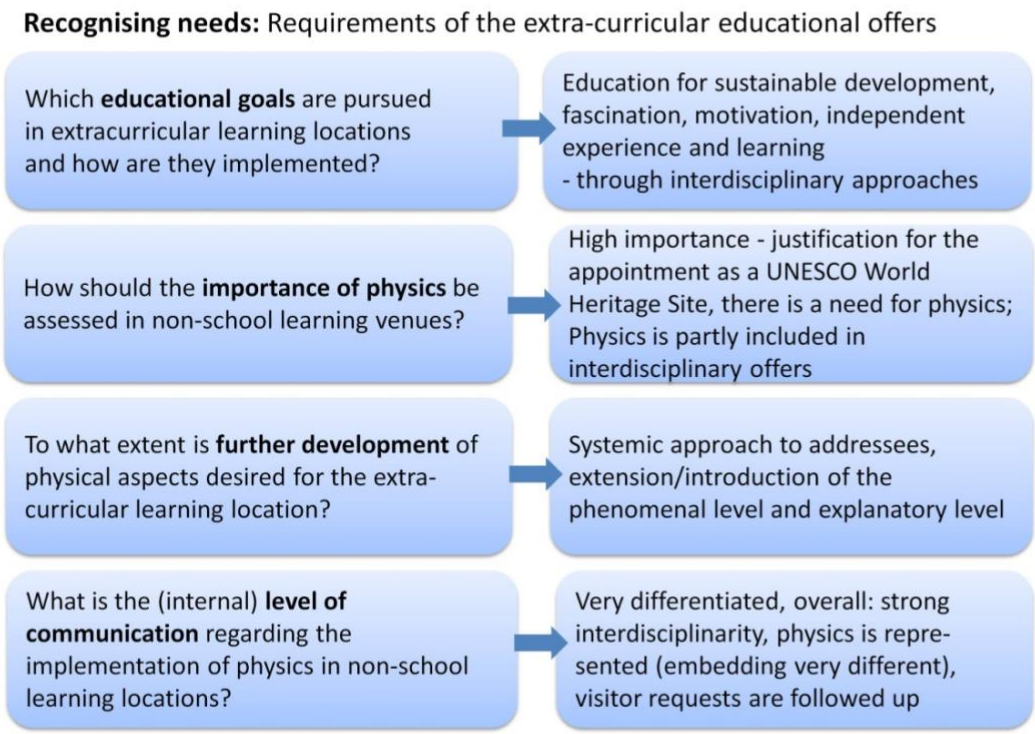

Figure 3. Expressed needs of those responsible for educational institutions on the coast

RESEARCH AND DEVELOPMENT EFFORTS

To further develop the educational offerings together with the operators of the out-of-school learning venues, the project pursues two lines; each is dedicated to one dissertation.

Development of exhibitions in the Design-Based Research cycle

As part of the project, a prototype exhibition was developed. It consists of six different exhibits that illustrate aspects of physical dynamics on the coast. These include ocean currents, tsunamis, formations of structures in granular matter, and tides. All exhibits were tested in the field with real visitors and in a laboratory study. Interviews and observation methods were used. The collected data was evaluated using qualitative content analysis (Mayring, 2014). The results were used in a design-based research cycle (Design-Based Research Collective, 2003) for the improvement and further development of the exhibits (Fig. 4). Also, research results were generalised to provide insights into the learning processes of visitors in exhibitions in general.

Formulation of educational guidelines using the Model of Educational Reconstruction

Through document analysis, scientific literature in the fields of continuum mechanics, thermodynamics, and the theory of complex systems (Bar-Yam, 2003; Demirel, 2014) was analysed to elucidate basic scientific ideas and general laws of coastal physics. It was shown that currents and structure formation mostly represent the physics of the coast. The analysis indicated that currents could be viewed as processes of equalisation, and structure formations can be explained based on positive and negative feedback mechanisms. Besides, empirical studies were conducted on learners' conceptions of physical dynamics on the coast. The empirical data were evaluated with qualitative content analysis (Mayring, 2014) and finally compared with the results of the document analysis. Based on the Model of Educational Reconstruction (Duit et al., 2012), educational guidelines are currently being formulated. These are comprised of both basic scientific ideas and information about the conceptions of learners in the relevant subject area. The educational guidelines address the operators of the out-of-school learning venues to help them integrate aspects of coastal physics into their educational offerings.

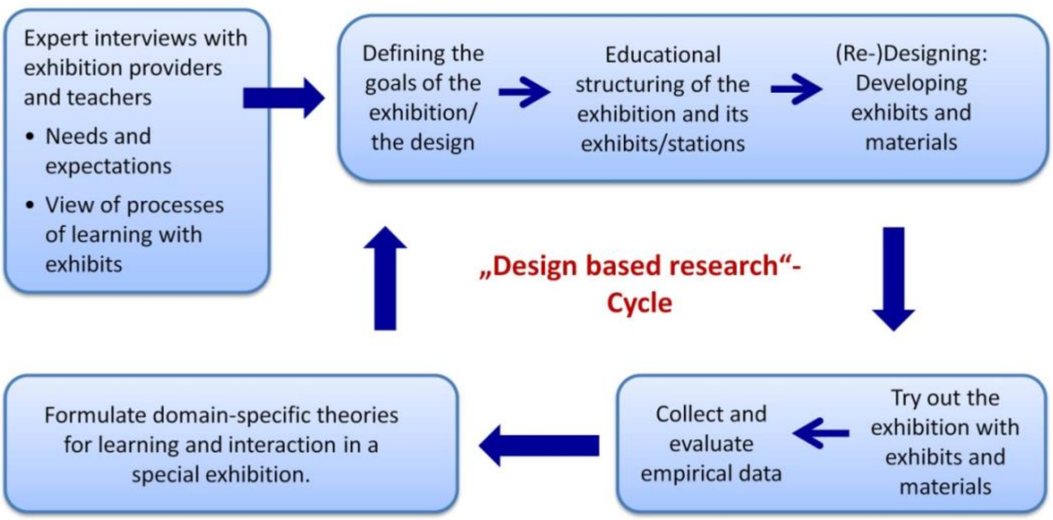

Figure 4. Design-based research cycle in an exhibition on natural structures and formations

Summary and Outlook

Many cooperation partners have well received the project. Cooperation is intensifying. Because the interest has grown significantly, a conference was held dealing with the integration of physical content in exhibitions. A manual and information materials of the produced and empirically evaluated exhibits will be published after the research and development work has been completed. In addition, a brochure will be released, which provides the operators of educational institutions with both the basic scientific ideas of coastal physics and the associated learners' conceptions.

In the meantime, further requirements of the operators and the Wadden Sea guides have become clear. The phenomenon of the tides and the associated forces between earth, moon, and sun represent a major physical and educational challenge. The explanations of the tides are usually misrepresented, both on written explanatory boards and from Wadden Sea guides while guiding in the mudflats. It is often said that the moon-facing tidal bulge is created by the attraction of the moon, while the other tidal bulge, facing away from the moon, is generated by the centrifugal force in the earth-moon system. This explanation is characterised by a separation explanation element and seems, therefore, intelligible, but it is physically incorrect. The two tidal bulges are created solely by differential gravitation in an inhomogeneous gravitational field, as created by the earth and the moon. The centrifugal force is not responsible for the tidal bulges, but it ensures that the earth and moon move around each other stably. These relationships are not easy to understand, neither for visitors on the coast nor for the Wadden Sea guides and the operators of the out-of-school learning venues. The project presented here now has the task not only to educationally prepare physical knowledge in the context of the coastal area but also to train the multipliers in an educational manner.

REFERENCES

Bar-Yam, Y. (2003). *Dynamics of Complex Systems*. Boulder: Westwing Press.

Demirel, Y. (2014). *Nonequilibrium Thermodynamics: Transport and Rate Processes in Physical, Chemical and Biological Systems*. Amsterdam: Elsevier.

Design-Based Research Collective (2003). Design-Based Research: An Emerging Paradigm for Educational Inquiry. *Educational Researcher, 32 (1),* 5-8.

Duit, R., Gropengießer, H., Kattmann, U., Komorek, M. & Parchmann, I. (2012). The Model of Educational Reconstruction – a framework for improving teaching and learning science. In: D. Jorde & J. Dillon (Eds.), *Science Education Research and Practice in Europe* (p. 13-37). Rotterdam: Sense Publishers.

Jacobeit, J. (2007). Zusammenhänge und Wechselwirkungen im Klimasystem. In W. Endlicher & F.-W. Gerstengarbe (Hrsg), *Der Klimawandel. Einblicke, Rückblicke und Ausblicke* (S. 1-16). Potsdam: PIK.

Mayring, P. (2014). Qualitative Content Analysis: Theoretical Background and Procedures. In: A. Bikner-Ahsbahs, C. Knipping & N. Presmeg (Eds.), Approaches to Qualitative Research in Mathematics Education (p. 365-380). Berlin, Heidelberg: Springer.

Ostendorf, R. & Piplak, K. (2018). Fachliche und fachdidaktische Analyse von ausgewählten Exponaten mit physikalischem Bezug in Nationalparkhäusern des Nationalparks Wattenmeer. Bachelor Thesis. Oldenburg: University of Oldenburg.

LEARNING OPPORTUNITIES AND OUTCOMES IN CITIZEN SCIENCE: A HEURISTIC MODEL FOR DESIGN AND EVALUATION

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Growing numbers of Citizen Science (CS) projects focus on learning about science through the collaboration of professional scientists and citizen scientists. However, resources for the design and evaluation of CS projects in terms of learning about science are scarce. Therefore, this chapter aims to provide a model for the heuristic analysis of the supply and use of learning opportunities in CS and apply it to different CS projects. We hope that the design of future CS projects considers the MODEL-CS as an approach to enable as many participants with different prerequisites as possible to take advantage of the learning opportunities provided.

Keywords: Environment, Research cooperation frameworks, Non-formal Learning

1 A MODEL FOR DESIGN AND EVALUATION OF LEARNING IN CS

This chapter aims to provide evidence for promoting science learning in Citizen Science (CS) projects which focus on education. In CS projects, citizens engage with professional scientists in scientific inquiries not only to push forward scientific endeavours but also to learn about science (Wals, Brody, Dillon, & Stevenson, 2014). Therefore, CS projects provide opportunities to learn in informal settings (National Academies of Sciences, Engineering, and Medicine [NASEM], 2018). However, research on learning in CS remains under-theorised (Crain, Cooper, & Dickinson, 2014), mainly for three reasons:

First, initiators of CS projects often lack capacities for designing learning opportunities and evaluating individual learning outcomes (Bonney, Phillips, Ballard, & Enck, 2016). Although CS projects provide informal settings for citizens to learn about science, only 7% of CS projects explicitly focus on education and those mainly on formal settings (Follett & Strezov, 2015). Hence, what citizens learn while participating is rarely the focus of most CS projects. Considering educational outcomes as one of the projects' goals, when planning a CS project, has the potential to improve the intentional design of learning opportunities (NASEM, 2018).

Second, the degree of participation in CS ranges from contribution (i.e. citizens contribute only to data collection) to co-creation (i.e. citizens participate in setting up the research; Shirk et al., 2012). Different degrees of opportunities to participate in scientific activities may impact the available learning opportunities. For example, project designers should ask themselves, if scientific reasoning skills of participants increase by just processing data in contributory CS projects (Jordan, Crall, Gray, Phillips, & Mellor, 2015). Furthermore, project designers need to consider how participants use these opportunities based on their assumed role, motivation, etc. and how it affects what they learn from participation (Phillips et al., 2019).

Third, the constructs to be addressed by learning in CS are not clearly defined, and corresponding assessment tools are scarce (Bonney et al., 2016). Designing opportunities for learning requires to define the constructs addressed (i.e. intentional design). Collaborations of scientists and other initiators of CS projects with science educators might help to address the challenges of intentional design for learning in CS projects.

In our collaborative attempt of natural scientists, science educators and psychologists to evaluate knowledge transfer in CS (WTimpact project), we developed a model to inform deliberate design and evaluation of learning in CS. The Model for the Design and Evaluation of Learning in CS projects (MODEL-CS; Figure 1) follows the framework for public participation in scientific research (Shirk et al., 2012) and integrates a supply-use model on the conditions of learning (Brühwiler & Blatchford, 2011). According to the MODEL-CS, prerequisites of professional and citizen scientists must be accounted for the supply and use of learning opportunities in CS projects. Furthermore, the supply of learning opportunities (e.g. inquiry activities) results in differing use (e.g. participation levels), which can be observed and measured. The resulting data output and the way how it is accessed by citizen and professional scientists influence the scientific as well as individual learning outcomes (e.g. in terms of knowledge development). In a feedback loop, the outcomes also affect citizen and professional scientists in that they result in changes at the individual, project or community level (Shirk et al., 2012).

This model now serves as a heuristic tool for the presentation and analysis of different CS projects. In the following, we illustrate how the MODEL-CS tackles the challenges mentioned above of designing and evaluating CS projects for learning about science. We will show how the model covers the design of learning opportunities and their use during participation as well as learning outcomes after participation. We will present three research projects about learning in CS and how they can be situated within the MODEL-CS.

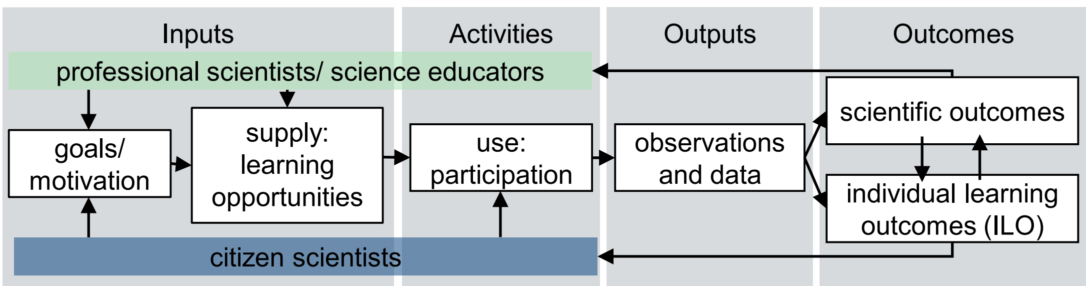

Figure 1. Model for Design and Evaluation of Learning in Citizen Science (MODEL-CS; Logic Model of PPSR; Shirk et al., 2012; Supply-Use Model; Brühwiler & Blatchford, 2011).

2 Youth participation in museum-led Citizen Science programmes

Natural history museum (NHM)-led CS provides a useful context in which to study learning outcomes and project design because both NHMs and CS share the dual goals of scientific research and science education (Ballard et al., 2017). NHM-led CS projects also provide the opportunity to systematically examine the specific nature of the learning settings (supply of learning opportunities) and the activities young people engage in (use of learning opportunities) when participating. The LEARN CitSci project, therefore, studies these two aspects of projects involving youth led by three NHMs (two in California; one in London) across two field-based settings (short-term BioBlitz events and ongoing monitoring projects focused on seaweed, backyard wildlife, or insects) and two online CS platforms (iNaturalist and Zooniverse).

2.1 Methods and Participants

To explore and characterise young people's participation and learning settings, we draw on Cultural Historical Activity Theory (CHAT; Engeström, 2001) and use Environmental Science Agency (ESA) as our research and analytical framework (Ballard, Dixon, & Harris, 2017).

2.1.1 Field-based settings

We relied upon ethnographic field observations to capture data about the participation of over 120 young people (5–19 years), in one ongoing field-based CS project (young people attending at least three sessions) and 3–5 short-term events (BioBlitzes) for each NHM. We developed observation protocols to focus on the features of each setting. Influenced by CHAT, we documented setting features in categories, e.g. tools, rules, division of labour, community setting, object (goals) and interactions with people. An iterative process of analysing field notes, including memo writing and qualitative data analysis using structural and thematic coding aimed to (a) identify types of participation and match them to ESA components, (b) identify and categorise setting features that open up or shut down ESA learning opportunities.

2.1.2 Online/ technology-enhanced programmes

To capture participation of young people in online CS programmes and identify the supply of learning opportunities, we analysed the technological affordances of tools on the Zooniverse and iNaturalist platforms and extracted log files from both platforms for 104 Zooniverse and 115 iNaturalist users. The participants were recruited through existing museum contacts, project activities run by the museums, and advertisement via Zooniverse.

2.2 Findings

2.2.1 Field-based settings

In about 80% of the observations, we saw evidence of young people engaging in scientific practices and opportunities to develop ESA. However, among those episodes in which participation in CS seemed to open up learning opportunities for ESA, we found important patterns in the ways that the CS contexts supplied opportunities for young people to develop and identify their own expertise in a scientific practice, as well as opportunities for constructive interactions around science with facilitators; specifically in short-term events (BioBlitz). We also saw a large proportion of episodes in which a setting feature had the potential to open up learning opportunities for ESA, but had to be characterised as "missed opportunities". These often centred around the design or framing of a programme that did not focus on, or sometimes did not even mention, the contribution to authentic scientific research of the CS activity.

2.2.2 Online/ technology-enhanced programmes

It could be argued that the two platforms afford a range of learning opportunities (e.g. observing, identifying and classifying wildlife or museum specimens), yet they differ substantially. iNaturalist acts as a social network site. Users' contributions and profiles are open to the public. The online community and machine learning techniques scaffold the process of identification. In Zooniverse, however, only scientists set up projects and have access to users' contributions. Observations (data that have been collected) are provided only by scientists, as are tutorials about how to participate (Herodotou, Aristeidou, Miller, Ballard, & Robinson, 2020). Our analysis showed differences in participation profiles (Table 1) and participation itself (use of learning opportunities). Most iNaturalist participants make observations only (taking/uploading pictures), while only 19 (out of the 115) young people also identified observed species. The average number of contributions per user was 22. Yet, 11 participants had between 170 to 17,169 contributions.

Table 1: Participation profiles, based on activity ratio, relative activity duration, variation in periodicity, daily devoted time.

Profiles	Zooniverse (*N* = 104)	%	iNaturalist (iNat; *N* = 115)	%
Systematic	Users are active, visit the platform regularly	5	Linked to iNat for a long period, systematic visits but relatively low activity	29
Casual	Users have inconstant visits, not very active	8	N/A	—
Moderate	Users have constant visits, not linked to the platform for long, not very active	15	Not linked to iNat for a long period, relatively systematic visits, relatively low activity	8
Visiting	Users contributed to projects one or two days only, very active during these days	33	Users only active for 1–2 days	51
Lasting	Linked to Zooniverse the longest, but do not visit regularly, only a few active days	39	Linked to iNat for a long period, very few active days, no systematic participation	12

2.3 Discussion and Implications

Given the wide variety of settings and ways that young people participate in CS, our analysis of how participation and setting features may open up and shut down learning opportunities points to key design features that can inform the design of environmental CS programmes. Specifically, we found that the ways that facilitators framed the activities and positioned young people at CS events like BioBlitzes greatly influenced whether and how young people took on roles in CS practices. For online settings, our findings reveal that the affordances of each platform allow for different forms of participation, as evidenced in the different forms of user contributions. Furthermore, the participation profiles based on cluster analysis provide a starting point for understanding and scaffolding young people's engagement in informal science learning via online CS. While some types of participation we observed are unique to a specific setting, for some types we found equivalents across field-based and online settings, pointing out opportunities for joint efforts in developing design modifications across CS settings to improve the supply and use of learning opportunities.

3 The Design for Participation Affects Pupils' Engagement with Learning Opportunities

From 2007–2017, the Austrian Ministry of Research has run a funding scheme called "Sparkling Science" to promote research cooperation between scientists, pupils and their teachers (Austrian Agency for International Cooperation in Education and Research, n. D.). Sparkling Science projects are quite similar to CS projects. Equally, Sparkling Science projects asked pupils to participate in reasonable research tasks. Bonney and colleagues (2016) suggest that CS projects should rely less on the personal experience of participating scientists and teachers, but should include more objective evaluation methods. Within ten years, we have observed five Sparkling Science projects, which offer different scientific research goals and participants activities (Table 2). All projects included accompanying evaluation research to learn about pupils' learning outcomes. Now we analysed and compared our findings again to find out whether there are common patterns observable among all five projects. The goal is to inform future project designers which activities are more likely to foster pupils' engagement with the learning opportunities offered in CS projects.

Table 2. Analysis of five Sparkling Science Projects regarding (1) scientists' interests, (2) time span, (3) pupil participation, (4) pupil tasks, (5) schools and grades, and (6) evaluation research with pupils.

	Top Klima Science	Alien Invaders	GrassClim	Viel-Falter	Woody Woodpecker
(1)	Hydrologic balance and global change: prospect for mountain areas in the face of changes in land use and climate	Alien plants and their role in reconstructions of river banks	Interactive effects of changes in climate and management on the yield and carbon dioxide source/sink strength of grasslands	Development and evaluation of a monitoring system of settlement-related butterfly habitats	Wood anatomy analyses of conifers at the alpine timberline
(2)	2008–2010	2008–2010	2010–2012	2013–2016	2014–2017
(3)	2 years	2 years	2 years	1 year or 2 years	1 year or 0,5 year
(4)	Data collection outdoors; data analysis; workshops at school and university; social event; publish results in agricultural journal	Data collection outdoors; data analysis; workshops at school and university	Data collection outdoors; workshops at school	Data collection outdoors; workshops at school and university; social event	Data collection outdoors; data analysis; workshop at school, at university, social event
(5)	High school with a focus on agriculture, grade 9	High school, grade 9	High school with a focus on agriculture, grade 9	Primary schools, Middle schools, High school with a focus on economics, grade 3, 4, 7, 8 & 12	High school, grade 10-12
(6)	50 pre-post-test (OECD, 2005); 12 semi-structured interviews	45 pre-post-test (OECD, 2005); 12 semi-structured interviews	10 semi-structured interviews	117 pre-post-test (Wilde et al., 2009); 19 in-depth interviews	45 pre-post-test (Urhahne et al., 2007); 12 semi-structured interviews

3.1 Setting, Participants and Methods

All five Sparkling Science projects (Table 2) followed a predefined set of requirements for integrating pupils and their teachers in a given research process and offered opportunities for pupils to participate in various research phases such as reflecting on hypothesis, collecting data and publishing results. It was expected that pupils develop an understanding of the scientific background of the project as well as how science works, e.g. what counts as high-quality data. Thus, emphasis was put on offering pupils a range of learning opportunities. As all projects conducted field research, pupils were able to work outdoors with scientists and accomplish research tasks independently, such as collecting, analysing and interpreting data. In addition, pupils participated in workshops at the university or their school and/or visited social events. All in all 267 pupils and more than 12 teachers participated in these five Sparkling Science projects. Earlier projects (Table 2) took theories on interest and motivation (e.g. Deci & Ryan, 1985) as a starting point to observe changes in pupil's interest and motivation to participate in these projects (e.g. Wilde, Brätz, Kovaleva, & Urhahne, 2009). Later projects added another focus and tried to observe the pupil's development in understanding the Nature of Science (Urhahne, Kremer, & Mayer, 2007). All projects included a content knowledge test on pupils' understanding of the scientific background. In addition, pupils participated in interviews during or at the end of the project (Table 2). In this study, we conducted a qualitative, comparative case study analysis (Flick, 2007) based on the evaluation reports published for each project.

3.2 Findings and Recommendation

The comparison of the projects' evaluation findings, especially those based on interviews with participating pupils (Table 2), reveals common patterns. All projects show a certain degree of incompatibility of research and everyday school life. Due to changing weather conditions, field research requires flexible planning whereas teachers need long term planning. Primary school teachers are more likely to adapt, whereas secondary and high school teachers may be more restricted. Students' situational enthusiasm does not always fit scientists' approach of persistent work, which follows a standard procedure. In terms of practical science activities, all pupils develop a better understanding of how scientific data is collected and that data quality is related to its accuracy and reliability. However, many pupils have difficulties in understanding the scientific background of the project and engaging in cognitive activities, such as reading and writing scientific protocols. These difficulties persist throughout the project duration. When working with younger children (age 6–15 years), it appears to be helpful to bridge the gap between pupils' needs and their role as researchers in the projects. In general, young pupils enjoy doing practical work or work outdoors. Teenagers are more likely to find research activities rather tedious. Educators who are experienced to work with a particular age group in out-of-school settings are more likely to meet children's needs (e.g. to make fun) than scientists or formal teachers. All pupils want to feel appreciated, valued and trusted for the work they contribute. Pupils expect researchers to be able to answer the research question at the end of the project and are disappointed if they do not learn about the results. The setting and/or expected research outcome should offer a direct link to pupils' personal life, e.g. to their local environment, or answer questions they value important for their own life. The duration of the project and the research activities should not last too long and should avoid repetitive tasks.

4 Learning outcomes in a CS biodiversity project

This CS project links biology education and environmental education in formal education. Research sites were private gardens, schoolyards and parks. Selected aims of the CS project were: (a) to record biodiversity through target species groups with school students (occurrence of selected garden birds; selected butterflies' presence and activities); (b) and aspects of acquired knowledge. Educational goals were defined to increase students' knowledge of the selected species groups and habitat-species relationships, as well as raising awareness towards the importance of green spaces and gardens for biodiversity conservation. Following the supply-use logic model, we inquired learning outcomes for students. Within MODEL-CS, we looked at the effects on individual learning outcomes. In a previous study, we focussed on the perspective of student citizen scientists and concentrated on educational goals and learning outcomes focusing on the following four individual learning outcomes (ILO) categories: (1) Interest in Science and the Environment, (2) Self-Efficacy, (3) Motivation, (4) Knowledge of the Nature of Science (Phillips et al., 2018, p. 7). These four were applied in evaluation via questionnaires, partly pre and post, some ILOs only after the project (Kelemen-Finan, Scheuch, & Winter, 2018). Additionally, a new ILO was introduced to measure attitudes, which were important for the evaluation of the environmental educational aims. Exemplary results show a significant pre-post-rise in the scale 'nature garden' (pre: $N = 317$, Mdn = 10 [3–12]; post: $N = 256$, Mdn = 11 [3–12]; $p < .001$) with a medium to large effect size of 0.52 (Cohen's *d)*. For the 'biodiversity' scale, the analysis also showed an increase, but with only small to medium effect size (Cohen's $d = 0.33$; Kelemen-Finan et al., 2018). In this study, the focus was the skills of students' species identification skills.

4.1 Methods and Participants

Over two years, 428 students from 27 school groups, supervised by 21 teachers, participated in this CS project. In total, 337 garden owners were interviewed with a standardised questionnaire, thereof, the students investigated 80 gardens and parks. Students used survey methods to monitor a set of common and easy-to-determine butterfly and bird species.

In addition to the questionnaires on the ILOs (see above), we tested the improvement of the students' species knowledge as a means to compare the students' perceived learning (i.e. scale 'self-efficacy') with the assessment of species identification rate as learning outcomes. In a quiz, students had to identify seven selected common bird species (four by picture; three by sound) and four common butterflies (pictures) at the closing event of the project. Overall, 186 students participated in this quiz. We compared the species knowledge of students who recorded target species (intervention group) to students who did not (comparison group). Birds were recorded by $n = 122$ students compared to $n = 64$ who did not, for butterfly activities the respective numbers were $n = 99$ for those who did record butterflies and $n = 87$ who did not.

4.2 Findings

Overall, the project improved students' knowledge of target species, and it raised attitudes towards the importance of man-made habitats such as gardens and parks for biodiversity conservation. With respect to species knowledge, the quiz showed that the correct species identification of the students who observed the respective species group were 10–25% higher compared to the group that did not work with the respective species group. For an overlook, see table 3, with visual identification being generally higher than auditive identification.

Table 3: Correct identification rates of the two groups.

Identification rate %	Recorded target species	Did not record target species
Bird Quiz Pic	81%	63%
Bird Quiz Sound	50%	35%
Butterfly Quiz	75%	60%
Overall	**70%**	**55%**

Overall, the recognition rate was highest for the Blue Tit (*Cyanistes caeruleus*, visually: 98% in both groups) and lowest for the Great Tit (*Parus major*, audio; both groups only about 10%). In general, bird song recognition was less successful (50% of students who recorded and 35% of students who did not record birds) than visual recognition (81% of students who recorded and 63% of students who did not record birds).

In the butterfly quiz, most students (95% for students who recorded vs. 69% for students who did not record butterflies) recognized the Swallowtail (*Papilio machaon*) correctly. Common but similar species within some families, such as Pieride (Common Brimstone, *Gonepteryx rhamni* vs. Small White, *Pieris rapae*) or Nymphalidae (Red Admiral, *Vanessa atalanta*, vs. various others) were commonly misidentified, but lesser so by students who had recorded them outdoors. Students who recorded and students who did not record butterflies differed by 4% more correct identifications for the Red Admiral and 26% for the Swallowtail.

4.3 Discussion and Implications

We could show with the birds' quiz that bird identification was satisfying in this CS project and therefore the results of the students reliable; this was not the case in some butterfly species. This aspect is crucial in CS projects to link the learning of the participants with ensuring data quality. Within the project, the science educators of the team did supply an activity with photos of birds and butterflies in a workshop for the students to help them learn the identification. The photos were selected to show the natural range of "good and bad" views on the target species (e.g. difference in illumination to show birds in full light and within treetops in green light). The selection can be an example of a purposefully designed learning opportunity, to support citizen scientists as well as enhancing data quality. The identification workshop did work for visual bird identification but not so well in some butterflies' cases, auditive identification training did not take place.

Therefore, models like the combined and logic model (Brühwiler & Blatchford, 2011; Shirk et al., 2012), or the checklist with ILOs of Philipps and colleagues (2018) are very helpful to link CS projects with educational aims and learning activities. Taking the MODEL-CS as a heuristic framework to think about motivation and goals of citizen scientists (Figure 1), we learned that students and teachers have different expectations and this has to be considered and to be negotiated with those of the scientists, even in contributory CS projects. This project can serve as an example that efforts to undertake evaluation on different individual learning outcomes with a focus on the students and the teachers (e.g. Scheuch et al., 2018) help to further develop CS as a meaningful way of learning in science and environmental education (Wals et al. 2014).

5 Summary Discussion and Conclusions

In this chapter, we provided MODEL-CS as a heuristic tool for connecting the analysis of learning in different CS projects to the logic of CS project design (Shirk et al., 2012). We extended it by accounting for participants' prerequisites and differentiating between the supply and the use of learning opportunities (Brühwiler & Blatchford, 2011). From the analysis of different CS projects in this chapter, the following components seem essential: (a) prerequisites (i.e. goals, interests, motivation, previous knowledge and skills), (b) supply of learning opportunities (i.e. design features), (c) use of learning opportunities (i.e. differences in participation) and (d) individual learning outcomes (i.e. aligned with goals, embedded in activities). Furthermore, the heuristic analysis with MODEL-CS facilitated the identification of interactions between prerequisites and the supply as well as the use of learning opportunities.

When designing and evaluating CS projects for learning, it has to be kept in mind that the interactions between the different goals, the supply and actual use of learning opportunities affect both, the scientific and individual learning outcomes. For the studies reported here, it was especially important to (1) coordinate prerequisites of citizen scientists and professional scientists for the design of learning opportunities, (2) to consider how different activities afford learning opportunities and (3) to embed the assessment of ILOs into the project activities. For example, the professional scientists' goal of acquiring a standardised data collection did not fit to students' situational enthusiasm and hence, resulted in the use of learning opportunities that differed from the standard procedure. This mismatch illustrates how coordinating professional scientists' goals and citizen scientists' prerequisites could inform and improve the design of learning opportunities, a demand for science educators as facilitators in CS projects.

The purpose of MODEL-CS is to provide a model that facilitates new insight into the design and evaluation of CS projects for learning. More specifically, applying MODEL-CS as a heuristic tool to different CS projects with a focus on education could highlight the interactions of participants' prerequisites with the supply and the use of learning opportunities. We hope that MODEL-CS can support the future design of CS projects by considering participants' prerequisites to improve the learning opportunities provided and increase their use.

Acknowledgements

WTimpact was supported by the Federal Ministry of Education and Research under grant number 01|O1727 (PI: Professor Ute Harms); LEARN CitSci was supported by Wellcome Trust and ESRC under grant number 206202/Z/17/Z and the National Science Foundation under grant number 1647276. The CS projects reported in sections 3 and 4 were funded by Sparkling Science (Austria).

REFERENCES

Austrian Agency for International Cooperation in Education and Research (n. D.). Sparkling Science. Retrieved 23. Januar 2020 from https://www.sparklingscience.at

Ballard, H., Dixon, C. and Harris, E. (2017). Youth-focused citizen science: Examining the role of environmental science learning and agency for conservation. *Biological Conservation, 208*, 65–75.

Ballard, H., Robinson, L., Young, A., Pauly, G., Higgins, L., Johnson, R., & Tweddle, J. (2017). Contributions to conservation outcomes by natural history museum-led citizen science: Examining evidence and next steps. *Biological Conservation, 208*, 87–97.

Bonney, R. E., Phillips, T. B., Ballard, H. L., & Enck, J. W. (2016). Can citizen science enhance public understanding of science? *Public Understanding of Science*, *25*(1), 2–16.

Brühwiler, C., & Blatchford, P. (2011). Effects of class size and adaptive teaching competency on classroom processes and academic outcome. *Learning and Instruction*, *21*(1), 95–108.

Crain, R., Cooper, C., & Dickinson, J. L. (2014). Citizen Science: A Tool for Integrating Studies of Human and Natural Systems. *Annual Review of Environment and Resources*, *39*(1), 641–665.

Deci, E. L., & Ryan, R. M. (1985). *Intrinsic motivation and self-determination in human behavior*. New York: Plenum Press.

Engeström, Y. (2001). Expansive Learning at Work: Toward an activity theoretical reconceptualization. *Journal of Education and Work, 14*(1), 133–156.

Flick, U. (2007). *Designing Qualitative Research*. London/ Thousand Oaks, CA/ Dehli: Sage.

Follett, R., & Strezov, V. (2015). An Analysis of Citizen Science Based Research: Usage and Publication Patterns. *PloS One*, *10*(11), e0143687.

Herodotou, C., Aristeidou, M., Miller, G., Ballard, H., & Robinson, L. (2020). What Do We Know about Young Volunteers? An Exploratory Study of Participation in Zooniverse. *Citizen Science: Theory and Practice, 5*(1), 2.

Jordan, R., Crall, A., Gray, S., Phillips, T., & Mellor, D. (2015). Citizen Science as a Distinct Field of Inquiry. *BioScience*, *65*(2), 208–211.

Kelemen-Finan, J., Scheuch, M., & Winter, S. (2018). Contributions from citizen science to science education: An examination of a biodiversity citizen science project with schools in Central Europe. *International Journal of Science Education*, *40*(17), 2078–2098.

National Academies of Sciences, Engineering, and Medicine (2018). *Learning Through Citizen Science: Enhancing Opportunities by Design*. Washington (DC): National Academies Press (US).

Organisation for Economic Co-operation and Development [OECD] (2005). Student Questionnaire for PISA 2006. Main Study December 2005. Retrieved from https://www.oecd.org/pisa/pisaproducts/PISA06_Student_questionnaire.pdf

Phillips, T., Porticella, N., Constas, M. and Bonney, R. (2018). A Framework for Articulating and Measuring Individual Learning Outcomes from Participation in Citizen Science. *Citizen Science: Theory and Practice, 3*(2), 3.

Phillips, T. B., Ballard, H. L., Lewenstein, B. V., & Bonney, R. (2019). Engagement in science through citizen science: Moving beyond data collection. *Science Education*, *103*(3), 665–690.

Scheuch, M., Panhuber, T., Winter, S., Kelemen-Finan, J., Bardy-Durchhalter, M., & Kapelari, S. (2018). Butterflies & wild bees: Biology teachers' PCK development through citizen science. *Journal of Biological Education*, *52*(1), 79–88.

Shirk, J. L., Ballard, H. L., Wilderman, C. C., Phillips, T., Wiggins, A., Jordan, R., . . . Bonney, R. E. (2012). Public Participation in Scientific Research: A Framework for Deliberate Design. *Ecology and Society*, *17*(2).

Urhahne, D., Kremer, K. & Mayer, J. (2007). Welches Verständnis haben Jugendliche von der Natur der Naturwissenschaften? Entwicklung und erste Schritte zur Validierung eines Fragebogens [What understanding do young people have of the natural sciences? Development and first steps towards validation of a questionnaire]. *Unterrichtswissenschaft, 36*, 72–94.

Wals, A. E. J., Brody, M., Dillon, J., & Stevenson, R. B. (2014). Convergence between science and environmental education. *Science*, *344*(6184), 583–584.

Wilde, M., Brätz, K., Kovaleva, A. & Urhahne, D. (2009). Überprüfung einer Kurzskala intrinsischer Motivation [Assessment of a short scale of intrinsic motivation]. *Zeitschrift für Didaktik der Naturwissenschaften, 15*, 31–45.

PRE-SERVICE PRIMARY TEACHER TRAINING ON RESPONSIBLE RESEARCH AND INNOVATION FRAMEWORK

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An approach in science education that recognizes science as a collective human endeavor and highlights its relationship both with society and technology, is the negotiation of socioscientific issues (SSI) in science lessons. Responsible Research and Innovation (RRI) framework seems to function as a scaffolding for teachers' implementation of socioscientific approaches in science courses. The aspects of the nature of scientific knowledge seem also to influence teachers' focus on the social aspects of science. The aim of the present study is to investigate the impact of the negotiation of Nature of Science aspects on the development of interactive artifacts about RRI issues by pre-service primary teachers. The results give insights into the balance pre-service primary teachers keep among the scientific content, the social aspects and the epistemological features of science while negotiating RRI issues.

Keywords: Socioscientific Issues, Nature of Science, Pre - service Teacher Education

INTRODUCTION

In recent years, the relationship of the Responsible Research and Innovation (RRI) framework with other established approaches of science education such as Socioscientific Issues (SSI) and Nature of Science (NoS), has been studied (Laherto et al., 2018; Blonder et al., 2016). The RRI framework consists of six aspects – *(1) Engagement of all societal actors, (2) Gender equality, (3) Science education, (4) Open access, (5) Ethics, (6) Governance* – (European Union, 2012). Blonder et al. (2016) notes that RRI aspects seem to function as a scaffolding for the implementation of socioscientific approaches in science courses. However, recent studies reveal that RRI is a difficult concept for students to understand and a difficult concept for teachers to manage during the educational process (de Vocht et al., 2017). Teachers' restriction to 'established' knowledge and their inadequate understanding of the tentative and subjective nature of scientific knowledge reinforce this challenge (e.g. Khishfe, 2017; Karisan & Zeidler, 2017). The correlation between the social aspects of science, that are negotiated via RRI, and the nature of scientific knowledge is highlighted through the Family Resemblance Approach (FRA) (Erduran & Dagher, 2014) which provides an insight of science by presenting it as a unified system of cognitive, epistemological and social aspects. FRA suggests that a deeper and a more realistic understanding of science requires equal emphasis on both scientific concepts and social aspects of science as well as on the nature of scientific knowledge (Erduran & Dagher, 2014). Hence, the connection of RRI with the Nature of Science (NoS) is one step that needs to be done in order to incorporate efficiently RRI in educational practice. Based on the above, our study investigates the extent that NoS aspects influence the negotiation of RRI issues via the development of interactive artifacts on contemporary scientific subjects by pre-service primary teachers. Particularly, the research question of the study is the following:

What is the effect of the negotiation of NoS aspects on the development of artifacts for science teaching focused on RRI issues by pre-service primary teachers?

THEORETICAL FRAMEWORK

The rapid development of science and technology in contemporary society has given rise to a variety of global concerns such as environmental pollution, global warming, manufacturing via nanotechnologies etc. It is widely accepted that students, as future citizens, need to develop argumentation and informed decision – making skills in order to deal with complex, real-world problems related to science and technology advances (Roberts, 2007). These skills can be promoted in science lessons through the negotiation of Socioscientific Issues (SSI), which are social dilemmas rooted in science and which are by definition complex, open-ended, with no definitive answers (Sadler & Zeidler, 2005). SSI are by nature controversial given the uncertain, changing and complex context of a controversy as well as given the lack of their epistemological and ethical structure. Controversies are not usually settled just by evidence due to the emotional and ethical issues that are integrated and due to the involvement of different people and groups that give conflicting explanations and solutions based on their diverse key beliefs and premises (Levinson, 2006).

Moreover, researchers have suggested a close bidirectional relationship between SSIs and NoS. On the one hand, NoS represent the characteristics of scientific enterprise and the epistemology of science and it is argued to be a prerequisite for the engagement in SSIs (Simonneaux, 2008). This means that teachers' and students' informed views of NoS support their understanding of the provisional nature of scientific knowledge and their argumentation based on evidence and the alternative viewpoints. On the other hand, SSIs provide an ideal context for discussing understandings of the NoS as these issues expose people to the limitations, possibilities of science as well as to the role of consensus in science (Khishfe, 2012). The recent conception of NoS by Erduran and Dagher (2014) in the Family Resemblance Approach (FRA), which considers science both as a cognitive-epistemic system and as a social institution, aligns with Responsible Research and Innovation (RRI) framework in shifting the perception of science from a body of knowledge to a complex process involving multiple perspectives, interests, values and uncertainties (Laherto et al., 2018).

RRI is a European Union policy that represents a contemporary view of the connection between science and society, which tries to build public's and other stakeholders' trust and confidence in research and innovation (Sutcliffe, 2011). Particularly, the European Commission (2012) has defined six key areas of RRI which highlight the strong connection between scientific research and societal needs: (1) *Engagement of all societal actors* - researchers, industry, policymakers and civil society - and their participation in the research and innovation process. In such a framework, all challenges are based on common principles and ethical concerns and all work together in order to find common solutions and avoid potential dangers of future innovations. (2) *Gender Equality*. Engagement means that all actors – women and men – are on board. The limited representation of women should be dealt with and especially research centers should be modernized as far as human resources is concerned. (3) *Science Education*. The current educational process should be updated in order to give to future researches and societal actors the necessary knowledge and tools for their participation in research and innovation. At the same time, it is needed to reinforce students' interest and motivation for science as they will participate in social debates about science and they will be future researchers. (4) *Open access.* Research and innovation should be transparent and accessible and that is why people should have free online access to the research results. In this way more and more people will use these results and innovation will be promoted. (5) *Ethics.* Our society is based on common values and principles. Research and innovation should follow and respect these values as only in this way the acceptability and the quality of the results of research will be increased and (6) *Governance.* Policymakers also have the responsibility to prevent harmful or unethical developments in research and innovation.

Despite RRI is mainly conceived as a European policy that aims at the optimization of scientific and technological processes and results, recent research in the field of science education reveal its educational potential (e.g. Blonder et al., 2017; Blonder et al., 2016; Ratinen et al., 2018; de Vocht & Laherto, 2017; de Vocht et al., 2017). RRI could be an appropriate tool that would equip all students, as future citizens, to acquire and use scientific knowledge in order to evaluate the consequences of the outcomes of innovations taking into account limitations of scientific research, societal needs and moral values (Blonder et al., 2016). RRI framework, like SSI-approaches, deals with dilemmas and equivocal situations that arise from the uncertain nature of contemporary scientific subjects. Dealing with such issues, makes it necessary for students to evaluate their scientific knowledge as well as to take into consideration knowledge from other disciplines such as politics, economics, environment etc. in order to form their argumentation and make their decisions about scientific products and innovations (Hofstein et al., 2011). Due to the emergent influence and the novelty of RRI as an educational framework, research about the use of RRI in school reality is really limited. Most studies are connected with the implementation of EU projects in which RRI had a crucial and central role (e.g. IRRESISTIBLE, ENGAGE, PARRISE, RRI-tools etc.). The results of these studies reveal that RRI is a difficult concept for students to understand (Ratinen et al., 2018) and a difficult concept for teachers to manage during the educational process (de Vocht & Laherto, 2017; de Vocht et al., 2017).

Based on the aforementioned, RRI framework reflects the relationship among science, technology and society. This relationship is captured in science education via the negotiation of SSI. However, both SSI approach and RRI framework requires the understanding of the nature of the scientific knowledge in order to handle the uncertainties that are inherent in research and innovation processes.

METHOD

Research Design

The study was conducted in two phases. Particularly:

Phase 1. The first phase of the study took place during the fall semester of 2016-2017. Twelve pre-service primary teachers took part in the investigation. They were divided into six groups of two. Phase 1 was organized in twelve weekly three-hour meetings. Initially, during the first six meetings pre-service primary teachers got familiar with RRI aspects and the scientific content of the contemporary scientific subject they chose to focus on. Firstly, pre- service teachers got familiar with the scientific content. Afterwards, an explicit teaching of the RRI concept took place and pre-service teachers got familiar with RRI aspects through the analysis of newspaper articles. The other six meetings were devoted to the development of their artifact (see table 1).

Phase 2. Due to the results that arose from the data analysis of the first phase, we proceeded to the second phase of the study, which was focused on the investigation of NoS aspects' role in the negotiation of RRI issues by pre-service primary teachers. The second phase took place during the fall semester of 2018-2019. Twelve pre-service primary teachers, who were divided into four groups of three, participated in the investigation. Phase 2 was also structured into twelve weekly three- hour meetings. During the first six meetings, pre – service primary teachers focused not only on the scientific content (focused on micro plastics' potential risks) and the corresponding RRI aspects but also on aspects of the nature of scientific knowledge. Particularly, we focused on three aspects of NoS: i. the tentative (scientific knowledge is subject to change), ii. the subjective (scientist' background, experiences and biases influence scientific knowledge) and iii. the empirical (scientific knowledge is based on observations of the natural world), which are believed to be closely related to socioscientific issues (Khishfe, 2017). Initially, pre – service teachers got familiar with core scientific ideas of micro plastics via inquiry based activities developed in the context of the European Union project "IRRESISTIBLE" (http://www.irresistible-project.eu/). Subsequently, they got familiar with the RRI framework and explore the societal implications of micro plastics via the analysis of newspaper articles. Finally, they discussed about the uncertainties of contemporary scientific topics and the tentativeness of scientific knowledge in general through their engagement in a "mystery box" activity (Lederman & Abd-El-Khalick, 1998). The other six meetings were devoted to the development of their artifact (see table 1).

Table 1. The phases of the study

Phase of the Study	Meetings	Description
Phase 1	Meetings 1 - 6	Pre service teachers' familiarization with: • the scientific content • the RRI aspects
	Meeting 7 -12	Development of the artifact
Phase 2	Meetings 1 - 6	Pre service teachers' familiarization with: • the scientific content • the RRI aspects • aspects of NoS
	Meetings 7 – 12	Development of the artifact

Data collection and analysis

In both phases, data was collected using: (a) audiotapes of every meeting, (b) the final artifact and (c) a final interview of each working group. Due to the exploratory nature of the investigation and the small number of final artifacts, qualitative methods of content analysis were used (Mayring, 2015). The data was analyzed in two axes: (1) the RRI focus of the artifact and (2) the nature of knowledge in RRI activities.

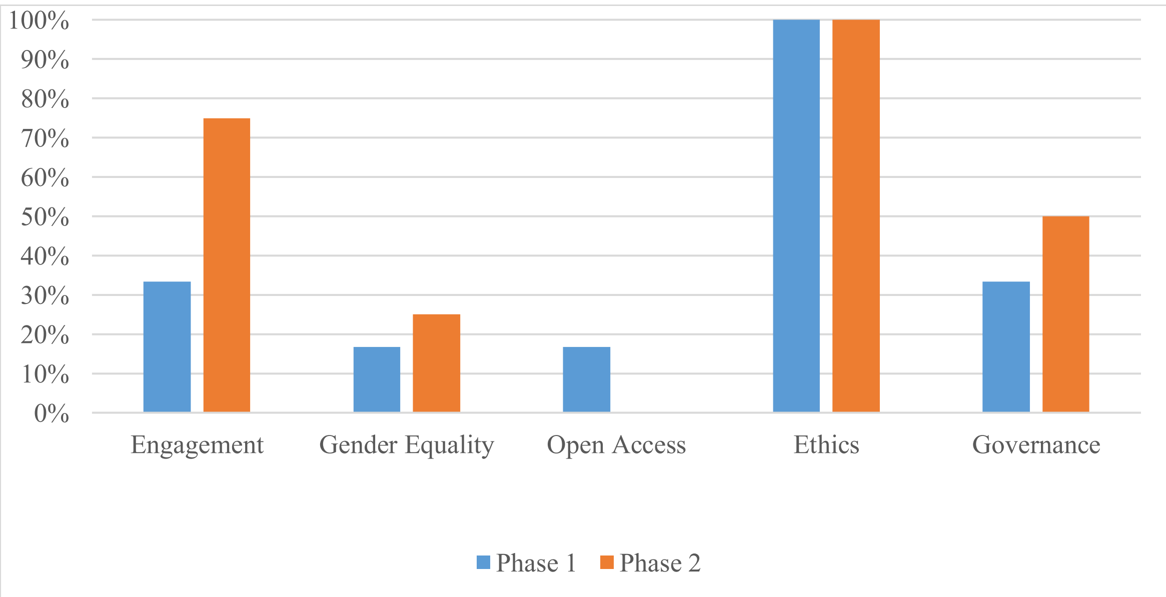
The category systems were developed on the basis of the relevant literature and were differentiated based on the new empirical data. So 'the constant comparative method' was followed, in which new empirical data is compared with data that was collected in previous studies (Strauss & Corbin, 1990). Specifically, concerning the RRI dimension of the artifacts, five out of the six RRI aspects constitute the five categories for the analysis. Relating to the nature of scientific knowledge incorporated into the RRI activities two main categories were developed (controversial – no controversial) based on whether or not the activities reflect the tentative, subjective and empirical nature of science.

RESULTS

Concerning the results of the investigation, in phase 1 pre-service teachers developed in total six artifacts focused on: (i) nanotechnology, (ii) mobile phones, (iii) vaping, (iv) breastfeeding, (v) reproduction -inheritance and (vi) genetically- modified food. In phase 2, pre-service teachers developed four artifacts, which referred to micro plastics with a special focus on: (i) human health, (ii) marine life, (iii) biodegradable bags and (iv) micro plastics in everyday life. The artifacts included both scientific information connected with the corresponding scientific subject and questions on RRI issues.

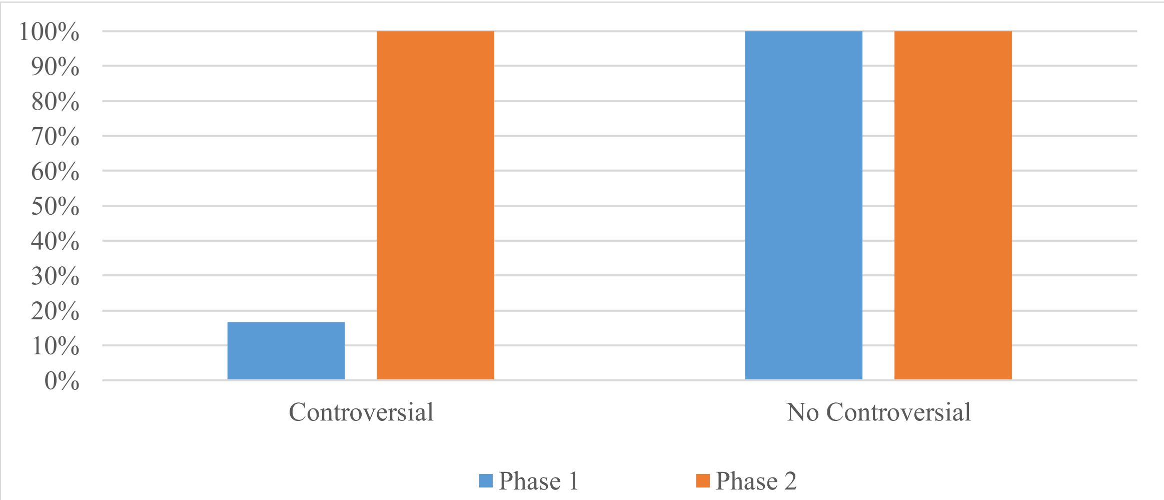
Regarding the RRI focus of the artifacts (see table 2), pre-service primary teachers mainly incorporated activities about ethics but also about engagement and governance. Thus, we notice that in both phases, the same RRI aspects prevail in the artifacts. The difference in the incorporation of the aspect of engagement in phase 2 can be attributed to pre-service teachers' familiarization with NoS given the fact that the activities about engagement were mainly role games that integrated conflicting information and asked students to take a role, to deal with uncertain statements and to form their own perspective.

Table 2. The RRI focus of the artifacts



Concerning the nature of the knowledge in the RRI activities (see table 3), in phase 1 just one artifact out of the six incorporated controversial information while in phase 2 all artifacts contained at least one RRI activity with controversial information. Particularly, in phase 1, pre-service primary teachers tried to communicate via the artifact mainly 'established' knowledge something that prevented them from emphasizing on the debatable nature of contemporary scientific subjects. Therefore, they included general questions concerning RRI aspect which do not require the use of scientific information in order to be answered. For instance, in the nanotechnology artifact, they included initially some general information about nanoscale without any reference to the pros and cons of nanotechnology applications and afterwards they asked some general RRI questions such as *"Should companies display that their products contain nanoparticles? Yes or No?"*. Similarly, in the artifact about vaping pre- service teachers ended up to provide information about conventional smoking due to the conflicting information they encountered during their research about vaping.

Table 3. The nature of knowledge in the activities.



In phase 2, the artifacts included debatable information and asked students to make decisions based on this information. For example, in the artifact of biodegradable bags pre-service teachers presented different perspectives about their value and asked students to reflect on the scientific information provided through the artifact in order to decide if it is worthy to use them in our daily life or whether government should take measures for their limitation. RRI activities in phase 2 gave the opportunity for deeper engagement with the scientific content and the diversity of the perspectives given the fact that the artifacts included empirical studies' results and conflicting information that students were asked to comment on. Moreover, pre-service teachers integrated in the artifacts evidence about new scientific findings for the gradual replacement of plastic as well as activities about the financial and political system's impact on research and innovation processes. All these practices reflected the empirical, tentative and subjective nature of scientific knowledge and provided students with the opportunity to negotiate contemporary controversies about micro plastics.

DISCUSSION AND CONLUSIONS

RRI is a novel framework proposed and developed by the EU in order to promote and foster the cooperation among all the stakeholders involved in research and innovation processes as well as in order to reinforce public's trust and confidence concerning scientific and technological innovations (Sutcliffe, 2011). Despite, RRI is a European policy, recently it has been investigated as an educational tool which enables teachers and students to negotiate societal implications of innovative scientific and technological products (Blonder et al., 2016). It seems that RRI aspects provide a useful scaffolding that equip teachers with specific axes to negotiate the societal implications of scientific and technological innovations. Using RRI aspects as guidelines pre-service teachers managed to approach contemporary scientific topics more globally, examining them not just from the scientific point of view but also from ethical, political and societal perspectives. In addition, when pre-service teachers aim to focus on the societal dimensions of contemporary scientific subjects, they tend to focus on ethics. This fact can be interpreted by the findings of related research which underline that ethical concerns are the most important factors that influence individual decision-making (Zeidler et al., 2002; Sadler et al., 2006).

Finally, pre-service teachers, in the initial phase of the study, wanted to present in their artifacts 'established' knowledge, although the element of uncertainty is inherent in contemporary scientific subjects at the cutting edge of research. This fact could be confirmed in the literature as it is noted that science teachers want to follow a value-free approach during their lessons by teaching just facts and phenomena (e.g. Forbes & Davis, 2008). However, this seems to be overcome via the engagement of pre –service primary teachers with aspects of the nature of scientific knowledge during the phase 2 of the study. Pre – service teachers' familiarization with the empirical, tentative and subjective nature of scientific knowledge seemed to restrict their difficulties of integrating different scientific views and scientific controversies in their artifacts. Thus, generally we could conclude that the inclusion of cognitive – epistemic – social aspects of science during pre - service teachers training seem to help them incorporate more efficiently the nature of RRI concept in their artifacts.

ACKNOWLEDGEMENT

The research work is supported by the Hellenic Foundation for Research and Innovation (HFRI) under the HFRI PhD Fellowship grant (Fellowship Number: 1490).

REFERENCES

Blonder, R., Rap, S., Zemler, E., & Rosenfeld, S. (2017). Assessing Attitudes about Responsible Research and Innovation (RRI): The Development and Use of a Questionnaire. *Sisyphus-Journal of Education, 5*(3), 122-156.

Blonder, R., Zemler, E., & Rosenfeld, S. (2016). The story of lead: a context for learning about responsible research and innovation (RRI) in the chemistry classroom. *Chemistry Education Research and Practice, 17*, 1145-1155.

de Vocht, M., & Laherto, A. M. P. (2017). Profiling teachers based on their professional attitudes towards teaching Responsible Research and Innovation. *European Journal of Science and Mathematics Education*, *5*(3), 271-284.

de Vocht, M., Laherto, A., & Parchmann, I. (2017). Exploring teachers' concerns about bringing Responsible Research and Innovation to European science classrooms. *Journal of Science Teacher Education, 28*(4), 326-346

Erduran, S., & Dagher, Z. R. (2014). *Reconceptualizing nature of science for science education*. Springer, Dordrecht

European Commission (2012). *Responsible Research and Innovation - Europe's ability to respond to societal challenges.* Retrieved from https://ec.europa.eu/research/ swafs/pdf/pub_rri/KI0214595ENC.pdf

Forbes, C. T., & Davis, E. A. (2008). Exploring preservice elementary teachers' critique and adaptation of science curriculum materials in respect to socioscientific issues. *Science & Education, 17*(8), 829-854

Hofstein, A., Eilks, I., & Bybee, R. (2011). Societal issues and their importance for contemporary science education—A pedagogical justification and the state-of-the-art in Israel, Germany, and the USA. *International Journal of Science and Mathematics Education, 9*(6), 1459-1483.

Karisan, D. & Zeidler, D.L. (2017). Contextualization of nature of science within the socioscientific issues framework: A review of research. *International Journal of Education in Mathematics, Science and Technology, 5*(2), 139-152.

Khishfe, R. (2012a). Nature of science and decision making. *International Journal of Science Education, 34*(1), 67–100

Khishfe, R., Alshaya, F. S., BouJaoude, S., Mansour, N., & Alrudiyan, K. I. (2017). Students' understandings of nature of science and their arguments in the context of four socio-scientific issues. *International Journal of Science Education, 39*(3), 299-334.

Laherto, A. M. P., Kampschulte, L., de Vocht, M., Blonder, R., Akaygün, S., & Apotheker, J. (2018). Contextualizing the EU's "Responsible Research and Innovation" policy in science education. *Eurasia Journal of Mathematics, Science & Technology Education, 13*(2), 2287-2300.

Lederman, N., & Abd-El-Khalick, F. (1998). Avoiding de-natured science: Activities that promote understandings of the nature of science. In *The nature of science in science education* (pp. 83-126). Springer, Dordrecht.

Levinson R., (2006). Towards a theoretical framework for teaching controversial socio-scientific issues. *International Journal of Science. Education., 28*(10), 1201- 1224.

Mayring, P. (2015). Qualitative Content Analysis: Theoretical Background and Procedures. In A. Bikner-Ahsbahs, C. Knipping, & N. Presmeg (Eds.), *Approaches to Qualitative Research in Mathematics Education (pp. 365-380)*. Dordrecht: Springer Netherlands.

Ratinen, I., Kähkönen, A. L., & Lindell, A. (2018). Pupils' Understanding about Responsible Research and Innovation. International Journal of Environmental and Science Education, 13(2).

Roberts, D. A. (2007). Scientific literacy/science literacy. In S. K. Abell & N. G. Lederman (Eds.), *Handbook of research on science education (pp. 729–780).* Mahwah, NJ: Lawrence Erlbaum Associates.

Sadler, T. D., & Zeidler, D. L. (2005). Patterns of informal reasoning in the context of socioscientific decision making. *Journal of Research in Science Teaching, 42*(1), 112-138.

Sadler, T. D., Amirshokoohi, A., Kazempour, M., & Allspaw, K. M. (2006). Socioscience and ethics in science classrooms: Teacher perspectives and strategies. *Journal of Research in Science Teaching, 43*(4), 353-376.

Simonneaux, L. (2008). Argumentation in socio-scientific contexts. In S.Erduran & M. P.JimenezAleixandre (Eds.), *Argumentation in science education: Perspectives from classroom-based research* (pp. 179–199). Dordrecht: Springer

Strauss, A., & Corbin, J. (1990). *Basics of qualitative research*. Newbury Park, CA: Sage

Sutcliffe, H. (2011). *A report on responsible research and innovation*. Brussels: Matter

Zeidler, D. L., Walker, K. A., Ackett, W. A., & Simmons, M. L. (2002). Tangled up in views: Beliefs in the nature of science and responses to socioscientific dilemmas. *Science education*, *86*(3), 343-367.

EXPLORING ASPECTS OF PRE-SERVICE PRIMARY TEACHERS' EPISTEMIC COGNITION WHILE DEALING WITH A SOCIO-SCIENTIFIC ISSUE: A THINK-ALOUD STUDY

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Framed within the literature of epistemic cognition and multiple-text comprehension, this mixed-method study explores aspects of pre-service primary teachers' epistemic cognition which are enacted while they are dealing with the socio-scientific issue of autonomous vehicles; and whether these aspects are connected to the comprehension and integration of multiple sources. Specifically, 20 pre-service primary teachers were asked to think aloud during a critical reading task, which resembles the real situation of dealing with available controversial information on the internet with regard to this issue. Afterwards, they were asked to form their own critical question and justify its significance regarding the socio-scientific issue, and further answer two integrative short-essay questions. Think-aloud protocols were audio-recorded, transcribed and coded through qualitative content analysis. Three coding rubrics were developed to score participants' critical question and their responses to the integrative questions. Data analyses indicated that many aspects of participants' epistemic cognition enacted while dealing with the SSI, mainly with regard to their justification for knowing, epistemic monitoring and source evaluation, and less with regard to their underlying epistemic beliefs. Furthermore, evidence that participants' epistemic cognition can support or hinder their engagement with the SSI were found. Addressing pre-service primary teachers as both learners and future teachers, it is crucial that we understand how they think about knowledge and knowing within the context of a controversial issue, in order to help them improve their epistemic cognition through tertiary education.

Keywords: epistemic cognition, socio-scientific issues, think-aloud protocols.

INTRODUCTION

In every corner of the world, people often encounter complex and conflicting information in their everyday lives regarding challenging issues, such as human causes of climate change, applications of artificial intelligence and consumption of genetically modified food (Greene & Yu, 2016). Such issues that evolve from the interaction of science and society have been called socio-scientific issues (SSIs) and are difficult for people to deal with, because they are open-ended and ill-structured problems, and consequently, subject to multiple perspectives (see Sadler & Zeidler, 2005). In order to understand and negotiate these issues, people need to understand science and integrate information from multiple sources, including contradictory information and claims, which appear to be very challenging especially for students (Bråten, Britt, Strømsø, & Rouet, 2011; Sinatra, Kienhues, & Hofer, 2014). Even though there are different lines of theory and research in educational research (e.g., scientific, reading and digital literacy) which use different terminology, there is a common interest in exploring learners' higher order cognitive processes which are involved when they engage in these issues (Greene, Sandoval, & Bråten, 2016; Sinatra et al., 2014). A growing body of theory and interdisciplinary research converge on the importance of epistemic cognition in understanding science and engaging in such controversial issues (see Greene & Yu, 2016).

Epistemic cognition "concerns how people acquire, understand, justify, change and use knowledge in formal and informal contexts" (Greene et al., 2016, p. 1); and it includes various aspects, such as epistemic dispositions, beliefs and skills with regard to how people determine what they actually know, believe or doubt (Greene & Yu, 2016). Consequently, when people are confronted with SSIs in their everyday lives, their epistemic cognition affects implicitly how they understand and interpret the available information, and further, whether they integrate different perspectives into a coherent representation of the issue (Bråten, Anmarkrud, Brandmo, & Strømsø, 2014; Bråten et al., 2011; Ferguson & Bråten, 2013; Sinatra et al., 2014). In more detail, according to Bråten et al.'s (2011) review, learners' epistemic beliefs, that is their beliefs about the nature of knowledge and knowing, play an important role in their comprehension of multiple sources and integration of different points of view when they are asked to participate in reading tasks. For example, students who view knowledge about a scientific topic as complex and tentative (more adaptive beliefs), it is more likely to engage in getting an overview of different perspectives, than students who view knowledge as certain, simple and isolated facts (less adaptive beliefs). However, most research has approached epistemic cognition through the construct of epistemic beliefs, by applying self-report questionnaires and interviews especially within the context of research in multiple-text comprehension (Bråten et al., 2011), followed by numerous limitations (Mason, 2016).

More recent studies have conceptualised epistemic cognition as a broader set of cognitive processes than merely epistemic beliefs, and approach it through think-aloud protocols, (Chevrier, Muis, Trevors, Pekrun, & Sinatra, 2019; Cho, Woodward, & Li, 2018; Greene, Yu, & Copeland, 2014), but there are no studies looking for connections between epistemic cognition and multiple-text comprehension in such terms, as far as we know. By adopting an integrative theoretical framework, this study aims to contribute to this growing body of knowledge by exploring aspects of pre-service primary teachers' epistemic cognition through think-aloud protocols, while dealing with a SSI within the context of a critical reading task; and further, examine whether these aspects are connected to the comprehension and integration of multiple sources. Based on an extensive literature review and after taking into account various terminology issues within this interdisciplinary field (for a review, see Greene et al., 2016), this study integrated many existing frameworks in order to define epistemic cognition (Barzilai & Weinstock, 2015; Chevrier et al., 2019; Chinn & Rinehart, 2016; Cho et al., 2018; Feucht, 2011; Greene & Yu, 2016; Greene et al., 2014; Hofer & Pintrich, 1997; Kuhn & Weinstock, 2002). Hence, epistemic cognition conceptualised as a broad set of cognitive processes and beliefs associated with the nature of knowledge and knowing regarding this SSI, including epistemic aims, epistemic beliefs, epistemic monitoring, justification for knowing and source evaluation.

Given that most studies have focused on biological and environmental SSIs, the SSI of this study derived from the field of artificial intelligence and pertains to whether autonomous vehicles (AVs) could replace human-driven vehicles (Fagnant & Kockelman, 2015). The research questions guided this study are following:

1. What aspects of pre-service primary teachers' epistemic cognition are enacted while they are participating in a critical reading task?
2. Are pre-service primary teachers' aspects of epistemic cognition connected with their comprehension and integration of multiple sources?
3. Are there any patterns in pre-service teachers' responses with regard to their epistemic cognition and multiple-text comprehension and integration within the context of the SSI?

METHOD

Participants and research design

Twenty pre-service primary teachers (16 female and 4 male) from three universities in Greece participated in this mixed-method study (Creswell, 2015; Johnson & Onwuegbuzie, 2004), during the spring semester of the academic year 2018-2019. This study is part of a larger research project in which participants participated in a set of pre and post assessments. During this study, participants were attending their last year of undergraduate studies and their mean age was 23.45 years (*SD* = 1.79). All of them had already attended at least three university courses in natural sciences (e.g., physics and computer science). Participants were recruited from regular lectures and participated in this study voluntarily, by adopting convenience sampling (Creswell, 2015).

Measures and procedures

Data were collected through think-aloud protocols (Ericsson & Simon, 1993; Mason, Ariasi, & Boldrin, 2011), the production of a critical question regarding the SSI and the justification of its significance (Cho et al., 2018), and two integrative short-essay questions (Ferguson & Bråten, 2013; Rukavina & Daneman, 1996), within the context of a critical reading task about the SSI of AVs.

In more detail, each and every participant met the first author in an educational laboratory in order to take part in this study individually. Initially, participants were trained how to think aloud and construct a good question for another SSI, that is, the use of drones. The training process endured around 15 minutes. Afterwards, they took part in the critical reading task and were asked to think aloud while reading an introduction and six sources for the SSI of AVs in order to construct their own critical question; and further, justify why they think that their question is an important one for this issue. In total, four empirical studies and two articles published in a scientific website about the AVs were the multiple sources included in the critical reading task, after having been adjusted into the Greek language by the first two authors (for a brief overview of the six sources, see Table 1).

Table 1. Overview of the six documents (multiple sources)

Type of document	Publisher	Author(s) (year of publication)	Content	Number of words into Greek
1. Empirical study	Risk Analysis	Brell, Philipsen, & Ziefle (2019)	Authors investigated German citizens' perceptions of autonomous vehicles, indicating more negative perceptions.	672
2. Empirical study	Safety Science	Hulse, Xie, & Galea (2018)	Authors investigated British citizens' perceptions of autonomous vehicles, indicating more positive perceptions.	603
3. Technical report	University of Michigan Transportation Research Institute	Schoettle & Sivak (2015)	Authors investigated the crashes of conventional and autonomous vehicles, arguing that autonomous vehicles are not safe at present.	587
4. Empirical study	Journal of Safety Research	Teoh & Kidd (2017)	Authors investigated the crashes of conventional and autonomous vehicles, arguing that autonomous driving can be considered safer that conventional.	663
5. Philosopher's article in a scientific website	The Conversation	Evans (2018)	Author stresses the importance of ethics in the field of autonomous driving and argues that autonomous vehicles are not ready to be used on public roads at present.	759
6. Mechanic's article in a scientific website	The Conversation	McDermid (2019)	Author argues that programming ethics in autonomous vehicles is rather impossible based on the current technology; and focuses on improving the safety of these vehicles.	758

By applying a critical reading task, this study attempted to avoid restricting participants in the common practice of asking them to construct arguments and counterarguments; it is crucial that we trigger them take part in this public discussion as citizens and think critically in order to construct a meaningful question. After finishing this task, participants were asked to answer the following direct and indirect integrative questions for the SSI within a short essay: 1) Please, explain the potential benefits and risks that autonomous vehicles will have on public roads (direct); 2) Could autonomous vehicles replace human-driven vehicles in public roads? Please, justify your answer (indirect).

Data analysis

After asking for their consent, participants' verbal reports from their engagement in the critical reading task were audio-recorded and transcribed, resulting in 20 think-aloud protocols (*Mean time* = 52.06 min, *SD* = 13.35; *min* = 25.57 min, *max* = 71.07 min). Think-aloud protocols were coded through qualitative content analysis (Hsieh & Shannon, 2005; Mayring, 2000) by using the Atlas.ti software. Specifically, each protocol was divided into codable segments and the units of analysis defined to be the segments captured the meaning of participants' thoughts or actions (Chi, 1997). The first two authors developed a coding scheme based on a sample of eight participants and relevant literature (Barzilai & Weinstock, 2015; Chevrier et al., 2019; Chinn & Rinehart, 2016; Cho et al., 2018; Greene et al., 2014), through a recursive process (for an overview of the coding scheme, see Table 2). Afterwards, the first author applied this coding scheme to all protocols. Finally, the second author coded independently five protocols and the intercoder agreement was 92%.

Table 2. Coding scheme for think-aloud protocols

Families	Codes	Description
Epistemic aims	Information	Participant simply wants to acquire information without judging whether it is sufficiently warranted.
	Knowledge	Participant states that she/he wants to "know" facts with either the explicit or implicit indication that sufficient warrant/justification is also required.
	Understanding	Participant's goal is to have deep knowledge of not only facts but also warrants for how processes work (if relevant), etc.
Epistemic beliefs	Certainty*Absolutism	Knowledge (about this topic) is certain/can be obtained with certainty.
	Certainty*Multiplism	Knowledge (about this topic) is uncertain and subjective/cannot be obtained with certainty.
	Certainty*Evaluativism	Knowledge (about this topic) cannot be obtained with certainty but it is possible to improve the degree of certainty/evolving and tentative nature of knowledge/ varying degrees of certainty.
	Knowledge is context specific	Participant implies that knowledge is seen as highly contextualised or situated.
	Knowledge is complex	Participant implies that knowledge is seen as a set of highly interconnected complex knowledge claims.
Justification for knowing	Establishing multiple justification	Participant established a warrant for a claim or denies a claim based upon the support of multiple sources of justification (e.g., testimony, coherence, rationality), or evaluates a claim as knowledge based upon the support of multiple sources of justification (e.g., testimony, coherence, rationality) but without definitive conclusion.
	Justification by personal perception	Participant uses one of her/his five senses as warrant for claim as knowledge, or a reason to disregard claim as knowledge, or to evaluate claim as knowledge but without definitive conclusion.
	Justification by rationality/logic/reasoning	Participant establishes warrant for claim or denies a claim based upon thinking, logic, reasoning, or evaluates claim as knowledge based upon thinking, logic, or reasoning but without definitive conclusion.
	Justification by authority/testimony	Participant establishes a warrant for a claim or denies a claim based upon the views/arguments/beliefs of someone that she/he believes is an authority on the matter, or evaluates claim as knowledge based upon the views/arguments/beliefs of someone that he/she believes is an authority on the matter but without definitive conclusion.
	Tentative justification	Stating confidence or likelihood about the veracity of a knowledge claim without definitively accepting it, or stating doubt or unlikelihood about the veracity of a knowledge claim without definitively denying it, or stating that a particular knowledge claim is "possibly" or "tentatively" justified true belief without indication of a strong tendency either for or against its veracity.
Source evaluation	Source evaluation (plus)	Statements indicate that the participant is investigating the quality of the source of a knowledge claim and the source in question can be considered trustworthy for providing knowledge claims whose veracity is high.
	Source evaluation (minus)	Statements indicate that the participant is investigating the quality of the source of a knowledge claim and the source in question cannot be considered trustworthy for providing knowledge claims whose veracity is high.
	Source evaluation (neutral)	Statements indicate that the participant is investigating the quality of the source of a knowledge claim. Despite clearly evaluating the source, no definitive claim is made regarding its trustworthiness for providing knowledge claims whose veracity is high.
	Inferring author bias	Participant indicates a source of knowledge may be biased in some way.
Epistemic monitoring	Active meaning making	Perception of the role of the reader in meaning making and demonstration of an active role in knowledge creation.

Passive information receiving	Acritical orientation to seeking and gaining information and to accepting information as true without judgment.
Integration of multiple perspectives/ sources	Evaluating, comparing and contrasting claims made across multiple sources; providing explanations to account for differences between the various perspectives.

By following equal coding procedures and based on relevant literature (Andresen, Anmarkrud, Salmerón, & Bråten, 2019; Cho et al., 2018; Latini, Bråten, Anmarkrud, & Salmerón, 2019), the first two authors also developed three rubrics (see Table 3) ranging from 0 to 3, in order to score participants' responses to the critical question and its justification, and the two integrative questions (the intercoder agreement for the critical question was: 93%; for the first integrative question: 87%; and for the second integrative question: 94%). All discrepancies were discussed and resolved among the three authors, resulting in 100% intercoder agreement.

Table 3. Rubrics for coding critical question and justification, and integrative short-essay questions

Score	Critical Question & Justification	1st Question (direct)	2nd Question (indirect)
0	Irrelevant question	Irrelevant information	Irrelevant information
1	Question is relevant with the SSI and has logical soundness. However, the justification of the question does not indicate its rationale and significance in order to extend the discussion on the SSI.	Mentioning benefits and risks as a numbered list (without writing a paragraph).	Mentioning one perspective with a brief explanation (the positive or the negative one).
2	**A:** Question is relevant with the SSI and has logical soundness by justifying its rationale with an elaborated explanation. However, the significance of the question in order to extend the discussion on the SSI is not included. **B:** Question is relevant with the SSI and indicates some significance in order to extend the discussion on the SSI. However, the question has low logical soundness without clearly justifying its rationale.	Mentioning benefits and risks (in a paragraph) by adding some more personal thoughts on the given sources without providing further explanations.	**A:** Mentioning both perspectives with an (elaborated) explanation of the one aspect. **B:** Mentioning one perspective with an elaborated explanation of the one perspective (and usually an implicit reference to the second perspective).
3	Question is relevant with the SSI and has logical soundness by justifying its rationale with an elaborated explanation. Also, the significance of the question in order to extend the discussion on the SSI is included.	Mentioning benefits and risks (in a paragraph) with elaborated explanations and further integration of both aspects by comparing and/or contrasting them and trying to reconcile them by demonstrating that they must not be mutually exclusive.	Mentioning both perspectives with elaborated explanations and further integration of both perspectives by comparing and/or contrasting them and trying to reconcile them by demonstrating that they must not be mutually exclusive.

RESULTS

Think-aloud protocols: Aspects of epistemic cognition and integration of multiple sources

Following the first research question, it is noted that all aspects of epistemic cognition found in participants' think-aloud protocols, more or less frequently, as it is depicted in the Table 4.

Table 4. Aspects of epistemic cognition and integration of multiple sources

Aspects	Number of participants	Total frequencies
Epistemic aims	**9**	**18**
Information	5	9
Knowledge	2	2
Understanding	5	7
Epistemic beliefs	**20**	**90**
Certain knowledge (Certainty*Absolutism)	4	4
Uncertain knowledge (Certainty*Multiplism)	10	13
Degrees of certainty (Certainty*Evaluativism)	11	22
Complex knowledge	14	23
Context-specific knowledge	12	28
Justification for knowing	**20**	**188**
By personal perception	19	108
By rationality/logic/reasoning	15	44
By authority/testimony	13	18
Tentative justification	6	7
Establishing multiple justifications	8	11
Source evaluation	**17**	**71**
Source evaluation (plus)	8	16
Source evaluation (minus)	7	14
Source evaluation (neutral)	16	30
Inferring author bias	8	11
Epistemic monitoring	**20**	**379**
Active meaning making	20	340
Passive information receiving	10	39
Integration of multiple perspectives/sources	**18**	**60**

Scores in critical question and its justification, and the integrative questions

Table 5 presents the scores for each and every participant regarding the critical question and its justification, the two integrative questions and in total.

Table 5. Participants' scores in critical question and its justification, the integrative questions and in total

	Participants																			
	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th	11th	12th	13th	14th	15th	16th	17th	18th	19th	20th
Critical Question	2	3	2	3	3	2	2	2	1	3	2	3	2	3	0	2	1	2	3	3
1st Question	2	3	2	2	3	2	1	1	1	3	1	2	2	2	1	2	1	1	2	3
2nd Question	2	2	2	0	2	3	3	1	2	2	1	2	3	1	1	3	1	2	1	3
Total	**6**	**8**	**6**	**5**	**8**	**7**	**6**	**4**	**4**	**8**	**4**	**7**	**7**	**6**	**2**	**7**	**3**	**5**	**6**	**9**

Connections between aspects of epistemic cognition and multiple-text comprehension and integration

Addressing together the second and third research question, some preliminary connections between the aspects of participants' epistemic cognition and their scores in multiple-text comprehension and integration were detected. What follows is a short description of the detected patterns in conjunction with specific quotations derived from the think-aloud protocols and written responses of two participants as representative examples.

In more detail, participants with the lowest total scores (i.e. 4th, 9th, 11th, 15th, and 17th participants, see Table 5) often articulated the epistemic aim of information and referred to total uncertainty, complexity and context-specific nature of knowledge. Also, they justified their claims by using their personal perception and rationality/logic/reasoning frequently. During the task, they also made meaning actively in a very intense way, while they often received information passively. Finally, they often evaluated the sources negatively or in neutral terms; and rarely attempted to integrate knowledge claims from different perspectives and sources.

In contrast, participants with the highest total scores (i.e. 2nd, 5th, 6th, 10th, and 20th participants, see Table 5) often stated epistemic aims such as knowledge and understanding, and referred to the improving degree of certainty, complexity and context-specific nature of knowledge. Furthermore, they justified their claims by using testimony and authority figures and/or by establishing multiple justifications very frequently. During the task, they also made meaning actively in many cases and evaluated the sources positively or in neutral terms. Finally, they frequently attempted to integrate knowledge claims from different perspectives and sources.

There are following two examples of participants' verbalisations during their participation in the critical reading task in combination with their written responses to the critical question and its justification, and the indirect integrative question; in order to give an overview of potential patterns from their way of thinking and acting. These two examples are representative of the participants with low and high total scores mentioned above. Specifically, there are following three extracts from the 15th participant's think-aloud protocol with regard to different aspects of epistemic cognition:

(She was reading) Also, I think that it is very dangerous. I know people who had such kinds of cars and they couldn't escape from them, and there was also a case in which the car was on fire and they couldn't open it." (justification by personal perception)

(She was reading) Young adults are dangerous with every vehicle in general. Their acceptance shouldn't be taken so seriously. (She was reading) Oh, the text agrees with me. Nice! (active meaning making) (She was reading) Also, it surprises me, because every source mentions one country. And every question is answered by different country. Germans have different roads, different law, different care. England is a different case, Greece is a different case, Danes as well. Their positionality is not right. (knowledge is context-specific; source evaluation [minus])

(She was reading) It would be wrong; indeed, it is wrong for a car to think like that. (passive information receiving)

Furthermore, her critical question with regard to the SSI and her response to the indirect integrative question are following:

Are there desirable all these that scientists want to try at times? Is the technology for the human or the human for the technology? I think that all thoughts about everything that the technology wants to insert in our everyday life start from there. (Score: 0)

(Could autonomous vehicles replace human-driven vehicles in public roads? Please, justify your answer.) According to my experience and the way that my opinion has been formed so far, no. There are no infrastructure and education, and they could not replace them. The only thing that I can think is their own road network that would look like the trains one. So, this makes me think that we don't really need them and that we shouldn't be involved in something that appears to bring additional dangers. (Score: 1)

Similarly, there are following four extracts from the 20th participant's think-aloud protocol with regard to different aspects of epistemic cognition:

(She was reading) According to things that I had read in Thessaly's sites, people were scared and could not accept "the different" because it is something different for the norms of Thessaly. But I think that younger and more open-minded people accepted it more positively than the older ones, who have more traditional perceptions and they are not ready to try different things and accept them. (establishing multiple justifications)

(She was reading) Okay, I am interested in learning more about the advantages, for which as I said, my personal opinion is that there will be, for sure, but I would like to read them in depth. And maybe this will help me, this process. (epistemic aim: understanding)

(She was reading) Yes, sure, the passenger has different perception, it is possible for her/him to fear the first time that will use it (an AV). As for the pedestrian, she/he considers it to be less dangerous, because she/he has more control. I think it makes sense. (integration; justification by rationality)

(She was reading) Okay, so, according to this study, they are considered safer in some way than the conventional cars, but the situation should progress in order to make more certain conclusions. (justification by authority; degrees of certainty)

Finally, her critical question with regard to the SSI and its justification, and her response to the indirect integrative question are following:

In order to acquire more adequate data that will be used in studies to prove the safety of AVs, there will be a transitional period, in which the two kinds of vehicles should be driven at the same network. Could the AVs and conventional vehicles coexist harmoniously? I consider this question as very important, because this issue has not been addressed yet in public discussions about AVs; and it could cause concerns about the risks of this transitional period. (Score: 3)

(Could autonomous vehicles replace human-driven vehicles in public roads? Please, justify your answer.) They (AVs) could replace them. However, this is something that requires time and work from experts. I believe that it will take many years before this situation becomes reality. ... Consequently, people, despite their concerns, should keep up with the spirit of the times and be more receptive. (Score: 2)

DISCUSSION & CONCLUSIONS

Overall, think-aloud protocols revealed many aspects of pre-service primary teachers' epistemic cognition in action, mainly with regard to their justification for knowing, epistemic monitoring and source evaluation; and less with regard to their epistemic beliefs which may underlie these cognitive processes. Hence, this study provides evidence that support the broader conceptualisation of epistemic cognition proposed in the literature (Chinn & Rinehart, 2016; Greene et al., 2014; Greene et al., 2016). However, it is likely that participants have beliefs that they did not verbalise during the task and it is crucial that further research attempt to clarify more these aspects of epistemic cognition, likely by also applying cognitive interviewing. Additionally, the kind of the applied task could be an important factor that guided participants to pay more attention to justification issues, without eliciting their typical reading behaviours (e.g., on the internet).

Furthermore, participants with the highest scores in multiple-text comprehension and integration found to a) state their epistemic aims while participating in the critical reading task; b) establish multiple justifications of knowledge claims with reference to authorities, their personal perception and reasoning; c) evaluate the trustworthiness of the provided sources; and d) integrate knowledge claims from different sources. In this respect, this study extends the existing literature (Bråten et al., 2014; Greene & Yu, 2016; Sinatra et al., 2014) which claims that learners' epistemic cognition can support or hinder their engagement with SSIs through their capability to integrate multiple and usually contradictory perspectives into a coherent representation of the issue. However, the results of this study should be interpreted with caution given the rather small sample size especially in terms of statistical analysis. Further research with representative samples is needed to replicate the usefulness of the coding scheme and rubrics, as well as these preliminary findings.

In conclusion, given that pre-service primary teachers at the last year of their undergraduate studies are young adults who have already faced SSIs in today's epistemologically challenging society, it is imperative that support them learn how to make informed decisions for themselves and others, including their future students. If epistemic cognition is the key in decision-making with regard to challenging issues, then more studies should focus on how tertiary education could change to include aspects of epistemic cognition in pre-service teachers' preparation, through both the applied curricula and instruction (Greene et al., 2016; Sinatra et al., 2014).

ACKNOWLEDGEMENT

Part of this research work was supported by the Hellenic Foundation for Research and Innovation (HFRI) under the HFRI PhD Fellowship grant (Fellowship Number: 231) which is allocated to the second author.

REFERENCES

Andresen, A., Anmarkrud, Ø., Salmerón, L., & Bråten, I. (2019). Processing and learning from multiple sources: A comparative case study of students with dyslexia working in a multiple source multimedia context. *Frontline Learning Research, 7*(3), 1-26. doi: 10.14786/flr.v7i3.451

Barzilai, S., & Weinstock, M. (2015). Measuring epistemic thinking within and across topics: A scenario-based approach. *Contemporary Educational Psychology, 42*, 141-158. doi: 10.1016/j.cedpsych.2015.06.006

Bråten, I., Anmarkrud, Ø., Brandmo, C., & Strømsø, H. I. (2014). Developing and testing a model of direct and indirect relationships between individual differences, processing, and multiple-text comprehension. *Learning and Instruction*, *30*, 9–24. doi: 10.1016/j.learninstruc.2013.11.002

Bråten, I., Britt, M. A., Strømsø, H. I., & Rouet, J.-F. (2011). The role of epistemic beliefs in the comprehension of multiple expository texts: Toward an integrated model. *Educational Psychologist*, *46*(1), 48–70. doi: 10.1080/00461520.2011.538647

Brell, T., Philipsen, R., & Ziefle, M. (2019). sCARy! Risk Perceptions in Autonomous Driving: The Influence of Experience on Perceived Benefits and Barriers. *Risk Analysis*, *39*(2), 342–357. doi: 10.1111/risa.13190

Chevrier, M., Muis, K. R., Trevors, G. J., Pekrun, R., & Sinatra, G. M. (2019). Exploring the antecedents and consequences of epistemic emotions. *Learning and Instruction, 63*. doi: 10.1016/j.learninstruc.2019.05.006

Chi, M. T. H. (1997). Quantifying qualitative analyses of verbal data: A practical guide. *The Journal of the Learning Sciences, (6)*3, 271-315.

Chinn, C. A., Rinehart, R. W. (2016). Epistemic cognition and philosophy: Developing a new framework for epistemic cognition. In J. A. Greene, W. A. Sandoval, and I. Bråten (Eds.), *Handbook of epistemic cognition* (pp. 460–478). New York, NY: Routledge.

Cho, B. Y., Woodward, L., & Li, D. (2018). Epistemic processing when adolescents read online: A verbal protocol analysis of more and less successful online readers. *Reading Research Quarterly, 53*(2), 197–221. doi: 10.1002/rrq.190

Creswell, J. W. (2015). *Educational research: planning, conducting, and evaluating quantitative and qualitative research* (5th ed.). Boston: Pearson.

Ericsson, K. A., & Simon, H. A. (1993). *Protocol analysis: Verbal reports as data* (Revised ed.). Cambridge, MA: MIT Press.

Evans, N. G. (2018, March 27). Self-driving cars can't be perfectly safe – what's good enough? 3 questions answered. *The Conversation: Academic rigour, journalistic flair*. Retrieved from https://theconversation.com/self-driving-cars-cant-be-perfectly-safe-whats-good-enough-3-questions-answered-92331

Fagnant, D. J., & Kockelman, K. (2015). Preparing a nation for autonomous vehicles: Opportunities, barriers and policy recommendations. *Transportation Research Part A: Policy and Practice*, *77*, 167–181. doi: 10.1016/j.tra.2015.04.003

Ferguson, L. E., & Bråten, I. (2013). Student profiles of knowledge and epistemic beliefs: Changes and relations to multiple-text comprehension. *Learning and Instruction*, *25*, 49–61. doi: 10.1016/j.learninstruc.2012.11.003

Feucht, F. C. (2011). The epistemic underpinnings of Mrs. M's reading lesson on drawing conclusions: A classroom-based research study. In J. Brownlee, G. Schraw, and D. Berthelsen (Eds.), *Personal epistemology and teacher education* (pp. 227–245). New York: Routledge.

Greene, J. A., Sandoval, W. A., Bråten, I. (2016). An introduction to epistemic cognition. In J. A. Greene, W. A. Sandoval, and I. Bråten (Eds.), *Handbook of epistemic cognition* (pp. 1–16). New York, NY: Routledge.

Greene, J. A., & Yu, S. B. (2016). Educating critical thinkers: The role of epistemic cognition. *Policy Insights from the Behavioral and Brain Sciences*, *3*(1), 45–53. doi: 10.1177/2372732215622223

Greene, J. A., Yu, S. B., & Copeland, D. Z. (2014). Computers & Education Measuring critical components of digital literacy and their relationships with learning. *Computers & Education*, *76*, 55–69. doi: 10.1016/j.compedu.2014.03.008

Hofer, B. K., & Pintrich, P. R. (1997). The development of epistemological theories: beliefs about knowledge and knowing and their relation to learning. *Review of Educational Research, 67*(1), 88-140. doi: 10.3102/00346543067001088

Hsieh, H.-F., & Shannon, S. E. (2005). Three approaches to qualitative content analysis. *Qualitative Health Research, 15*(9), 1277–1288. doi: 10.1177/1049732305276687

Hulse, L. M., Xie, H., & Galea, E. R. (2018). Perceptions of autonomous vehicles: Relationships with road users, risk, gender and age. *Safety Science*, *102*, 1–13. doi: 10.1016/j.ssci.2017.10.001

Johnson, R. B., & Onwuegbuzie, A. J. (2004). Mixed methods research: A research paradigm whose time has come. *Educational Researcher, 33*(7), 14–26. doi: 10.3102/0013189x033007014

Kuhn, D., & Weinstock, M. (2002). What is epistemological thinking and why does it matter? In B. K. Hofer & P. R. Pintrich (Eds.), *Personal epistemology: The psychology of beliefs about knowledge and knowing* (pp. 121-144). Mahwah, NJ: Erlbaum.

Latini, N., Bråten, I., Anmarkrud, Ø., & Salmerón, L. (2019). Investigating effects of reading medium and reading purpose on behavioural engagement and textual integration in a multiple text context. *Contemporary Educational Psychology, 59*. doi: 10.1016/j.cedpsych.2019.101797

Mason, L. (2016). Psychological perspectives on measuring epistemic cognition. In J. A. Greene, W. A. Sandoval and I. Bråten (Eds.), *Handbook of epistemic cognition* (pp. 375-392). New York, NY: Routledge.

Mason, L., Ariasi, N., & Boldrin, A. (2011). Epistemic beliefs in action: Spontaneous reflections about knowledge and knowing during online information searching and their influence on learning. *Learning and Instruction*, *21*(1), 137–151. doi: 10.1016/j.learninstruc.2010.01.001

Mayring, P. (2000). Qualitative content analysis. *Forum: Qualitative Social Research*, *1*(2). doi: 10.17169/fqs-1.2.1089

McDermid, J. (2019, January 24). Self-driving cars: why we can't expect them to be 'moral'. *The Conversation: Academic rigour, journalistic flair*. Retrieved from https://theconversation.com/self-driving-cars-why-we-cant-expect-them-to-be-moral-108299

Rukavina, I. & Daneman, M. (1996). Integration and its effect on acquiring knowledge about competing scientific theories from text. *Journal of Educational Psychology, 88*(2), 272-287.

Sadler, T. D., & Zeidler, D. L. (2005). The significance of content knowledge for informal reasoning regarding socioscientific issues: Applying genetics knowledge to genetic engineering issues. *Science Education*, *89*(1), 71–93. doi: 10.1002/sce.20023

Sinatra, G. M., Kienhues, D., & Hofer, B. K. (2014). Addressing challenges to public understanding of science: epistemic cognition, motivated reasoning, and conceptual change. *Educational Psychologist*, *49*(2), 123–138. doi: 10.1080/00461520.2014.916216

Schoettle, B., & Sivak, M. (2015). *A preliminary analysis of real-world crashes involving self-driving vehicles* (Report no. UMTRI-2015-34). Retrieved from University of Michigan Transportation Research Institute website: http://www.umich.edu/~umtriswt/PDF/UMTRI-2015-34.pdf

Teoh, E. R., & Kidd, D. G. (2017). Rage against the machine? Google's self-driving cars versus human drivers. *Journal of Safety Research*, *63*, 57–60. doi: 10.1016/j.jsr.2017.08.008

HOW DO PRIMARY PRE-SERVICE TEACHERS ASSESS CIRCUS WITH ANIMALS AND ITS EDUCATIONAL VALUE? A STUDY WITH PORTUGUESE, SPANISH AND GREEK STUDENTS

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This study aimed to check the opinion of primary pre-service teachers about circus with animals, including if they recognize any educational value in this type of show and how they assess the animals' treatment in this place. For that, a questionnaire with open and closed questions was administered at the beginning of the school year of 2018/2019 in three higher education institutions, one in Portugal, one in Spain and one in Greece. Among students of the different countries, the results were very similar, and the participants tend to consider that this show has no educational or even recreational interest for children, mainly based on arguments centred on animals. Therefore, they considered that this show mutilates animals' welfare, but one third of the participants showed difficulties in assessing how animals are treated in certain aspects. The results suggest that in their future practice the majority of the students will not convey an uncritical view of this show to their pupils. Even so, only a few Portuguese students recognize the value of circus as a controversial issue to be explicitly approached in class, a reason that could be related to the syllabus content of Didactic of Science, a curricular unit in their course plan.

Keywords: Pre-service teachers, Human-Animals Relationship, Circus

INTRODUCTION

In Science Education the discussion of socio-scientific issues, most of them controversial, is a way to develop students' critical thinking. Therefore, socio-scientific issues are informed by scientific knowledge, involve forming opinions, are frequently media reported and involve values and ethical reasoning (Ratcliffe & Grace, 2003). In the absence of these issues in the curriculum, the awareness of a role as a world citizen is somehow missing.

Human relationship with other animals involves several controversial issues, including performing that seems to be an interdisciplinary point of interest (Grant, Ramos Gay, & Alonso Recarte, 2018), and is a relevant theme in Science Education. There are a number of educational arguments in favour of students undertaking such considerations. Such teaching, apart from its value in learning science issues might: a) heighten the ethical sensitivity of students, b) increase the ethical knowledge of students, c) improve the ethical judgment of students, and d) make students better people in the sense of making them more virtuous or otherwise more likely to implement normatively right choices (Reiss, 2017). However, it has not always received the relevance it deserves, at least in the countries where the present study was developed. And even knowing that several non-profitable associations and also political parties are putting animal issues in the agenda, socio-scientific issues centred on science and technology impacts are more often more selected for discussion (see, for instance, Easton, 2009). Also, environmental education seems to be more focused on other topics. According to Reingard (2016), animal welfare and the care for the environment have taken separate ways, with their own agendas and groups, and also with a dissimilar social and political impact.

The behaviour of teachers during the approach of controversial issues also motivates discussion, especially if they should or not take a position in class. Common knowledge tells us that, teachers are not neutral during their teaching-learning process and tend to transmit their values to pupils in an explicit or implicit way. For instance, a study done by Almeida (2011), involving teachers from the Lisbon area (Portugal), found that the majority of them did not consider the existence of zoos a controversial issue, and the same in the case of the use of animals in cultural acts, even though in a less expressive trend. But if this kind of issues is not considered as controversial, probably an instrumental view of other animals, which includes the assumption that they deserve less moral consideration than humans, is transmitted, since it has been the dominant perspective in the western thought (Steiner, 2005).

In fact, during centuries, animals have been seen in an instrumental way and they have been used for different human purposes, including fun. But according to Franklin (2008), since the sixties, the idea that we can use animals for any human purpose is changing as a result of the emergence of several animal movements. The development of scientific knowledge in the fields of physiology, animal behaviour and animal cognition also helps to this change, since it has allowed a better understanding of the negative impact of certain human uses of animals. According to Bekoff and Bekoff (2017) science can not produce obvious moral 'outputs', but it can inform our ethical judgments and behaviours.

Circus with animals is a show created for humans, an American invention with roots in Roman public exhibitions and medieval travelling exhibitions (DeMello, 2012). However, the use of wild animals has been especially criticized due to several reasons: their welfare lives are affected due to an inadequate diet, poor house conditions, health problems related to the effect of repeated performances, physical and emotional punishment suffering during their training and having to travel constantly in cages (Iossa, Soulsbury, & Harris, 2009). Dorning, Harris, and Pickett (2016) provide an impartial literature review based on scientific evidence of the impact on animals of travelling circuses and other animal performing acts. They highlight the following evidence that confirm the negative impact of these shows both physically and mentally: i) contact with small and poor environments; ii) inappropriate social conditions, as isolation of social groups; iii) difficulties in having adequate food; iv) impossibility to meet climatic and environmental needs of many species; v) submission to coercion, force and aggression; vi) physical deformities, injuries, lameness and psychological distress due to unnatural performances.

Aristotle is responsible for the idea that every living being has its own good only when its natural activity or function is achieved (telos). Based on this idea Rollin (2010) claims that the circus is responsible for the perversion of the *telos* of an animal, as it is possible to confirm with the above mentioned problems caused to animals.

As far as animals in circuses is concerned, to the best of our knowledge, educational research is rare and usually is a part of wider studies related to the use of animals. For example, Stanisstreet, Spofforth, and Williams (1997) found that more than half of a sample of 433 pupils, aged 11-16 years, objected to the use of animals in circuses and a major factor here was apparently the thought that circus activities demean animals. Similarly, Pagani, Robustelli, and Ascione (2007) investigated Italian youths' (9–18 years of age) attitudes and behaviours toward animals. Various aspects of child–animal relationships were analyzed, including the use of animals in circuses. In their findings they recorded that the majority of their sample (82% of the girls and 71% of the boys (difference statistically significant, $p<0.001$) was against the use of animals in circuses, with younger pupils, aged 9–10 years, being more often against the use of animals in circuses when compared with those aged between 11 and 18.

Therefore, the present study tried to identify the opinion of primary pre-service teachers from Portugal, Spain and Greece about the circus, including whether they recognize any didactic purpose in this kind of show. In fact, the circus can be seen as a way to promote children's contact with animals, allowing learning about them, and ignoring the main criticisms already presented. Also, it will be important to identify if at least a few of these negative impacts are recognized by the students and if they inform their opinions about this kind of show.

When the study was designed, the situation about the use of animals in circuses was different in the three countries. In Portugal, the use of wild animals in circuses was banned by law (after the starting of the present research project), and licenses for their use will expire within 6 years. During this transitional period circuses must move animals to rescue centres (Decreto-Lei nº 20/2019); In Spain, the use of wild animals is banned in certain autonomous regions and municipalities ("Nearly 300 Spanish towns," 2016); In Greece the use of animals in circuses was banned by Law nº 4039, 2012. In this country there are no national circuses and foreign circuses with animals are not allowed to perform (Euro group for animals, n.d.). Despite the ban, a dolphinarium was operated in a private zoo in Athens and till 2019 there were shows with dolphins, although high fines were imposed.

Even knowing that the legal situation in the three countries tends not to support this kind of show, the present study is still important for the following reasons: i) the contact with this kind of shows is still possible in Portugal and Spain and in a few border countries of Greece; ii) law and ethical positions are not exactly the same, as the changes in legislation along time have proved. Also, an activity that is illegal today can be made legal again tomorrow.

METHODS

The sample involved 94 Portuguese, 78 Spanish and 49 Greek primary pre-service teachers from three higher school institutions, almost all females, and the average age of the groups was, respectively, 23.4, 23.2 and 22.7 years old. The Portuguese institution was in an urban context; The Spanish and the Greek institutions were from smaller cities, in rural areas. The Greek one is also in a city near the border.

A questionnaire, validated by two experts from each country, was administered on line, using the Google drive tool, at the beginning of the school year of 2018/2019, more precisely in October. The administration was in the main language of each country (Portuguese, Spanish and Greek), but an English version was used during the design process and validation. With the Google drive tool, the students could only see the questions of the next section after answering the previous one, a possibility that was important to check the reliability of their ideas in different moments of the questionnaire. The different sections and questions are in Table 1. In section 1, the inclusion of different shows was a way to know students' opinion about the circus in a more dissimulated way; in the other sections, the questions were exclusively about the circus.

Table 1. The sections and questions of the questionnaire.

Sections	Questions
Section 1	In a scale from 1 to 5 indicate the degree of relevance of including the different shows of animals during primary school activities: exhibitions with birds of prey, circus, racing horses, pets' competitions, exhibitions with aquatic mammals. Justify.
Section 2	1. Have you ever seen a live circus show with animals? Yes No; 1.1. If you said yes, why did you go to this kind of show?
Section 3	1. Do you think that the circus with animals can be an educative show? Yes No. Justify; 2. The circus is a show that can use animals or not. Which kind of show is more relevant for children? a) Circuses with animals; b) Circuses without animals; c) Both kinds of circuses. Justify. 3. Is the circus an adequate place for animals? Yes No. Justify. 4. In your opinion, circuses should exhibit: a) All kinds of animals (wild and domestic ones); b) Only wild animals; c) Only domestic animals; d) Performances without animals. Justify.
Section 4	1. In general, animals in the circus…1.1 Are well fed ; 1.2 Do enough exercise; 1.3 Have their natural features respected; 1.4 Like to show themselves to the viewers; 1.5 Suffer physical and psychological abuse; 1.6 Are in general well treated (For all: Yes, No, Don't know)
Section 5	1. In your opinion, should the use of animals in circuses be forbidden? Yes No. Justify.

The relative frequency of the answers in section 1for each country was analyzed after the categorization of the justifications, including each category ideas which were considered similar. The content analysis of all the answers allowed to create three main categories: animal centred reasons, e.g. "Animals were kept in bad conditions", human centred reasons, e.g. "It could be a way to learn about exotic animals" and mixed reasons, e.g. "It has no educational value and animals are not in their habitats". A few mores examples of answers from these categories are included in the results section.

Two other categories were also created: other kind of reasons, especially those that were inclusive like "It is not good for children" or "I never thought about that", and Don´t know. With question of the questionnaire's first section, related to the circus, the Kruskal Wallis *H* test (inferential statistics) was used to check statically differences between the means obtained from the students of the three countries, concerning the different shows and exhibitions included in the questionnaire. The median for each show by country was also included.

The relative frequencies of the results of the questions from the other sections were also calculated.

RESULTS

In the question of the first section related to the circus, 73.4% of the Portuguese students, 74.3% of the Spanish and 76.3 of the Greek selected value 1 and 2 of the Likert scale, considering that the circus does not have any didactic interest, stating that animals are not in their habitat and are bad treated. Animal centred answers were almost exclusively given by those that value the circus very low, with a high relative percentage (65% in the Portuguese sample, 41.4% in the Spanish and 75.8% in the Greek). A few examples of these answers are “It is not suitable for children since the animals are abused and far from their environment” or “Animals suffer during the training”. Even so, the students from the three countries that value this show with 4 and 5 were 12.7% of the Portuguese sample, 9% of the Spanish and 13.1% of the Greek. In this selection, the arguments were almost exclusively human centred. The difference of the results for 100% is from those that selected value 3 in the Likert scale. The result of applying the Kruskal Wallis *H* test showed no statistical differences between the students of the three countries ($p = 0.412$). Just a few examples of students’ justifications: “At the end of the school period, it can be a leisure activity”, “Children enjoy seeing animals and the show can motivate them to research information about them”, “This show is a way to allow pupils to see exotic animals” or simply “It is a great show”. In the group of students that gave 3 (neutral position), 4 and 5 to the didactic relevance of the circus, some Portuguese students stated that it could be a relevant controversial issue to discuss with children, an argument not presented in the samples of the two other countries.

In Table 2 the median value obtained for each show by country in question 1 is compared.

Table 2. The comparison of the median values for the didactic value of the different shows obtained by the sample of each country.

	Portuguese Students	Spanish Students	Greek Students
Circus	1	1	1
Exhibitions with birds of prey	3	3	2
Racing horses	2.5	3	3
Pets’ competitions	1.5	2	3
Exhibitions with aquatic mammals	3	2.5	3.5

As it is possible to conclude, the circus was rated by the students of the three countries as the show with smaller didactic value for children in a set of five shows involving animals. Even so, the shows with aquatic animals have received much more recognition, and they can be considered very similar to circus acts.

Considering the section 2 of the questionnaire, 94.7% of the Portuguese students, 80.8 of the Spanish and 69.4% of the Greek had seen this kind of show live at least once. The reasons for attending this show were diverse. But in all the samples, families’ options were the main reason stated, and 20% of the Portuguese sample also mentioned that during primary school it was a common activity and few remembered that it was an offer from the town council. This kind of experience during primary school was only evoked by 2.6% of the Spanish and of the Greek students.

The educational value of the circus was considered irrelevant by 73.4% of the Portuguese students, by 67.4% of the Spanish and by 64.6% of the Greek, a result obtained in question 1 of section 3, percentage values quite similar to the ones obtained in the question of section 1 (Table 1). Even so, 15% of the Portuguese said it could be a way to learn about animals, a reason also stated by 14% of the Spanish and by 7% of the Greek. A few Portuguese students stated again the possibility of developing children's critical thinking, a reason absent among the Spanish and quite rear among the Greeks (2.3%).

Considering the presence of animals in circuses, section 3 – question 2 (Table 1), 73.4 of the Portuguese sample, 84.6% of the Spanish and 90% of the Greek were against it, evoking the bad welfare conditions given to animals. But considering the possibility of having wild, domestic or both types of animals in circuses, section 3 – question 3, near 12% of the Portuguese sample, near 7% of the Spanish and 10% of the Greek accepted the third possibility. For defending the circus with animals, the participants evoked mainly two reasons: it is a show that children like; it can only be acceptable if the animals are well treated.

In relation to the assessment of different aspects related to animals in the circus, section 4, the results are present in Table 3.

Table 3. The opinions of primary pre-service teachers about animals' circus conditions. For each statement is included the percentage of agreement (Yes, No and DK – Don't know).

1. In general, animals in the circus…	Portuguese students			Spanish students			Greek students		
Agreement…	Yes	No	DK	Yes	No	DK	Yes	No	DK
1.1 Are well fed;	12,8	27,7	59,5	9	32,1	60	46.9	-	53.1
1.2 Do enough exercise;	7,5	44,6	47,9	15,4	42,3	42,3	28.6	32.7	38.8
1.3 Have their natural features respected;	1,1	86,2	12,7	2,6	87,2	10,2	2	77.6	20.4
1.4 Like to show themselves to the viewers;	5,3	48,9	45,8	3,9	53,9	42,2	6.1	53.1	40.8
1.5 Suffer physical and psychological abuse;	64,9	2,1	33,0	66,7	-	33,3	79.6	-	20.4
1.6 Are in general well treated.	7,4	56,6	36,0	5,2	61,5	33,3	4.1	67.3	28.6

The opinion of the students of the three groups tended to consider that animals are badly treated and are deprived of their natural features. Even so, a high percentage of the students don´t know how to assess several of the aspects considered. It was the case of the items "Are well fed", "Do enough exercise" and "Like to show themselves to the viewers".

Finally, the legal prohibition of the circus with animals, section 5, was supported by 85.1% of the Portuguese sample, by 88.5% of the Spanish and 76% of the Greek based on the harm done to animals.

DISCUSSION AND CONCLUSIONS

In the present study, the results obtained in the different questions were very similar in the samples of the three different countries, since the majority of pre-service teachers did not recognize any relevant didactic value or even recreational interest in the circus with animals, evoking essentially reasons centred on the animals. Even so, about one third of the participants in each country had difficulties in assessing how animals are treated in some specific aspects, and a percentage below 15% tended to think that the circus with animals is a good show. It seems that, at least in the case of the circus, the way animals are treated is not totally known by the participants and more information is needed to increase awareness about this kind of show.

Some Portuguese students evoked that the circus could be a controversial issue to approach in class and this could be related to the fact that only in the course attended by these students there is the inclusion of controversial issues in the syllabus of the curricular unit of Didactic of Science.

Curiously, none of the Greek students evoked in their answers the fact that the present show is not a legal activity in their country, a ban created in Greece in 2012. This may be related to the lack of knowledge about this situation or because they gave priority to other reasons in their justifications.

The results also support the idea that during their future teaching practice a great majority of these students probably will not attend with their future pupils this kind of show, especially in Portugal, where there is still a transitory period of six years until the total prohibition of the use of wild animals in circuses, and in Spain where the circus with wild animals is still possible to be seen in certain regions. This supposition is in line with the idea that, at least in certain subjects, a change is occurring in our society about how animals should be treated. Even so, the recognition of a great didactic value of shows with aquatic mammals is of concern, since they are in fact circus acts, apparently not identified as such by the students.

Finally, the inclusion of controversial issues related with human-animals relationship seems to be a relevant issue to be included in teacher training courses. With this approach, the future teachers will be much more prepared to deal with this kind of subject, helping to build a less instrumental view towards animals.

ACKNOWLEDGEMENT

This study is included in the ANIMALIS project (IPL/2018/ANIMALIS_ESELx), which is funded by the Polytechnic Institute of Lisbon, Portugal.

REFERENCES

Almeida A. (2011). A abordagem de temas controversos na Educação Científica: importância atribuída pelos professores do 2º e 3º Ciclos e Secundário [The approach of controversial subjects in Science Education: importance given by the teachers of the 2nd and 3rd Cycle of schooling and Secondary]. In L. Leite, A. S. Afonso, L. Dourado, S. Morgado, T. Vilaça & S. Almeida (Org.). *Atas do XIV Encontro Nacional de Educação em Ciências* (pp. 659-671). Braga: Instituto de Educação da Universidade do Minho.

Bekoff, M., & Pierce, J. (2017). *The Animals' agenda. Freedom, compassion, and coexistence in the human age*. Boston: Beacon Press.

Decreto-lei nº 20/2019 de 22 de Fevereiro [Decree-Law]. Diário da República – I.ª Série – nº 38. Lisboa: Diário da República Eletrónico. Retrieved from: https://dre.pt/application/conteudo/120038534

DeMello, M. (2012). *Animals and society*. New York: Columbia University Press.

Dorning J., Harris S., & Pickett H. (2016). *The welfare of wild animals in travelling circuses.* Retrieved from: https://www.ispca.ie/uploads/The_welfare_of_wild_animals_in_travelling_circuses.pdf

Easton, T. A. (2009). *Taking Sides. Clashing Views in Science, Technology and Society* (8th ed.). Boston: McGraw Hill.

Eurogroup for Animals. (n.d.). *Wild Animals in EU Circuses. Problems, risks and solutions*. Retrieved from: https://www.eurogroupforanimals.org/media-2-3

Franklin, A. (2008). *Animals & modern cultures*. London: Sage Publications Inc.

Grant, T., Ramos Gay, I., & Alonso Recarte, C. (2018). Introduction: real animals on the stage. *Studies in Theatre and Performance*, *38*, 103-112.

Iossa, G., Soulsbury, C.D., & Harris, S. (2009). Are wild animals suited to a travelling circus life? *Animal Welfare*, 18, 129-140.

Jacobson, N. S., & Truax, P. (1991). Clinical significance: A statistical approach to defining change in psychotherapy research. *Journal of Consulting and Clinical Psychology, 59,* 12–19.

Nearly 300 Spanish towns ban 'cruel' animal circuses, (2016, March 1), *The Local*. Retrieved from: https://www.thelocal.es/20160301/increasing-number-of-towns-ban-animal-circuses-in-spain

Pagani, C., Robustelli, F., & Ascione, F. (2007). Italian youths' attitudes toward, and concern for, animals. *Anthrozoö*s, *20*, 275-293.

Ratcliffe, M., & Grace, M. (2003). *Science Education for citizenship*. Maidenhead: Open University.

Reingard, S. (2016). Animals in environmental education research. *Environmental Education Research*, 23, 63-74.

Reiss, M. J. (2017). A framework within which to determine how we should use animals in Science Education. In M. Mueller, D. Tippins & A. Stewart (Eds.), *Animals and Science Education. Ethics, curriculum and pedagogy* (pp. 243-258). Cham: Springer.

Stanisstreet, M., Spofforth, N., & Williams, T. (1993). Attitudes of children to the uses of animals. *International Journal of Science Education*, 15, 411-425.

Steiner, G. (2005). *Anthropocentrism and its discontents*. Pittsburg: University of Pittsburg Press.

PROSPECTIVE TEACHERS' PERCEPTION OF THE RELEVANCE OF SCHOOL – INDUSTRY COLLABORATION

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Unpopularity of science subjects, in particular physics and chemistry, among many students remains one of the major challenges of science education. In order to manage mentioned issues current educational policy recommends that chemistry teachers should make chemistry education more relevant. One of the possibilities to enhance different relevance dimensions suggests chemistry education based on industry collaboration. The article focused on perception of prospective teachers of chemistry contents at primary and secondary level about the relevance of school-industry collaboration. Altogether, 189 prospective teachers of chemistry contents from the University of Ljubljana, Slovenia, were selected with non-random sampling. The data was collected with the questionnaire about the perception of the relevance of school-industry collaboration, and analyzed using content analysis. The most important outcomes indicate that that prospective teachers of chemistry contents at primary and secondary level recognized relevance of the collaboration between school-industry with benefits for schools, students and industry. They pointed out the importance of the collaboration to enhance different relevance dimensions, and thereby focused more on the cognitive domain, and emphasized less the affective and skills domain. The most important value of the results is recognized in revealing the state of art at the national level and the needs for development possibilities in the future.

Keywords: Science Education, Initial Teacher Education, Socioscientific Issues

THEORETICAL FRAMEWORK

To ensure effective learning of chemistry contents, it has to be perceived as relevant in the eyes of students (Hofstein, Eilks, & Bybee, 2011). Stuckey et al. (2013) proposed a model to describe the relevance of the science education focusing on the idea of consequences. Whereby, chemistry learning is defined as a relevant when it has positive consequences for the student's life. The developed model suggests three dimensions of the relevance of the chemistry education: (1) an individual; (2) a societal and (3) a vocational dimension, whereby of each dimension covers intrinsic and extrinsic components, as well as the aspects of present and future meaning (Figure 1). The mentioned dimensions are interrelated and can partially overlap (Eilks & Hofstein, 2015).

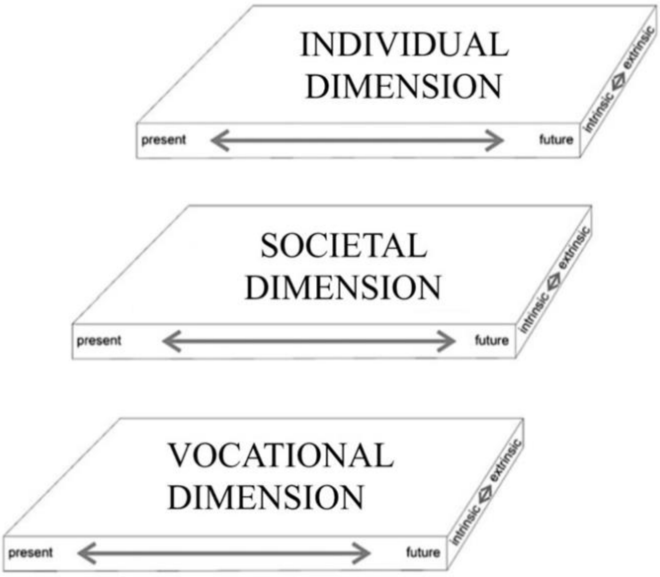

Figure 1. Dimensions of the relevance of the chemistry education: individual, societal and vocational dimension (Stuckey et al., 2013; Eilks & Hofstein, 2015).

To enhance different relevance dimensions Hofstein and Kesner (2006, 2015) suggest applying chemistry education based on industry collaboration in order to include economically and ecologically features of modern life and its technological achievements. Industry-school collaboration enables to emphasize chemistry socio-economic and environmental consequences and therefore represents a possibility for achieving the goals of discipline-oriented education for sustainable development by adding sustainable development issues to the chemistry curriculum (Burmeister, Rauch, & Eilks, 2012; Jegstad & Sinnes, 2015).

Students are encouraged to develop not only their societal relevant chemistry knowledge but also their ability to evaluate chemistry-related issues, such as possible contributions of chemistry to sustainable communities or appropriate natural resources stewardship in the future (Burmeister & Eilks, 2012). Due to the importance of teachers' personal perceptions, which may represent one of the most important factors for inhibiting the effective implementation of relevant chemical education (Lumpe, Haney & Czerniak, 2000), the purpose of the paper is to examine the perception of future teachers who will teach chemical contents in the education vertical.

AIM AND RESEARCH QUESTIONS

The main aim of this study was to investigate the perception of the relevance of school – industry collaboration from the perspective of prospective teachers of chemistry contents at the primary and lower secondary levels.

With regard to this research aim, the following research questions (RQ) were defined:

(**1st RQ**) What is the perception of prospective teachers of chemistry contents at primary level (PST) about the relevance of school-industry collaboration?

(**2nd RQ**) What is the perception of prospective teachers of chemistry contents at secondary level (CT) about the relevance of school-industry collaboration?

RESEARCH METHOD AND DESIGN

Sample. For the purpose of the research, 189 prospective teachers of chemistry contents from the University of Ljubljana were selected with non-random sampling. The sample consisted of 127 prospective teachers at primary level (PST) and 62 prospective chemistry teachers at lower secondary level (CT).

Instrument – Questionnaire about the perception of the relevance of school-industry collaboration. The questionnaire about the perception of the relevance of school-industry collaboration, which was used in the study, was developed for the research purposes. The questionnaire in full text can be obtained from the authors.

Data collection and data analysis. The data was collected in the study years 2016/17 and 2017/18 with the questionnaire about the perception of the relevance of school-industry collaboration, and analyzed using content analysis (Aksela, Wu, & Halonen, 2016; Vogrinc, 2008). Two researchers separately analysed 10 % questionnaires (n=19) to develop categories representing natural units of meaning related to the prospective teachers' perception of the relevance of school-industry collaboration. The reliability of coding was 95% and was achieved by coordinating the independent coding of two researchers, authors of the paper.

FINDINGS

In the Table 1 fifteen categories are described that were recognized as benefits of school – industry collaboration from the perspective of prospective teachers of chemistry contents.

Table 1. Recognised categories of the relevance of school – industry collaboration.

Relevance of collaboration for	Categories	
Students	*Students* get acquainted with the meaning of **chemistry knowledge in the society and for their individual life**	
	Directing *students* to **choosing professions** related to the field of chemistry	
	Students gain new **experiences or knowledge** (in general)	
	Students gain specific **experiences or knowledge**	in the field of **cognitive** domain
		in the field of **affective** domain
		in the field of **skills**
Schools	*School or teachers* gain new **experiences or knowledge** (in general)	
	School or teachers gain specific **experiences or knowledge**	in the field of **cognitive** domain
	School obtains **sponsorship or donations**	
	School obtains the opportunities for **out-of-school learning**	
	Other added value for the learning process	
Industry	**Promotion** of *industry or companies*	
	Industry or industry representatives gain new **knowledge** (in general)	
	Industry or industry representatives gain specific **experiences or knowledge**	in the field of **cognitive** domain
	Industry obtain **quality future staff**	

Prospective teachers of chemistry contents (PST+CT) pointed out mostly the relevance of collaboration for students, thereby CT highlighted categories that emphasize the relevance for students in comparison with PST ($f_{\%PST}$=43,0 %; $f_{\%CT}$=67,3 %). CT have also highlighted the categories of that emphasize the relevance of school – industry collaboration for the industry ($f_{\%PST}$ =12,2 %; $f_{\%CT}$=16,7 %).

Prospective teachers of chemistry contents (PST+CT) mostly indicated the category *Students gain specific experiences or. knowledge in the field of cognitive domain* ($f_{\% PST}$=20,4 %; $f_{\% CT}$=17,3 %).

Examples of responses:

Prospective PST A: »*Students get an insight into the work of companies, what are they making and how, etc.*.«

Prospective CT A: »*Students can get acquainted with the activity of the company, e.g. when visiting a company dealing with plastic packaging, they can learn about polymers and their properties.*«

Besides that, PST emphasized also the importance of the categories *School obtains sponsorship or donations* ($f_{\%PST}$ =28,5 %) and *School obtains the opportunities for out-of-school learning* ($f_{\%PST}$=11,3 %).

Examples of responses:

Prospective PST B: »*Companies can be sponsors, provide funds or some equipment that make work easier and more efficient*.«

Prospective PST C: »*We can visit companies with students and see how things work.*«

On the other hand, CT emphasized also the categories *Students get acquainted with the meaning of chemistry knowledge in the society and for their individual life* ($f_{\% CT}$=25,3 %) and *Students gain new experiences or. knowledge in general* ($f_{\%CT}$=13,3 %).

Examples of responses:

Prospective CT B: »*Students see that chemistry knowledge is useful in their everyday life*«

Prospective CT C: »*In my opinion, participation is beneficial for students as they gain new experiences*«

Prospective teachers of chemistry contents (PST+CT) pointed out the subcategories that include both the individual and the social dimension of relevance of school-industry collaboration from the students' perspective. As can be seen from Table 2, in this regard, especially the following the subcategories: (1) *Students get acquainted with the meaning of chemistry knowledge in society* ($f_{\% PST}$=10,5 %; $f_{\% CT}$=20,8 %), that supports societal dimension, (2) *Students gain specific experiences or knowledge in the field of cognitive domain related to the activity of individual companies* ($f_{\% PST}$=13,7 %; $f_{\% CT}$=15,8 %), that supports vocational dimension were emphasized.

Table 2. Recognised categories of the relevance for students.

Categories with subcategories			Dimensions of the relevance*
Students get acquainted with the meaning of chemistry knowledge		in general	I, S
		for individual life	I
		in society	S
Directing *students* to choosing		professions related to the field of chemistry by stimulating interest in professions related to the field of chemistry	V
		professions related to the field of chemistry resulting from other advantages of collaboration	V
		further education related to the field of chemistry	V
Students gain		new knowledge	I
		new experiences	I
Students gain <u>specific</u> experiences or knowledge	in the field of **cognitive** domain related to	the activity of individual companies	V
		the operation of companies	V
		career opportunities related to the field of chemistry	V
		developing an understanding of the role of chemistry in society	S
	in the field of **affective** domain related to	promoting changes in attitudes towards chemistry	I, S
		promoting interest in chemistry	I, V
	in the field of **skills** related to	developing collaborative skills	S

Additionally, PST emphasized also the subcategories *Students gain specific experiences or knowledge in the field of cognitive domain related to career opportunities related to the field of chemistry* ($f_{\%\,PST}$=21,1 %), *Directing students to choosing professions related to the field of chemistry resulting from other advantages of collaboration* ($f_{\%\,PST}$=15,8 %), and *Students gain specific experiences or. knowledge in the field of cognitive domain related to the operation of companies* ($f_{\%\,PST}$=11,6 %), which all support vocational dimension of relevance for students.

On the other hand, CT pointed out also the subcategory, *Students get acquainted with the meaning of chemistry knowledge for individual life* ($f_{\%CT}$=10,9 %), that emphasized the individual dimension for students.

DISCUSSION OF FINDINGS AND IMPLICATIONS

It is important to note, that prospective teachers of chemistry contents at primary and secondary level recognized the relevance of the collaboration between school-industry with benefits for schools, students and industry. It was found that prospective teachers of chemistry contents at primary and secondary level in Slovenia recognize the important added value of chemical education, which involves the integration of school, university and economy, i.e. to enable students to develop an understanding of chemistry in everyday life and to learn about the links between chemistry, the economy and society (Hofstein and Kesner, 2006, 2015).

They pointed out the importance of the collaboration to enhance different relevance dimensions, and thereby focused more on the cognitive domain, and emphasized less the affective and skills domain, which indicates a need for developing further understanding of the relevance of school-industry collaboration on the national level. At the international level, collaboration with the industry is also defined as a potential approach to achieving sustainable development goals (Burmeister et al., 2012; Jegstad and Sinnes, 2015), while encouraging students to develop their own knowledge in addition to developing understanding of socially relevant chemical knowledge skills for socially responsible behavior and engagement in society (Burmeister and Eilks, 2012).

REFERENCES

Aksela, M., Wu, X., & Halonen, J. (2016). Relevancy of the Massive Open Online Course (MOOC) about Sustainable Energy for Adolescents. *Education Sciences*, *6*(4), 40.

Burmeister, M., & Eilks, I. (2012). An example of learning about plastics and their evaluation as a contribution to Education for Sustainable Development in secondary school chemistry teaching. *Chemistry Education Research and Practice*, *13*(2), 93-102.

Eilks, I., & Hofstein, A. (2015). From some historical reflections on the issue of relevance of chemistry education towards a model and an advance organizer–A prologue. In I. Eliks, & A. Hofstein (Eds.), *Relevant chemistry education* (pp. 1-10). SensePublishers.

Hofstein, A., & Kesner, M. (2006). Industrial chemistry and school chemistry: Making chemistry studies more relevant. *International Journal of Science Education*, *28*(9), 1017-1039.

Hofstein, A., & Kesner, M. (2015). Learning from and about Industry for Relevant Chemistry Education. In I. Eliks, & A. Hofstein (Eds.), *Relevant Chemistry Education* (pp. 285-299). SensePublishers.

Hofstein, A., Eilks, I., & Bybee, R. (2011). Societal issues and their importance for contemporary science education: A pedagogical justification and the state of the art in Israel, Germany and the USA. *International Journal of Science and Mathematics Education*, *9*(6), 1459–1483.

Jegstad, K. M. in Sinnes, A. T. (2015). Chemistry Teaching for the Future: A model for secondary chemistry education for sustainable development. *International Journal of Science Education*, *37*(4), 655–683.

Lumpe, A. T., Haney, J. J. in Czerniak, C. M. (2000). Assessing teachers' beliefs about their science teaching context. *Journal of Research in Science Teaching*, *37*(3), 275–292.

Stuckey, M., Hofstein, A., Mamlok-Naaman, R., & Eilks, I. (2013). The meaning of ‘relevance’in science education and its implications for the science curriculum. *Studies in Science Education*, *49*(1), 1-34.

Vogrinc, J. (2008). *Kvalitativno raziskovanje na pedagoškem področju*. Ljubljana: Univerza v Ljubljani Pedagoška fakulteta.

KNOWLEDGE OF SPANISH PRE-UNIVERSITY STUDENTS REGARDING DIFFERENT AREAS OF BIOTECHNOLOGY

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This paper analyses the knowledge of 184 students in the last course of secondary education in Spain in relation to different areas of biotechnology: medical, food, agricultural, industrial and environmental. The information was obtained from students in 2nd year of Baccalaureate, the previous year to enroll in a University grade, in six high schools of different characteristic (regarding size, type of environment and the location in the city). The instrument used was a written questionnaire that was designed and validated for this purpose. A descriptive statistical analysis was carried out, which allowed us to better understand the current situation of biotechnology in the classrooms, focusing on those students who manifested a predisposition toward learning science (they were students who had chosen the scientific branch, thus they had to study Biology at this level). The results show that a significant number of students complete secondary education with imprecise notions about applications of biotechnology. Regarding the attitude, this will depend not only on the application and purpose of them but also on the organism involved. Students tend to accept applications with beneficial effects on human health, although they are against them when they perceive a loss of natural character, damage to the environment or moral consequences.

Keywords: Secondary Education, socio-scientific issues, genetics

INTRODUCTION

The scientific and technological training that students receive during secondary education must enable them to engage in responsible decision making in 21st century society (Prieto, España, & Martín, 2012). These kinds of decisions present dilemmas or controversies based on scientific notions related to social, ethical, political and environmental fields (Jiménez, 2010). The growing impact of biotechnology in recent years requires citizens who can understand the notions related to this subject to have adequate intellectual tools to make relatively informed decisions regarding their position about the applications of biotechnology in daily life (Fonseca, Costa, Lencastre, & Tavares, 2012). Being immersed in some socio-scientific controversies, students of biotechnology not only are motivated to know their biological principles, but also to be aware of the possible benefits and risks (of political, social, legal and ethical nature) that derive from its development (Hammann, 2018). These circumstances have had an impact on the curriculum of most advanced countries, and thus, the inclusion of biotechnology in secondary education has become an international tendency. This fact has caused students to have to learn basic concepts of genetics (France, 2007) and a large amount of new knowledge related to the applications of biotechnology, which are not easy to adapt in science classes (Gericke & Wahlberg, 2013). In this sense, simulation games or role-playing activities and debates (Simonneaux, 2002) allow students to analyse and assess the positive and negative aspects of different applications in the context of scientific research and express their opinions on the suitability of their use. Further, the introduction of peer discussions and debates about socio-scientific issues in connection to biotechnology into the teaching of science in schools permit students to progress in ethical reasoning and encouraged them to reason and explain their claims, offering alternative solutions (Berne, 2014).

Regarding the knowledge of basic notions of genetics and of applications of biotechnology, in many studies, basic errors have been found, such as a lack of knowledge of key points of genetics, for instance about the knowledge of DNA itself and its transmission. 'Common tomatoes do not contain genes, while genetically modified tomatoes do contain genes' is a sentence that is usually presented in studies on biotechnology (de la Vega, Lorca, & de las Heras, 2018). Among the numerous investigations carried out on these aspects, some of the most interesting for our work might be related to the location of hereditary information (Banet & Ayuso, 2000; Ruiz, Banet, & López-Banet, 2017a), to the hereditary information in some living beings (Caballero, 2008; Ruiz, Banet, & López-Banet, 2017b), and to the knowledge about biotechnology (Fonseca et al. 2012; Occelli, Vilar, & Valeiras, 2011; Prokop, Lesková, Kubiatko, & Diran, 2007; Usak, Erdogan, Prokop, & Ozel, 2009). About the applications of biotechnology in different fields we could mention food (Chen, Chu, Lin, & Chiang, 2016; Dawson, 2007; Fonseca et al. 2012; Occelli et al. 2011; Öztürk-Akar, 2016; Prokop et al., 2007; Usak et al., 2009), medical (Fonseca et al., 2012; Öztürk-Akar, 2016) or agricultural, livestock and environmental (Ayuso, Ruiz, & López, 2019; Fonseca et al., 2012; Öztürk-Akar, 2016).

In relation to the medical field, studies have suggested that students are favourable to the use of genetic engineering for research (Chen et al., 2016), the use of genetically modified organisms in medicine (Öztürk-Akar, 2016), the production of new medicines and the diagnosis and/or treatment of diseases (Occelli et al., 2011), and gene therapy and classical applications (Fonseca et al. 2012). However, in other cases, it is indicated that the use of techniques such as gene therapy is not widely accepted (Gardner & Troelstrup, 2015). In Spain, Sáez, Gómez-Niño and Carretero (2008, p. 177) identified 'the maxim of health' as one of the values considered by students when they deem that improving the health of people justifies any type of technological intervention, which is an explanation that could explain the previously mentioned studies. Although students are not favourable towards applications that involve the manipulation of animal or human embryos, they recognise that future generations will benefit from advances in biomedical applications (Fonseca et al., 2012). Nor are they in favour of applications that require the modification of animals by introducing genes from human beings, but they are in agreement with the use of animals to produce useful drugs for people (Usak et al., 2009). In the field of food and, in particular, in terms of attitudes towards the consumption of genetically modified foods, many students do not feel that it is safe to buy these products (Öztürk-Akar, 2016). Some consider that they may involve health risks by containing chemicals capable of damaging the human body (Usak et al., 2009). In other cases, students are opposed to the modification of fruit genes (Prokop et al., 2007). With regard to this, in Sáez et al.'s (2008, p. 177) analysis of some assessments made by students, they describe 'the principle of the natural', which is understood as normal or appropriate. On the other hand, many students recognise that they do not usually look at the labels of the food they eat, although they consider the labeling of transgenic foods to be very important (Fonseca et al., 2012; Occelli et al., 2011). According to Chen et al. (2016), students do not favour applications of biotechnology in the agricultural, livestock and environmental fields, showing some concern about the negative impact that the use of genetic engineering in the agricultural industry can cause to the environment. However, students display more positive attitudes towards the elimination of diseases in plants or wastewater treatment (Öztürk-Akar, 2016) and to applications such as plant improvement or livestock production (Occelli et al., 2011). The acceptance by students of research in genetic technology for environmental sustainability is also very high, but they show some concern about the regulation of the risks in the environment associated with biotechnology (Gardner & Troelstrup, 2015). Finally, the use of microorganisms in biotechnological processes (Dawson & Schibeci, 2003) and in wastewater treatment (Usak et al., 2009) has been accepted by students.

Considering the contributions of the bibliographic review, in this study, we analyse, at the beginning and at the end of the second year of baccalaureate (2B onwards), the following research problem: What knowledge do students have about some basic notions of biotechnology?

METHODS

The participants of our investigation were 184 Spanish students (71 at the beginning of the course and 113 at the end) of a scientific modality 2B, belonging to an incidental sample of different secondary schools and with a medium-high academic level, according the opinions of their teachers. We used a written questionnaire whose fine-tuning was carried out as follows. Considering the curricular orientations (Ministry of Education, Culture and Sport [MECD], 2015), as well as the analysed antecedents, a concept map was elaborated (Appendix 1) that, in our opinion, included the most outstanding references to carry out the initial selection of the contents under study. Based on this scheme, an initial questionnaire was designed and was tested through individual interviews with 12 students from diverse centres and different academic performance. We eliminated a question that was too complex and modified the language and the structure of others. The obtained information was analysed through a combination of quantitative and qualitative strategies. The quantitative ones were realised using the Statistical Package of Social Sciences (SPSS) version 20.0 to obtain the descriptive statistics (frequencies and means), non-parametric statistics (Mann-Whitney U test at a significance level $\alpha<0.05$ to reveal the differences between groups) and the Pearson correlation coefficient.

RESULTS

This information was obtained from several questions. For the selection of the areas analysed, we took into account not only the interest they provoked in previous research but also our criteria in considering them to be better known by the students. The first question was an open one for which the students had to write the applications they knew about medicine, food, agriculture, industry and the environment. In the second, which was provided after the students had finished the former one so as not to influence in their answers, they were asked to assess the advantages and disadvantages of a set of applications in some indicated areas and also to indicate their level of knowledge; in the third one, they had to mark as true or false certain affirmations about the applications of biotechnology.

Question 1. Knowledge about certain applications of biotechnology

As they were open questions, many of the answers were very imprecise, so we only considered those that made reference to the name of the application (therapeutic cloning, bioremediation, obtaining transgenic plants, etc.) or should lead one to suppose the nature of it (determining how much kinship there is between two people in the same family, knowing if you are going to have diseases, biotechnology enables you to create more specific food products, etc.) to be adequate. The results (Table 1) show that before having studied biotechnology, the level of knowledge is minimal or medium, while at the end of 2B, the number of students citing three or four applications increases. It also highlights the significant decrease that occurs between those who do not mention any and the increase in those who cite more than seven applications.

Table 1. Applications cited (in%).

No. Applications	Beginning	End	α
0	23.94	4.42	**0.000**
1-2	36.62	38.05	0.845
3-4	30.99	41.59	0.149
5-7	8.45	8.85	0.770
More than 7	0	7.08	**0.033**

As shown in Table 2, at the beginning of the course, the students cite more applications in the medical and food fields (above 55%), while there are very few examples related to the environment. This knowledge increases among students who finish 2B, and it grows significantly in medicine (reaches 85%) and the environment. Nevertheless, the number of students who refer to an application in relation to industry did not reach 40%.

Table 2. Applications cited in each of the areas (in%).

Area	Beginning	End	α
Medicine	56.3	85	**0.000**
Food	56.3	63.7	0.319
Agriculture	43.7	54.9	0.145
Industry	21.1	31.0	0.140
Environment	11.3	36.3	**0.000**

Question 2. Degree of knowledge, advantages and disadvantages of some applications

To analyse the degree of knowledge of the applications of biotechnology, the students could point to 1 (I have never heard of it), 2 (I have heard of it but I do not know what it means) or 3 (I have heard of it and I know what it means). We considered those who marked it and those who gave an adequate definition of it as level 3, even if they had marked 2. The best known applications were those related to food (in particular, transgenic foods) and the use of DNA tests in forensic science (Table 3). Only between 15 and 25% of students knew about other examples in the medical field (preventive molecular diagnosis or gene therapy). The use of plants or bacteria in industry or microorganisms for waste treatment (bioremediation) was not well known.

Table 3. Degree of knowledge of some applications of biotechnology (in%).

Applications	Beginning			End			
	1	2	3	1	2	3	α
Preventive molecular diagnosis	53.5	26.8	15.5	38.9	35.4	25.7	**0.026**
Gene therapy	35.2	36.6	25.4	26.5	29.2	42.5	**0.034**
Fermentation for food production	7.0	49.3	39.4	8.8	36.3	54.0	0.154
Transgenic foods	4.2	23.9	67.6	2.7	17.7	79.6	0.163
Use of plants or bacteria in industry	23.9	40.8	26.8	14.2	42.5	42.5	**0.027**
Use of microorganisms for waste treatment	36.6	33.8	22.5	16.8	21.2	61.9	**0.000**
DNA tests in forensic sciences	9.9	33.8	49.3	8.8	21.2	69.0	**0.041**

The percentage of students who complete the baccalaureate and affirm that they know the meaning of the applications given increases in a statistically significant manner for most of them. However, from our point of view, the results cannot be considered satisfactory. We believe that the low results obtained in the medical field (only 25.7% report knowing the meaning of ‘preventive molecular diagnosis’) may be because they do not recognise the terminology or the proposed applications, because, in the previous question, they indicated many examples in this field. Some examples of the benefits and drawbacks that students mentioned for each of these applications are shown in Table 4.

Table 4. Advantages and disadvantages of biotechnology applications considered by students.

Applications	Advantages	Disadvantages
Preventive molecular diagnosis and gene therapy	Know possible diseases to which a person will be prone and be able to cure it	Moral type
Fermentation for food production	Food production	Derived from the microorganisms that are used to produce them
Transgenic foods	Obtaining food with desired characteristics, without adding chemicals (pesticides)	Unnatural foods that can cause health problems or in the environment
Use of plants or bacteria in industry	Obtaining beneficial products for human beings	Possible damage to the environment
Use of microorganisms for waste treatment	Reduce pollution	--
DNA tests in forensic sciences	Resolve a crime or identify a corpse	--

These results coincide with other investigations in which the main benefits that are indicated have to do with the improvement of human health, while the reasons why they would reject these techniques are related to moral aspects, damage to the environment or the loss of natural character (Sáez et al., 2008).

Question 3. Assessment of some claims related to biotechnology

The results of this part of the questionnaire (Table 5) show that, at the beginning of 2B, the majority of students respond correctly to the first one (genetic screening) and also to the one about which they previously had claimed no knowledge, which is associated with preventive molecular diagnosis. There are also many students who identify the use of enzymes in industry (e).

Table 5. Valuations of claims about biotechnology (correct answers in %).

Affirmation (correct answer)	Beginning	End	α
a. The analysis of the genes of an individual (genetic screening) can help to identify the diseases to which they will be more prone (V)	94.4	89.4	0.658
b. Only genetically modified microorganisms can produce antibiotics (F)	67.6	66.4	0.786
c. Transgenic plants have genes, but non-transgenic plants do not have genes (F)	71.8	88.5	**0.004**
d. It is not possible to transfer genes from one species to another (F)	64.8	72.6	0.320
e. Enzymes have a great applicability in industry in sectors such as food, clothing or paper (V)	63.4	66.4	0.621
f. Bioremediation by genetically modified microorganisms capable of eliminating materials that have difficulty degrading naturally is a decontamination method used, for example, in oil spills (V)	36.6	77.0	**0.000**

Although the results for the term bioremediation (f) are much worse among the students who start the course, there is a significant improvement among those who finish 2B. We did not observe notable differences in relation to two of the three statements that explicitly referred to genes (b and d). However, the knowledge that all plants have genes, not only transgenic ones, improves significantly in students who finish 2B (option c) due to a notable decrease in the number who do not respond to this question. In any case, at the end of the baccalaureate, about 30% maintain that it is not possible to transfer genes from one species to another or that only genetically modified microorganisms can produce antibiotics; these are circumstances that question, from their base, the notion of biotechnology that these students can learn.

CONCLUSIONS AND EDUCATIONAL IMPLICATIONS

The results presented show that a significant number of students complete secondary education with imprecise notions about applications of biotechnology, for instance, there is a high number of students who finish 2B without knowing the meaning of the fermentation processes, despite this course deals with the specific study of this content and even describes some of the metabolic pathways. Moreover, although students who start 2B are able to cite some applications of biotechnology, those who complete this course know more (particularly in medicine and food), thus improving the quality of their explanations about them and the vocabulary they use. Accordingly, our results reveal the incidence of teaching in the last year of baccalaureate. Regarding the advantages and disadvantages of biotechnology applications considered, students tend to accept applications with beneficial effects on human health, although they are against them when they perceive a loss of natural character, damage to the environment or moral consequences. Therefore, many have a favourable attitude towards those applications related to food (but are less favourable when they involve genetic modifications of animals and plants for experimental or even food purposes, about which they express doubts regarding their impact on the environment or on health) and medicine, accepting the alteration of genes in tissue cells whenever it is related to curing diseases.

As regards the educational implications of this research, it seems relevant to highlight the following:

- Before approaching the contents of biotechnology in baccalaureate, it is necessary for the students to possess adequate knowledge about the basic notions of genetics that are fundamental to understand it even at the elementary level (Chen et al., 2016). Otherwise, it is necessary to include in the teaching programme specific activities that allow them to progress from their misconceptions to scientifically more acceptable notions. On the contrary, if teachers assume that the analysed contents have been learned in previous courses, this will contribute to the persistence of many of these ideas, making it difficult to understand biotechnology.

- Due to the complexity of this subject, both because of the nature of its concepts, techniques and applications, as well as its social implications, the contents of biotechnology should be presented to students in an organised manner in order to facilitate their learning and their relationship with knowledge already studied.

- We consider that it is important to take advantage of the interest of students in biotechnology, particularly in relation to applications with direct repercussions on health, taking them as a starting point to present not only more examples but also more areas (genetic modification of microorganisms, plants or animals, industry, environment). In this sense, putting into practice role-playing activities and debates about socio-scientific issues in connection to biotechnology (Berne, 2014; Simonneaux, 2002) could be interesting. On the other hand, it would be appropriate to analyse the analogies and differences between traditional and modern biotechnology, as well as the evolution that has taken place in science to move from the former to the latter. Thus, the latter could not be seen as something new and exclusive to scientists, because the applications of biotechnology have always been used by humanity.

Finally, it seems important to emphasise that, much more often than desirable, the rhythm of the classes implies the introduction of a large number of new terms, concepts or techniques without establishing enough opportunities for students to reflect on new learning and relate it to other learning addressed previously. In our opinion, this circumstance could explain, to a large extent, the difficulties that many students have in understanding, in an adequate way, the knowledge we have analysed in this research.

ACKNOWLEDGEMENT

This research has been carried out within the project PGC2018-097988-A-I00 funded by: FEDER/ Ministry of Science and Innovation (MCI) of Spain - State Research Agency (AEI). The authors would also like to thank teachers of the different schools who participated in this research for their availability to help us to obtain the information we present.

REFERENCES

Ayuso, G.E., Ruiz González, C., & López Banet, L. (2019). ¿Cómo justifican los estudiantes del último curso de Bachillerato lo que saben y opinan sobre las aplicaciones en biotecnología industrial? [How do students in the last year of High School justify what they know and think about applications in industrial biotechnology?]. In C. Vasconcelos, R. A. Ferreira, C. Calheiros, A. Cardoso, B. Mota, & T. Ribeiro (Eds.), *Livro de Resumos: XVIII ENEC | III ISSE Educação em Ciências: cruzar caminhos, unir saberes* (114-115). Faculdade de Ciências da Universidade do Porto: U. Porto Edições.

Banet, E. & Ayuso, E. (2000). Teaching Genetics at Secondary School: A Strategy for Teaching about the Location of Inheritance Information. *Science Education*, 84(3), 313–351. doi: 10.1002/(SICI)1098-237X(200005)84:3<313::AID-SCE2>3.0.CO;2-N

Berne, B. (2014). Progression in ethical reasoning when addressing socio-scientific issues in biotechnology. *International Journal of Science Education*, 36(17), 2958–2977. doi: https://doi.org/10.1080/09500693.2014.941957

Caballero, M. (2008). Algunas ideas del alumnado de secundaria sobre conceptos básicos de genética [Some secondary pupils' preconceptions of basic concepts]. *Enseñanza de las Ciencias*, 26(2), 227–244. Retrieved from https://www.raco.cat/index.php/Ensenanza/article/view/118096

Chen, S. Y., Chu, Y. R., Lin, C. Y. & Chiang, T. Y. (2016). Students' knowledge of, and attitudes towards, biotechnology revisited, 1995-2014: Changes in agriculture biotechnology but not in medical biotechnology. *Biochemistry and Molecular Biology Education*, 44(5), 475–491. doi: https://doi.org/10.1002/bmb.20969

De la Vega Naranjo, M., Lorca Marín, A. A., & de las Heras Pérez, M. de los A. (2018). Conocimientos y actitudes hacia la biotecnología en alumnos de último curso de Educación Secundaria Obligatoria [Knowledge and attitude towards biotechnology in students of the last course of Compulsory Secondary Education]. *Revista Eureka sobre enseñanza y divulgación de las Ciencias*, *15*(5). doi: https://doi.org/10.25267/ RevEurekaensendivulgcienc.2018.v15.i3.3301

Dawson, V. (2007). An exploration of high school (12-17 Year Old) students' understandings of, and attitudes towards, biotechnology processes. *Research in Science Education*, 37(1), 59–73. doi: https://doi.org/10.1080/00219266.2003.9655889

Dawson, V. & Schibeci, R. (2003). Western Australian high school students' attitudes towards biotechnology processes. *Journal of Biological Education*, 38(1), 1–6. doi: https://doi.org/10.1080/00219266.2003.9655889

Fonseca, M. J., Costa, P., Lencastre, L., and Tavares, F. (2012). Multidimensional analysis of high-school students' perceptions about biotechnology. *Journal of Biological Education*, 46(3), 129–139. doi: https://doi.org/10.1080/00219266.2011.634019

France, B. (2007). Location, Location, Location: Positioning Biotechnology Education for the 21st Century. *Studies in Science Education*, *43*, 88–122. doi: https://doi.org/10.1080/03057260708560228

Gardner, G. E. & Troelstrup, A. (2015). Students' Attitudes Toward Gene Technology: Deconstructing a Construct. *Journal of Science Education and Technology*, 24(5), 519–531. doi: https://doi.org/10.1007/s10956-014-9542-4

Gericke, N. & Wahlberg, S. (2013). Clusters of concepts in molecular genetics: a study of Swedish upper secondary science students understanding. *Journal of Biological Education*, 47(2), 73–83. doi: https://doi.org/10.1080/00219266.2012.716785

Hammann, M. (2018). Biotechnology. In K. Kampourakis & M. J. Reiss (Eds.), *Teaching Biology in Schools Global Research, Issues, and Trends* (192–201). New York: Routledge.

Jiménez Aleixandre, M. P. (2010). *10 ideas clave: Competencias en argumentación y uso de pruebas. Ideas clave* [10 key ideas: Competences in argumentation and use of evidence. Key ideas]. Barcelona: Graó.

Ministry of Education, Culture and Sport. (2015). Real Decreto 1105/2014 [Royal Decree-Law 1105/2014]. *Boletín Oficial Del Estado*, Sec. I (Num. 3), 169–546. Retrieved from https://www.boe.es/buscar/doc.php?id=BOE-A-2015-37

Occelli, M., Vilar, M. T. & Valeiras, N. (2011). Conocimientos y actitudes de estudiantes de la ciudad de Córdoba (Argentina) en relación a la biotecnología [Students' knowledge and attitudes about biotechnology in Córdoba (Argentine)]. *Revista Electrónica de Enseñanza de las Ciencias*, 10(3), 227–242. Retrieved from http://reec.uvigo.es/volumenes/volumen10/ART1_VOL10_N2.pdf

Öztürk-Akar, E. (2016). Turkish university students' knowledge of biotechnology and attitudes toward biotechnological applications. *Biochemistry and Molecular Biology Education*, 45 (2), 115–125. doi: https://doi.org/10.1002/bmb.20996

Prieto Ruz, T., España Ramos, E., & Martín, C. (2012). Algunas cuestiones relevantes en la enseñanza de las ciencias desde una perspectiva Ciencia-Tecnología- Sociedad [Some relevant questions in science education from the perspective of a ScienceTechnology-Society]. *Revista Eureka sobre enseñanza y divulgación de las Ciencias*, 9(1), 71–77. doi: https://doi.org/10498/14625.

Prokop, P., Lesková, A., Kubiatko, M., & Diran, C. (2007). Slovakian students' knowledge of, and attitudes toward, biotechnology. *International Journal of Science Education*, 29(7), 895–907. doi: https://doi.org/10.1080/09500690600969830

Ruiz, C., Banet, E., & López-Banet, L. (2017a). Conocimientos de los estudiantes de secundaria sobre herencia biológica: implicaciones para su enseñanza [Knowledge of high school students on biological inheritance: implications for teaching]. *Revista Eureka sobre enseñanza y divulgación de las Ciencias*, 14(3), 550–569. Retrieved from https://revistas.uca.es/index.php/eureka/article/view/3246

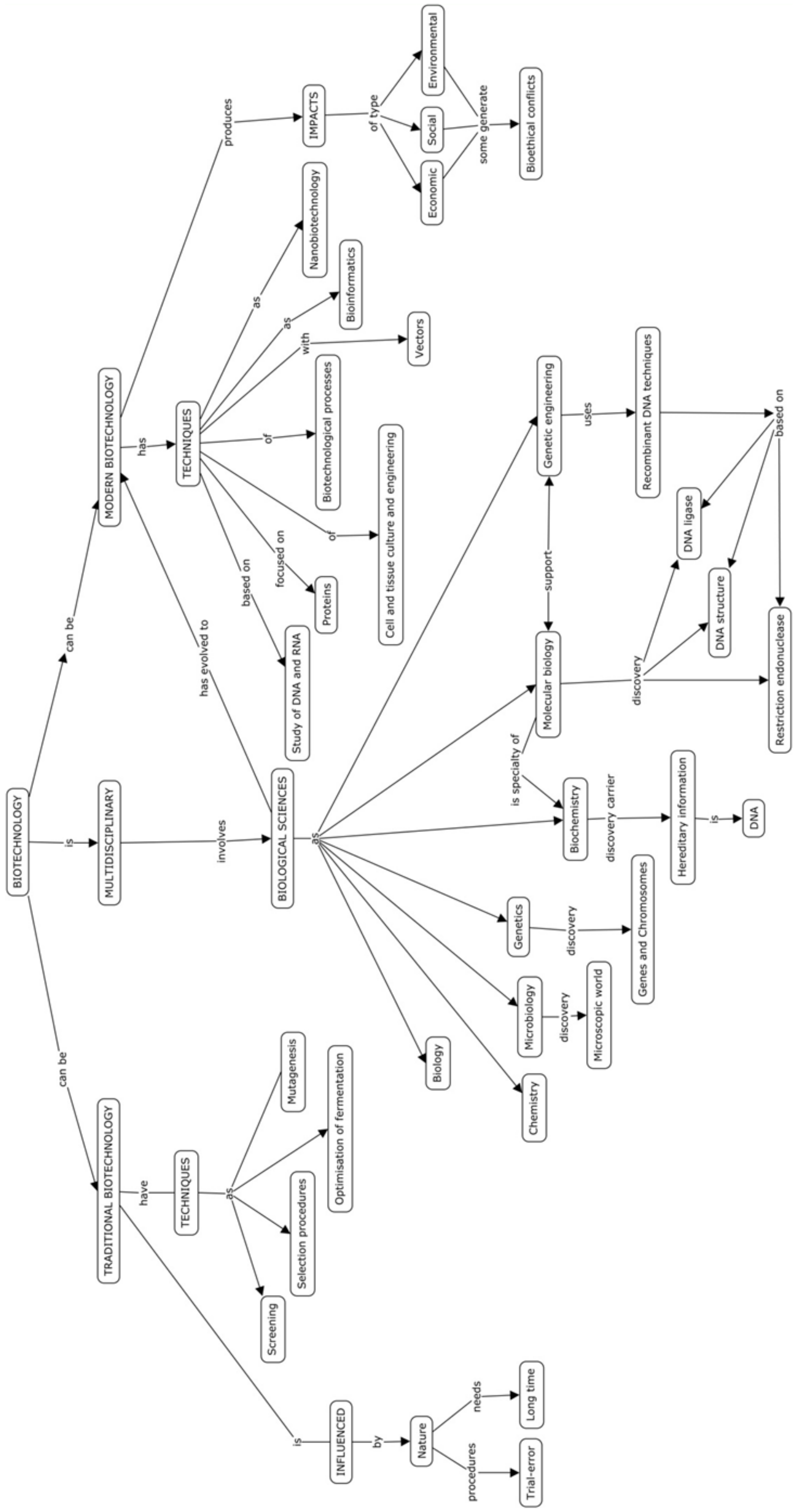
Ruiz, C., Banet, E. & López-Banet, L. (2017b). Conocimientos de estudiantes que inician el Bachillerato sobre nociones básicas de Genética y aplicaciones de la biotecnología [Knowledge of students who start the baccalaureate about basic notions of genetics and applications of biotechnology]. *Enseñanza de las Ciencias*, Núm. Extra, 1421–1428. Retrieved from https://ddd.uab.cat/pub/edlc/edlc_a2017nEXTRA/37_-_Conocimientos_de_estudiantes_que_inician_el_Bachillerato_sobre_nociones_basicas_de_Genetica.pdf

Sáez, M., Gómez-Niño, A., & Carretero, A. (2008). Matching society values: Students' views of biotechnology. *International Journal of Science Education*, 30(2), 167–183. doi: https://doi.org/10.1080/09500690601152386

Simonneaux, L. (2002). Analysis of classroom debating strategies in the field of biotechnology. *Journal of Biological Education*, 37(1), 9–12. doi: https://doi.org/10.1080/00219266.2002.9655839

Usak, M., Erdogan, M., Prokop, P., & Ozel, M. (2009). High school and university students' knowledge and attitudes regarding biotechnology. *Biochemistry and Molecular Biology Education*, 37(2), 123–130. doi: https://doi.org/10.1002/bmb.20267

Appendix 1. Map of concepts on techniques and the development of biotechnology



A STUDY ON STEM HUMAN RESOURCES COMMUNITY ABILITY; FOCUS ON HIGHER EDUCATION STUDENTS IN JAPAN AND AFRICA

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Higher education in Japan is facing drastic changes. Based on connections between primary and secondary education, "zest for life," "fostering academic abilities," and "three elements of academic abilities" should be continued in higher education, while "fundamental competencies for working people" are being promoted on the industry side in Japan. Both Japan and other countries are preparing to create competencies. With regard to such competencies in international frameworks, it is necessary to attend to comparative study due to the cultural background of the target person. In this research, I focus on the consciousness and recognition required to build a STEM human resources community in the early years of higher education as well as to examine the capacity elements required for STEM human resources. I conducted a survey among Japanese students and students in the Republic of Malawi examining the skills and abilities of people with common abilities in a STEM resources community. The results revealed no significant differences between the students in Japan and Malawi for 5 out of the 21 ability elements. Common abilities in the STEM resources community are "listen closely and carefully to information," "innovate using critical thinking," and "easily disseminate information to other people in different cultural areas, based on control stress." For future research, I will seek to collect more data and conduct further interview research with questionnaire respondents.

Keywords: Scientific competencies / STEM education / Higher education

INTRODUCTION

Higher education in Japan has undergone a transformation promoted by the government. Central Education Council in Japan (2014) stated that the cultivation of "zest for life" and "fostering academic ability," based on connections between primary and secondary education, should be continued in higher education. This transformation covers all fields and includes STEM students as follows: "Three elements of academic ability" from primary education to higher education are required: (1) knowledge and skills, (2) thinking ability, judgment ability, and expression, and (3) initiative and collaboration. In addition, the Minister's Meeting on Human Resource Development for Society (2018) proposed the following definition of STEM and common citizen competence: (1) ability to accurately interpret and respond to writing and information, (2) ability to engage in and apply scientific thinking and inquiry, and (3) sensitivity and ability regarding discovering and creating value; curiosity and inquisitiveness. On the industry side, the Ministry of Economy, Trade and Industry in Japan (METI) has promoted the idea of "fundamental competencies for working persons" (METI, 2006). That is, society (especially in Japan) has expressed a demand for human resources with the basic skills necessary to work in organizations and communities. These skills consist of the following three competencies comprising a total of 12 competency factors: (1) Ability to step forward (action): Initiative, Ability to influence, Execution skill; (2) Ability to think through (thinking): Ability to detect issues, Planning skills, Creativity; (3) Ability to work on a team (teamwork): Ability to deliver messages, Ability to listen closely and carefully, Flexibility, Ability to understand situations, Ability to apply rules and regulations, and Ability to control stress. In addition, many skill sets and competency models around the world, including key-competency from the OECD (Organization for Economic Co-operation and Development) (Rychen & Salganik, 2003) and 21st-century skills (The Partnership for 21st Century Learning, 2015), contain similar concepts.

While Japan and other foreign countries are preparing to create competencies, Aikawa (2007), on the one hand, mentions the limitation of a wide variation in students depending on the culture and background of both the region and the individual. On the other hand, the OECD (2015) states that comparative study is possible in certain cultural areas since concepts such as competency are universal. In other words, when seeking to understand these competencies in the international context, it is necessary to pay attention to comparative study due to the cultural background of the target person; however, such a comparison is only possible in the same cultural sphere (linguistics). It is thus assumed that the STEM community has a unique culture and background, and that by focusing on the STEM community itself, it will be possible to compare the competencies required of STEM human resources on a global level.

Therefore, I focus on the consciousness and recognition required for the STEM human resources community in the early years of their higher education careers and examine the capacity elements required for STEM human resources.

This research has the following RQs. RQ1: To clarify the characteristics of the STEM human resources community for students in the target country. RQ2: To clarify the characteristics of the STEM human resources community by clarifying common consciousness and recognition through an international comparison.

METHOD

I conducted a survey among Japanese students and students in the Republic of Malawi in order to compare, as far as possible, students from two separate cultures. The Japanese students were first-year university students (228 students) studying at the local national university in the Faculty of Science, with the survey conducted at the end of Quarter 2 (the university's year runs according to a quarter system) . In this Faculty, students can major in the fields of mathematics, physics, chemistry, biology and geography, with around 36% currently advancing to graduate schools.

The participants from Malawi were first- and second-year students (82 students) at an ICT vocational school, and the survey was conducted at the end of the year. The Republic of Malawi, as the subject of the survey, is one of the poorest countries in the world, with a GNI (Gross National Income) per capita of 320 US dollars (World Bank, 2018). The country's national policy emphasizes science and technology in economic growth (Republic of Malawi, 2017). The Japanese government has worked for many years in Malawi to implement educational support for science and mathematics as official development assistance. Because of this support, it shares in some characteristics of science and mathematics education with Japan; this makes it an ideal candidate for comparison.

In this research focusing on the consciousness and recognition of STEM human resources, I used five methods to elicit responses concerning the elements of ability required for STEM human resources. The following question was posed: ‘How important are these skills and abilities for people with STEM careers?’ The ability elements comprised 21 items based on ‘Fundamental Competencies for Working Persons’ in Japan and 21st century Skills of 4Cs skills (Critical thinking, Creativity, Collaboration, Communication). The questionnaire permitted responses on a scale of 1–5, with 5 being ‘very important’, 4 ‘important’, 3 ‘somewhat important’, 2 ‘not very important’ and 1 ‘not at all important’, with average values calculated based on the responses.

RESULTS AND DISCUSSION

Figure 1 (Results from Japanese respondents) and Figure 2 (Results from Africa (Malawi) respondents) summarize the results of the responses in Japan and Malawi. Careful attention should be paid to the fact that the responses were mainly positive, and there was a difference in the number of Japan and Malawi respondents.

These data show that many items incurred a response rate of higher than 80 percent positive (choices 5 and 4), and, in particular, in Japan, five items exceeded 90 percent (General Expertise; Executing Plans; Ability to Detect Issues; Creativity; Flexibility), as did four items in Malawi (Leadership; Information, Media, and Technology Literacy; Critical Thinking; Communication). In terms of the characteristics of each country, it is clear that there is a low recognition of the importance of Collaboration and Innovation in Japan, as well as weak recognition of Ethics and Career Development and Planning. By contrast, in Malawi, even for STEM human resources who are professionals, the numerical values of the items were low for both Expertise and Initiative and Ability to Detect Issues.

In addition, a *t*-test was conducted regarding the abilities of the STEM human resources communities of the two countries, with a significant difference seen for 16 of the 21 items (as shown in Table 1). Focusing on the five items that did not reveal any significant differences, it can be seen that the STEM human resources who can also work in the STEM human resources community have several abilities in common: to Listen Closely and Carefully to Information, to Innovate Using Critical Thinking, and to Easily Disseminate Information to Other People in Different Cultural Areas. And then must needs control stress. Since there is no tendency to be biased towards either of the large average values, it is suggested that these items may be strongly influenced by culture.

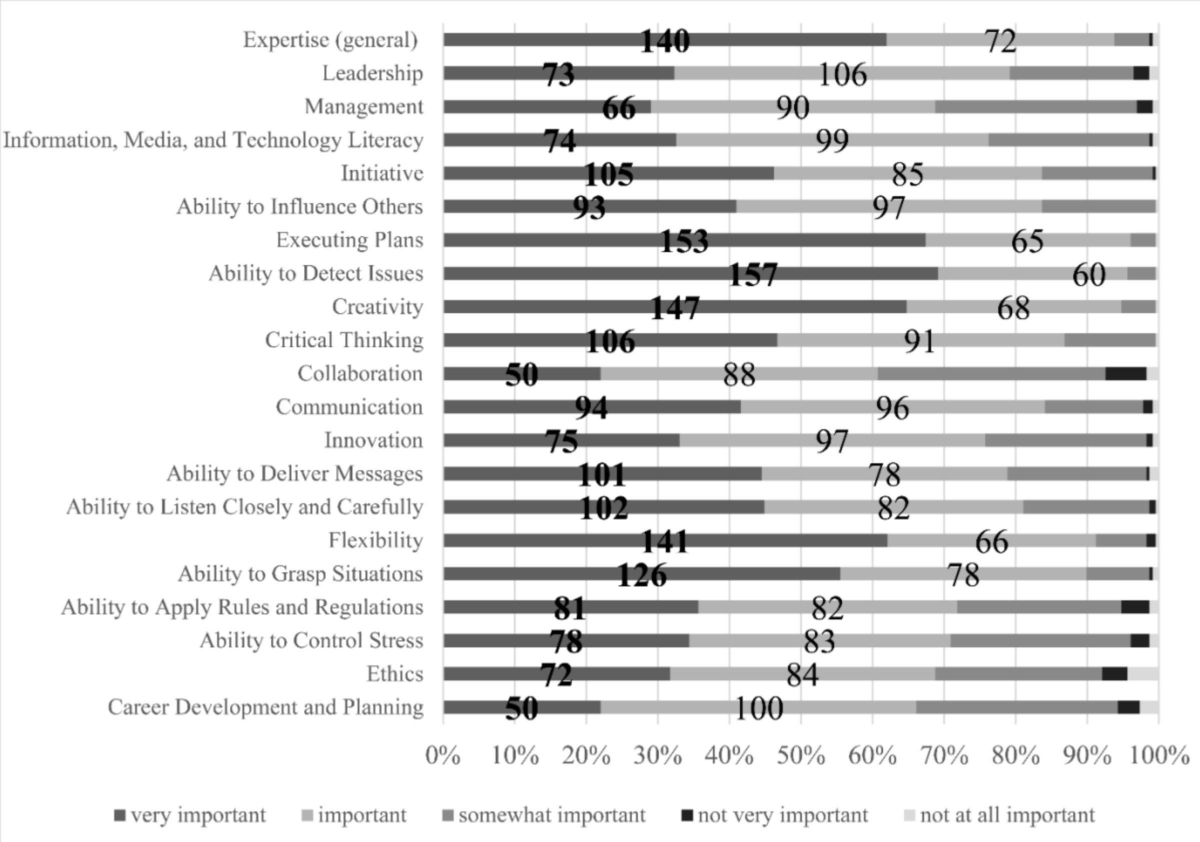

Figure 1. Results from Japanese respondents

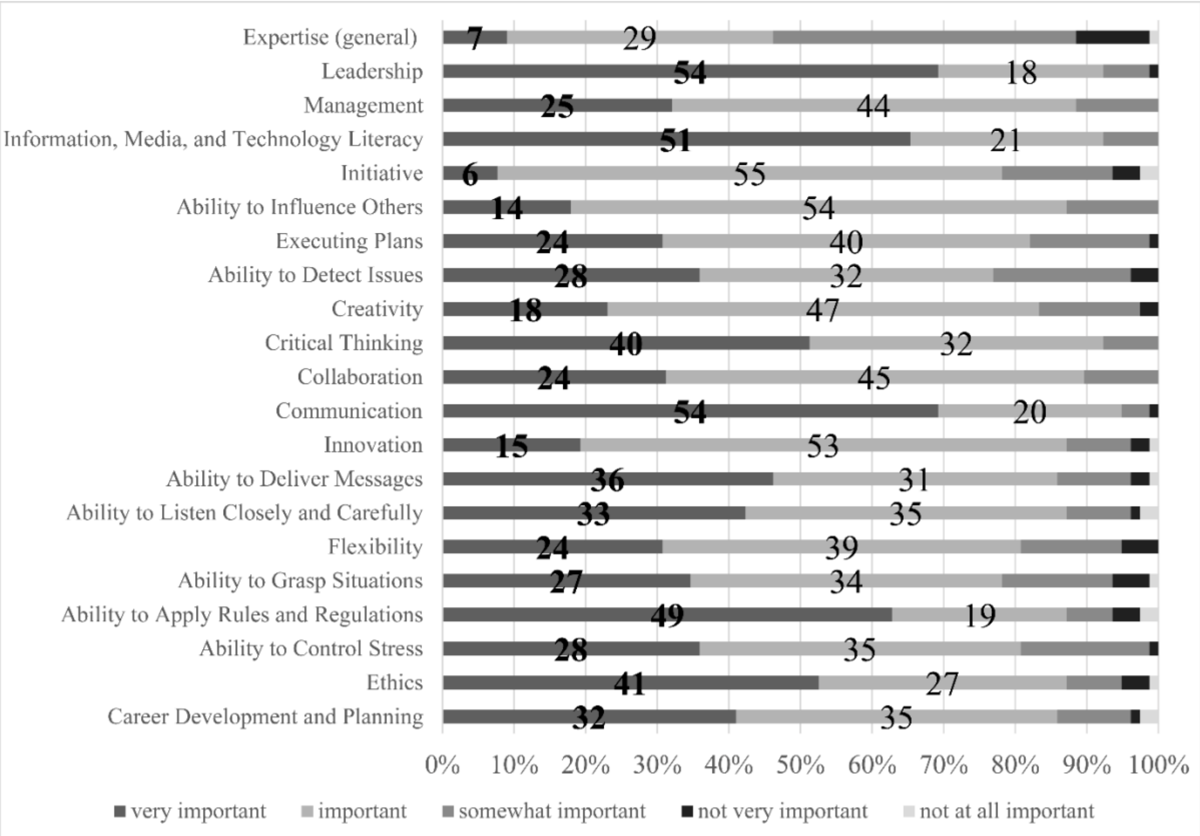

Figure 2. Results from Africa (Malawi) respondents

Table 1. STEM human resources community ability *t*-test (JAPAN - AFRICA: MALAWI)

		JAPAN Mean(SD)		AFRICA (MALAWI) Mean(SD)	*t*	df
1	Expertise (general) ***	4.54(0.694)	>	3.42(0.845)	10.5	114.8
2	Leadership ***	4.07(0.838)	<	4.60(0.671)	-5.11	302.0
3	Management **	3.94(0.866)	<	4.21(0.632)	-2.92	181.3
4	Information, Media, and Technology Literacy ***	4.07(0.804)	<	4.58(0.635)	-5.09	303.0
5	Initiative ***	4.29(0.771)	>	3.77(0.755)	5.19	136.2
6	Ability to Influence Others*	4.24(0.744)	>	4.05(0.556)	2.33	178.0
7	Executing Plans ***	4.63(0.599)	>	4.12(0.720)	6.15	303.0
8	Ability to Detect Issues ***	4.64(0.604)	>	4.09(0.841)	5.32	105.6
9	Creativity ***	4.59(0.628)	>	4.04(0.692)	6.47	303.0
10	Critical Thinking	4.33(0.728)		4.44(0.636)	-1.19	303.0
11	Collaboration ***	3.74(0.927)	<	4.21(0.614)	-5.07	198.8
12	Communication ***	4.23(0.799)	<	4.63(0.626)	-4.54	169.4
13	Innovation	4.06(0.818)		4.01(0.712)	0.503	152.1
14	Ability to Deliver Messages	4.20(0.859)		4.27(0.848)	-0.593	303.0
15	Ability to Listen Closely and Carefully	4.24(0.803)		4.23(0.867)	0.107	303.0
16	Flexibility ***	4.51(0.723)	>	4.06(0.811)	4.55	303.0
17	Ability to Grasp Situations ***	4.43(0.746)	>	4.05(0.910)	3.67	303.0
18	Ability to Apply Rules and Regulations ***	4.01(0.931)	<	4.41(0.959)	-3.26	303.0
19	Ability to Control Stress	4.00(0.907)		4.15(0.757)	-1.34	303.0
20	Ethics ***	3.88(1.04)	<	4.33(0.878)	-3.45	303.0
21	Career Development and Planning ***	3.80(0.909)	<	4.21(0.873)	-3.45	303.0

※ * : p <.05 ** : p <.005 ***: p<.001

CONCLUSION

This paper has focused on perceptions of required abilities within the STEM human resources community. No significant differences were found between Japan and Malawi for 5 out of the 21 ability elements. It was found that students from both countries believe that certain abilities (Listening Closely and Carefully to Information, Innovating Using Critical Thinking, and Disseminating Information Easily to Other People in Different Cultural Areas) are important, based on control stress.

However, the research has a number of limitations. First, it looks at data from only two countries (regions). It is therefore necessary to collect data from more countries. In addition, in the future, we will not focus on ideas and perceptions of these ability elements; it will be necessary to gather additional data and conduct further interview research with questionnaire respondents.

ACKNOWLEDGMENT

This works supported by Ehime University Faculty of Science and Shizuoka University Graduate School of Science and Technology.

REFERENCES

Aikawa, A. (2007). Can international comparison of social skills be possible? In A. Kikichi (Ed.), Measure social skills: KiSS-18 Handbook (166–172). Japan: Kawashima Shoten. (Japanese)

Central Education Council Report (2014). Universal reform of high school education, university education and university entrance selection toward realization of a high connection that is suitable for a new era - all young people to bud new dreams and goals, to make them flower in the future - (report). Japan: Ministry of Education, Culture, Sports, Science and Technology. (Japanese)

Minister's Meeting on Human Resource Development for Society / Task Force on Developing Skills to Live Prosperously in the New Age (2018). Human Resource Development for Society 5.0 ~ Changes to Society, Changes to Learning ~. Japan: Ministry of Education, Culture, Sports, Science and Technology. (Japanese)

Ministry of Economy, Trade and Industry (2006). Study group on fundamental competencies for working persons – (Interim Report). Japan: Ministry of Economy, Trade and Industry. (Japanese).

Organization for Economic Co-operation and Development (2015). Skills for social progress: The power of social and emotional skills. Paris: OECD Publishing.

The Partnership for 21st Century Learning (2015). P21 Framework definitions. USA: Partnership for 21st Century Learning.

Republic of Malawi (2018). The Malawi growth and development strategy (MGDS) III. Malawi: Republic of Malawi.

Rychen, D. S., & Salganik, L. H. (Eds.) (2003). Key competencies for a successful life and a well-functioning society. Boston, MA: Hogrefe & Huber Pub.

World Bank (2018). Gross national income per capita 2017, Atlas method and PPP. Data Catalog. Retrieved January 31, 2019 from World Development Indicators database.

INVESTIGATING PERSPECTIVE-TAKING ON SOCIOSCIENTIFIC ISSUES AMONG JAPANESE PRIMARY SCHOOL STUDENTS

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In recent years, socioscientific issues (SSI) have gained attention in the field of science education research. In the context of socioscientific reasoning, previous researchers suggested the importance of 'perspective-taking', which is one's ability to recognise and consider the diverse cognitive and emotional viewpoints of others. Some studies on SSI have targeted primary school students. However, no studies assessed primary school students' perspective-taking skills prior to SSI-based instruction. In this research, therefore, we assessed primary school students' perspective-taking skills before SSI-based instruction to provide basic data for instructional design. This research targeted 63 Japanese fifth-year (10- and 11-year-old) primary school students. Participants were assigned a decision-making task relating to electric cars, which is SSI in Japan. The descriptions written by the primary school students during the decision-making task clearly showed that these students had indeed already acquired perspective-taking skills. However, it was also clear that these skills were limited. In other words, although these students had obtained perspective-taking skills regarding their own positions and counter-positions, they had not yet learned to integrate these perspectives. These findings suggest that there is still room to improve the perspective-taking skills of Japanese primary school students. This research provides a method for assessing how primary school students engage in perspective-taking on SSI in science education. Further research is needed to examine whether the tasks and evaluation criteria from this study could be applied to the creation of tasks pertaining to SSI in other cultural contexts.

Keywords: socioscientific issues, primary school, elementary school, perspective-taking

THEORETICAL FRAMEWORK

Socioscientific issues (SSI) are social issues concerning science and technology, ethics, or morals that incite controversy (Sadler, Amirshokoohi, Kazempour, & Allspaw, 2005). SSI has gained attention in the field of science education research (Chang, Chang, & Tseng, 2010; Lin, Lin, & Tsai, 2014; Lin, Lin, Potvin, & Tsai, 2018).

In the context of socioscientific reasoning, previous researchers (e.g., Kahn & Zeidler, 2016) have suggested the importance of 'perspective-taking', which is one's ability to recognise and consider the diverse viewpoints of others (Sadler & Donnelly, 2006). Perspective-taking is important for socioscientific reasoning, because the ultimate goal of such a process is to engage in decision-making to resolve SSI. During the decision-making process, it is necessary to consider multiple perspectives and then compare, integrate, and develop them (Eggert, Ostermeyer, Hasselhorn, & Bögeholz, 2013; Fang, Hsu, & Lin, 2018; Sutter, Dauer, & Forbes, 2018). As perspective-taking requires a range of processes, it may be difficult for students.

Some research on SSI has targeted primary school students (Evagorou, 2011; Karpudewan & Roth, 2018; Papadouris & Constantinou, 2010). However, no research has assessed primary school students' perspective-taking skills prior to SSI-based instruction. In this study, therefore, we assessed primary school students' perspective-taking skills before SSI-based instruction to provide basic data for instructional design.

AIM AND RESEARCH QUESTION

The purpose of this study is to assess Japanese students' perspective-taking skills prior to SSI-based instruction. The research question is: Have Japanese primary school students already obtained perspective-taking skills before SSI-based instruction?

METHOD

Participants

This research targeted 63 Japanese fifth-year (10- and 11-year-old) primary school students.

SSI topic

The issue of subsidies for electric cars was chosen as the topic of the decision-making task for two reasons. First, the issue of electric cars is not unique to Japan. Rather, they are a global problem. The question of whether to promote electric cars is one of the typical SSI because it involves various socioscientific aspects including those related to the environment, economy, and public policy. Many countries have actively introduced and continue to introduce electric cars. For example, in 2016, over 750,000 electric cars were sold globally, and the cumulative number of electric cars worldwide exceeded 2 million (Next Generation Vehicle Promotion Center, 2017). However, the introduction of electric cars is influenced significantly by policy support. For example, policy support (evaluation of environmental performance, fuel efficiency regulations, and tax measures, based on local government measures) is still important for the smooth introduction of electric cars (Next Generation Vehicle Promotion Center, 2017).

Second, students are familiar with electric cars because Japanese fifth-grade students have the opportunity to learn about them in social studies classes. Students also learn about environmental issues in fourth grade. Therefore, the issue of electric cars is an appropriate topic for elementary school students with little social experience.

SSI decision-making task

Participants were assigned a SSI decision-making task relating to electric cars. Participants were given 45 minutes to complete this task.

They first learned about electric cars and the supporting and opposing opinions. Table 1 shows three socioscientific aspects related to electric cars, as well as supporting and opposing opinions for each of these aspects. The aspects set as the focus for this topic were 'convenience, the environment, and the economy'. The students studied the supporting and opposing opinions related to these aspects. Under the aspect of economy, the supporting opinion endorsed low fuel costs, while the opposing opinion highlighted that electric cars incur hefty expenses. Under the aspect of convenience, the supporting opinion was that it is easy to charge electric cars, whereas the opposing opinion was that it takes a lot of time to do so. Under the aspect of environment, the supporting opinion was that electric cars are eco-friendly, whereas the opposing opinion was that electric cars are not eco-friendly.

Then, they answered the SSI decision-making question, 'If you are the mayor of Town A, do you agree to provide subsidies for electric cars? In addition, as the mayor, what kind of proposals do you want to give to the residents? Write your opinion or proposal here.' Each student assumed the role of the mayor of the town and was asked to engage in decision-making on whether to provide subsidies for electric cars or not, and to provide grounds for his or her decision in writing.

Table 1. Three aspects of electric cars and opinions

Positions	Aspects	Opinions
Supporting	Convenience	It is easy to charge electric cars. The popularity of electric cars is increasing. Charging stations are increasing. If the use of electric cars increases because of subsidies, the number of charging stations will increase, and we will be able to charge electric cars more easily. Another major advantage is that you can easily charge an electric car at home, and send electricity from your car to your home during a power outage.
	Economy	Its low fuel costs. Fuelling electric cars costs less than half the cost of fuelling gasoline-only cars. Those who drive long distances every day can save on fuel costs. In addition, gas prices can quickly rise because of global conditions, so electric cars are economic for car users.
	Environment	Electric cars are eco-friendly. Electric cars emit half as much carbon dioxide as do conventional cars, and they emit no carbon dioxide while driving. This leads to less air pollution. As they are eco-friendly, we should subsidise and promote the use of electric cars.
Opposing	Convenience	It is not easy to charge electric cars. There 40% fewer charging stations than gas stations. While you can find charging stations in places other than gas stations, it takes time to find them. When the battery is running low, it can be problematic. Even if you find a charging station, it takes long for an electric car to charge and you may have to wait for other cars to finish charging. If you live in a condominium or an apartment, you cannot set the charging stations to suit your own convenience. For these reasons, electric cars are difficult to charge and inconvenient for car users, so we should not subsidise them.
	Economy	Electric cars are expensive to maintain. Although there is no gasoline charge, the purchase price is higher than that of a conventional car, even with subsidies. As they have large batteries, electric cars are larger than conventional ones, and are thus taxable and cannot fit in the parking space for small cars. People who want to charge their cars at home have to pay for the necessary equipment.

Environment	Electric cars are not eco-friendly. In Japan, electricity is mainly provided by thermal and nuclear power, so producing electricity to power electric cars does lead to carbon dioxide emissions. If subsidies are issued and the number of electric vehicle users increases, the electricity required to power the cars will increase and power plants must be expanded. Power plants pose several environmental problems, such as the disposal of spent fuel from nuclear power generation and the emission of carbon dioxide from thermal power generation.

Analysis

The descriptions written by the primary school students during the decision-making task were assessed. Building on the evaluation criteria of Sadler and Donnelly (2006), new evaluation criteria to measure the students' levels of perspective-taking was created. Based on these criteria, each description was categorised according to four levels of perspective-taking, from 0 to 3. Table 2 shows some examples of the descriptions written by students at each level.

Level 3 (multiple perspective-taking) meant that the students were able to state an opinion of the counter-position and proposals to integrate counter-position with their own positions and to solve SSI. Level 2 (plural perspective-taking) means that the students stated an opinion regarding the counter-position. Level 1 (single perspective-taking) means that the students only stated an opinion denoting their own position. Level 0 (non-perspective-taking) means that the students did not state an opinion. To ensure reliability, 20% of the descriptions were assessed independently by two coders.

Table 2. Examples of the descriptions written by students at each level

Level	Examples
3	*Example 1* I do not agree to provide subsidies for electric cars. Some say that it is easy to charge electric cars, and that it is eco-friendly *[supposing opinions]*. However, it is not always possible to find a place to charge or it is not eco-friendly *[opposing opinions]*. There are some suggestions for promoting electric cars. We will install more charging stations for electric cars. For example, we will install charging spots for electric cars at each gas stations *[a proposal]*. It is also necessary to secure electricity through power generation that does not emit carbon dioxide, such as wind power generation *[a proposal]*. Also, for people living in condominiums, I think it would be good to make a parking lot exclusively for electric cars in the area *[a proposal]*. The problem that charging takes a lot of time [would be] solved by increasing the number of charging ports in the car *[a proposal]*. *Example 2* I agree to provide subsidies for electric cars. A town issues a subsidy. There is an opinion that it takes time to find the location of the charging stations *[supposing opinions]*. In order to solve the problem, I think that we should draw up a map describing the location of the charging stations *[a proposal]*. For the opposing opinion that charging electric cars takes time, it is a good idea to expand the number of charging stations *[a proposal]*. This proposal also solves the problem of difficulty in putting in charging stations. While considering car charging, carbon dioxide emission fees are not zero *[opposing opinions]*. However, carbon dioxide emission rates are very low compared to conventional cars, and it can be said that this is eco-friendly *[supposing opinions]*. For this reason, towns should issue subsidies.

2	*Example 1*	
		I agree to provide subsidies for electric cars because, if a disaster occurs and the house loses power, you can send electricity from the electric car to the house to ensure safety *[supporting opinions]*. In addition, fuel costs are lower than those for ordinary cars. The price of gasoline is rising rapidly [supporting opinions], so I think it is better to switch to an electric car early. However, some people say that there are not many charging facilities, and that it is difficult to charge, and that the car itself costs more money *[opposing opinions]*. The popularity of electric cars has increased in recent times. The number of charging stations will increase accordingly *[supporting opinions]*. Considering fuel costs, if you use a car every day, electric cars are definitely economical *[supporting opinions]*. The car itself does not emit carbon dioxide at all, but more improvements are needed. For example, CO_2 is emitted from the factory, and it is not eco-friendly *[opposing opinions]*. However, the money and convenience are better than that of ordinary cars, so I will give residents a subsidy for electric cars.
	Example 2	
		I agree to provide subsidies for electric cars. Electric cars are not always good for the environment *[opposing opinions]*. However, I think there is no doubt that using electric cars can be better for the environment than using a gasoline car for a long time *[supposing opinions]*. The reason is that the total amount of carbon dioxide emissions that cause global warming, from the stage of making electricity to driving, is half. There are still some problems in charging *[opposing opinions]*, but as the number of users increases, it is expected that the number of charging stations will increase. So you can charge wherever you want to charge *[supposing opinions]*. Furthermore, if more people use electric cars, I think that the cost of cars and equipment can be reduced.
1	*Example 1*	
		I agree to provide subsidies for electric cars because they are eco-friendly *[supposing opinions]*. Electric cars emit less carbon dioxide, so we can prevent global warming.
	Ex*ample 2*	
		I do not agree to provide subsidies for electric cars. Town A does not issue subsidies, because it takes time to charge and you have to wait if another car is charging *[opposing opinions]*. Electric cars are bigger than conventional ones, so they are taxable and cannot fit in the parking space for small cars*[opposing opinions]*. It has major problems such as the disposal of spent fuel from nuclear power generation and the emission of carbon dioxide from thermal power generation *[opposing opinions]*. It is not environmentally friendly.
0	*Example 1*	
		I do not agree to provide subsidies for electric cars. If you have an accident, you will lose the security deposit money and the cost of charging the electric cars up to the point of the accident. Using electric cars is not good for residents of apartments. I think that using an electric car costs more than before. It is better to use a gasoline car every day. To put it simply, there are more disadvantages to using an electric car. This is one of the socioscientific issues *[there are no supporting or opposing opinions]*.

RESULTS

Table 3 shows the distribution of students for each level. Level 3 (the highest level) contained a smaller number of students, or 23.8%. Table 3 shows that before SSI-based instruction the students were able to achieve Level 2. However, only a few were able to reach Level 3.

Table 4 lists the aspects stated by students as grounds for their decision (supporting or opposing). Of the 63 students, 39 (62%) supported subsidies for electric cars, while 24 (38%)

were opposed. Table 4 shows that when engaged in decision-making, it was easier for the students to state an opinion from the position they considered as their own, rather than to state an opinion from a counter-position (Nussbaum & Kardash, 2005).

Table 3. Distribution of primary school students for each level

Level	Explanation	N (%)
3	*Multiple perspective-taking* The student is able to state an opinion about the counter-position and integrate it with an opinion (an proposal) based on his/her own position.	15 (23.8)
2	*Plural perspective-taking* The student states an opinion of the counter-position.	21 (33.3)
1	*Single perspective-taking* The student only states an opinion of his/her own position.	24 (38.1)
0	*Non-perspective-taking* The student does not state an opinion.	3 (4.8)

N=63.

Table 4. Aspects stated by students during decision-making

Aspects	Agree (*N*=39) (%)	Disagree (*N*=24) (%)
Supporting opinions		
The aspect of convenience	20 (51)	3 (13)
The aspect of economy	13 (33)	4 (17)
The aspect of environment	27 (69)	4 (17)
Opposing opinions		
The aspect of convenience	14 (36)	17 (71)
The aspect of economy	13 (33)	14 (58)
The aspect of environment	18 (46)	20 (83)

N=63.

DISCUSSION OF FINDINGS AND IMPLICATIONS

Our assessment clearly shows that the Japanese primary school students involved in this study had already acquired perspective-taking skills. However, it was also clear that these skills were limited. Although these students had obtained perspective-taking skills regarding their own positions and counter-positions, they had not integrated these perspectives. These findings suggest that there is still room to improve the perspective-taking skills of Japanese primary school students.

In the decision-making process, it is necessary to consider multiple viewpoints, and compare, integrate, and develop them. Fostering these complex perspective-taking skills in elementary school students will lead to better decision-making skills (Eggert et al., 2013; Fang et al., 2018; Sutter, Dauer, & Forbes, 2018).

This study provides a method for assessing how primary school students engage in perspective-taking on SSI in science education. Further research is necessary to examine whether the tasks and evaluation criteria from this study can be applied to the creation of tasks pertaining to SSI in other cultural contexts.

ACKNOWLEDGEMENT

This work was supported by JSPS KAKENHI Grant Numbers JP17H01979, JP18K18646.

REFERENCES

Chang, Y., Chang, C. & Tseng, Y. (2010). Trends of science education research: An automatic content analysis. *Journal Science Education Technology*, *19*, 315-331.

Eggert, S., Ostermeyer, F., Hasselhorn, M., & Bögeholz, S. (2013). Socioscientific decision making in the science classroom: The effect of embedded metacognitive instructions on students' learning outcomes. *Education Research International*, doi:10.1155/2013/309894.

Evagorou, M. (2011). Discussing a socioscientific issue in a primary school classroom: The case of using a technology-supported environment in formal and nonformal settings. In T. Sadler (Ed.), *Socioscientific issues in the classroom* (pp. 133–160). New York: Springer.

Fang, S.-C., Hsu, Y.-S., Lin, S.-S. (2018). Conceptualizing socioscientific decision making from a review of research in science education. *International Journal of Science and Mathematics Education,* doi:10.1007/s10763-018-9890-2.

Kahn, S., & Zeidler, D., L. (2016). Using our heads and HARTSS*: Developing perspective-taking skills for socioscientific reasoning (*Humanities, ARTs, and Social Sciences). *Journal of Science Teacher Education, 27*, 261-281.

Karpudewan, M., & Roth, W.-M. (2018) Changes in primary students' informal reasoning during an environment-related curriculum on socio-scientific issues, *International Journal of Science and Mathematics Education, 16*, 401-419.

Lin, T.-C., Lin, T.-J., & Tsai, C.-C. (2014). Research trends in science education from 2008 to 2012: A systematic content analysis of publications in selected journals. *International Journal of Science Education*, *36*, 1346–1372.

Lin, T.-J., Lin, T.-C., Potvin, P., & Tsai, C.-C. (2018). Research trends in science education from 2013 to 2017: a systematic content analysis of publications in selected journals. *International Journal of Science Education, 41*, 367-387.

Nussbaum, M., & Kardash, C. M. (2005). The effects of goal instructions and text on the generation of counterarguments during writing. *Journal of Educational Psychology, 97*, 157-169.

Next Generation Vehicle Promotion Center (2017) S*urvey report on the spread of clean energy vehicles.* http://www.cev-pc.or.jp/lp_clean/

Papadouris, N., & Constantinou, C. P. (2010). Approaches employed by sixth-graders to compare rival solutions in socio-scientific decision-making tasks. *Learning and Instruction*, *20*, 225 – 238.

Sadler, T. D., Amirshokoohi, A., Kazempour, M. & Allspaw, K. M. (2005). Socioscience and ethics in science classrooms: Teacher perspectives and strategies. *Journal of Research in Science Teaching, 43*, 353-376.

Sadler, T. D., & Donnelly, L. A. (2006). Socioscientific argumentation: The effects of content knowledge and morality. *International Journal of Science Education, 28*, 1463-1488.

Sutter, A. M., Dauer, J. M., & Forbes, C. T. (2018). Application of construal level and value-belief norm theories to undergraduate decision-making on a wildlife socio-scientific issue. *International Journal of Science Education*, *40*, 1058-1075.

IDENTIFYING EVERYDAY DECISION SITUATIONS OF LEARNERS IN SCIENCE EDUCATION

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According to the concept of Scientific Literacy, students should be empowered to recognise scientific issues in order to make critical decisions by using scientific knowledge. However, results of a previous study reveal that students do not even recognise open decision situations with a scientific issue in everyday life. Therefore, they need to be supported in order to be able to link those situations to appropriate content in chemistry classes. For this purpose, the "decision diary" tool was developed. It aims to make them aware of their everyday decision situations with scientific issues as well as enable them to identify decision situations in which they are willing to adopt new evidence-based decision strategies. This provides the opportunity to initiate fruitful learning processes in students on the basis of the conceptual change theory, since the tool reveals conflicts in everyday decision situations and can thus be used to develop and plan authentic interventions for chemistry courses. First results indicate that the "decision diary" is an appropriate tool for identifying students' decision situations with scientific issues in their everyday lives.

Based on these results, our research project tries to use the identified decision situations for science teaching. The decision diary was tested in 4 chemistry classes with students of different age groups and from different school forms. Data was collected with document analysis of the decision diaries, semi-structured interviews and open-ended questionnaires and analysed by qualitative content analysis. The results so far indicate that the decision diary provides the opportunity to identify open decision situations with cognitive conflict among students for science education.

Keywords: Decision Making, Conceptual Change, Scientific Literacy

INTRODUCTION

PISA 2006 defines Scientific Literacy as *„the capacity of students to identify scientific issues, […] and make decisions in life situations involving science and technology."* (OECD, 2007, p.33). Sadler & Zeidler (2009) criticise that the items of the PISA study are embedded in a backstory that is nonrelevant to the expected answer. This statement differs from the interpretations in the framework of socio-scientific issues, which deal with life-like contexts related to science and affect other domains like psychology or sociology.

Looking at everyday contexts, students rarely use scientific decision criteria (cf. Table 1), but are rather used to habitualised decision routines (Menthe & Parchmann, 2015; Sander & Höttecke, 2016). As an example, the decision tree of a student (see Figure 1) shows her habitualised decision strategy for buying a deodorant. The student says that she currently chooses her deodorant based on the appearance of the packaging. Most important for her is a pink packaging. If it is not pink, she will not take it. Then she smells the deodorant and finally looks at the price. These habitualised routines are a product of her history of socialisation (Bourdieu, 2000) and usually prove to be sustainable in everyday life. And these routines turn out to be very persistent and new arguments that do not fit into the existing decision strategies are rejected out of hand (Chinn & Bewer, 1998). This leads to the hypothesis that students do not use scientific knowledge to make personal decisions in their everyday lives in which scientific knowledge is necessary.

Table 1. Summary of possible decision criteria (Aikenhead, G. S. (1985); Halverson, K. L. Siegel, M. A., & Freyermuth, S. K. (2009); Heitmann, P. (2012); Uskola, A., Maguregi, G., & Jiménez-Aleixandre, M. (2010)).

Decision criteria	characteristic values
subjective and emotional	appearance
	smell
	feeling
	taste
	pragmatism
	hedonism
scientific	health
	ecology
	technology
sociocultural	social environment
	media
	economy
	policy
	law
	ethics/religion

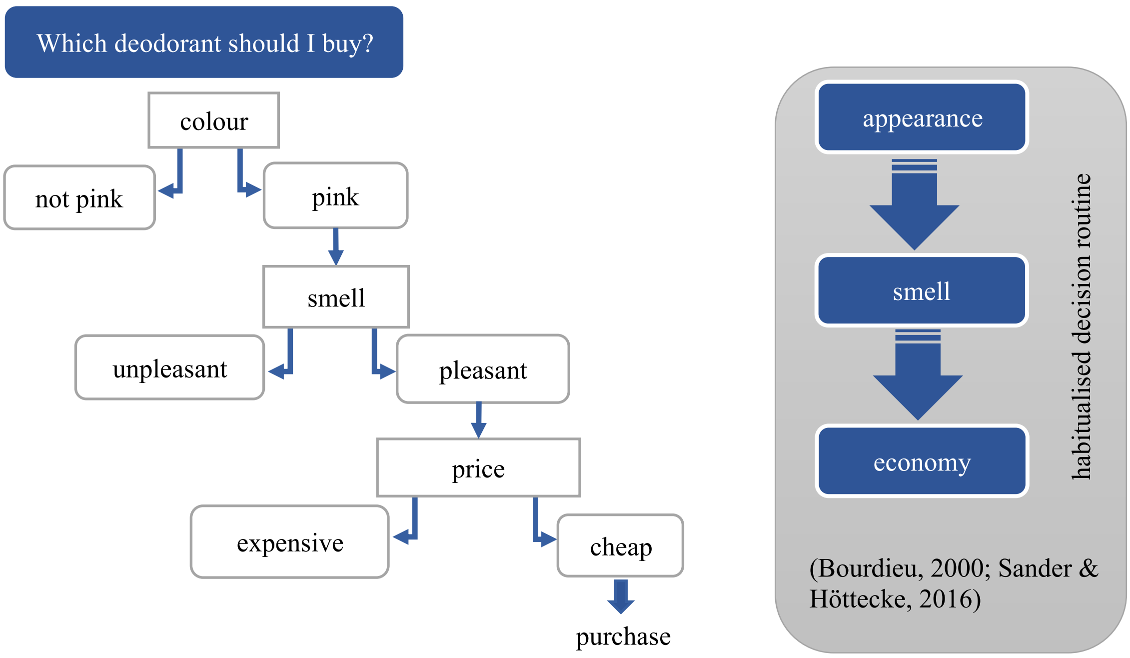

Figure 1. Decision tree of a student to buy deodorant.

But what insights do psychological theories provide in order to break through these habitualised decision making routines, to enable students in the sense of Scientific Literacy to become rational decision makers in everyday life situations?

Kahneman & Tversky (1979) established a decision theory based on two systems: unreflected decisions are assigned to "System 1". It makes decisions fast, unconscious and therefore is susceptible to mistakes (Kahneman, 2011). In everyday life “System 1” helps to decide quickly (Kahneman, 2011). If reasons for the decision are asked for, arguments are generated *post hoc* so that decision routine can be justified. “System 2” is activated if an irritation occurs in “System 1”. Thereupon a conscious and slower process is initiated. The cognitive processing of decision making requires attention and is often perceived as tiring and exhausting. If the complexity of the decision situation is perceived as too high or ineffective, this leads to the abandonment of the process in "System 2" and the routine decision strategy is maintained.

According to this theory, decision situations that lead to an irritation in “System 1” must be found in order to activate “System 2”. Thus, students must be supported in adopting complex scientific decision criteria so that they do not fall back into routines due to excessive demands. In some respects, similarities to the *conceptual growth theory* (Duit & Treagust, 2003) are already obvious. Based on this, dissatisfaction with existing decision strategies is required to make students ready fot the adoption of new concepts. Therefore, the motivation is to develop a tool that evokes dissatisfaction in everyday decisions and makes it tangible for science education.

This gives rise to the research question: In which way is the developed instrument “Decision Diary” suitable to initiate fruitful learning processes in the sense of conceptual change theory?

In order to clarify the general research question, it can be divided in three questions:

1. Is the decision diary an adequate instrument to identify student relevant decision situations? **(Diagnosis)**
2. How can lessons be planned along the decision diaries to provide students with the chemical content they need to decide? **(Structuring)**
3. In which way can the occasions of the decision diaries, together with the necessary expertise, help students make informed decisions? **(Intervention)**

This paper focuses on answering question 1 by considering the following sub-questions:

- How do students work on the task of the decision diary?
- What kind of questions are revealed by the decision diary entries?
- How complex do students perceive the self-chosen decision situations?
- Has the developed tool potential to uncover dissatisfaction with decisions?

The “Decision Diary” tool

The decision diary consists of a request and detailed tasks (cf. Figure 2). The tasks encourage students to identify everyday situations with chemical relevance. After identification, the students must reflect on whether a decision situation is of importance and whether it personally concerned them. During the photographic decision diary, this cognitive process is accompanied by the development of a photo that illustrates the decision situation. In order to meet the demand for individual support, a drawing decision diary was developed in addition to the photographic decision diary.

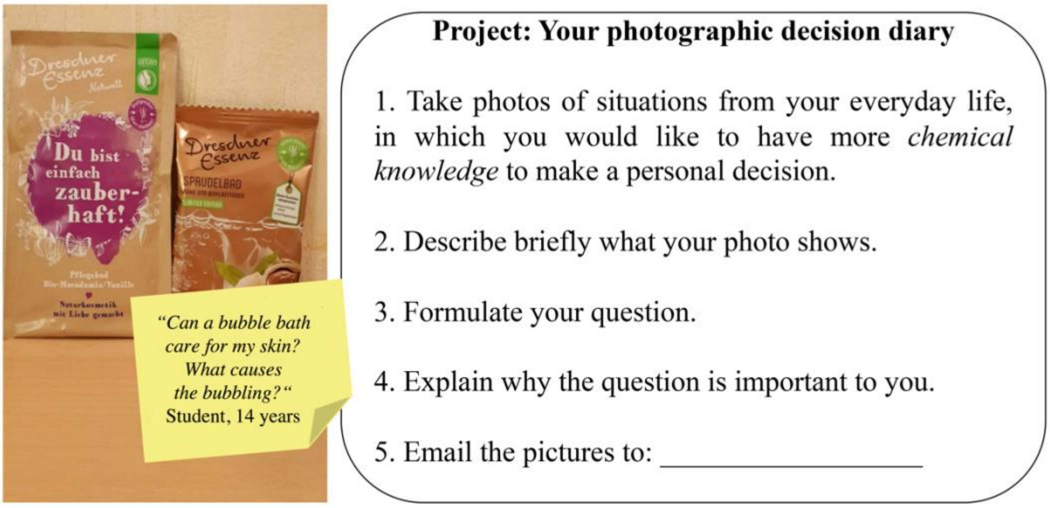

Figure 2. The decision diary tool with a student example. [German quotations were translated by the author.]

RESEARCH DESIGN AND METHODOLOGY

The diagnostic tool was tested in four chemistry classes with students of different age groups and from different school forms. The procedure for data collection is shown in Figure 3. Overall 53 students have participated so far. In each class three students were selected for interviews (n=9) according to the type of processing in decision diary. Participation in the interviews was voluntary. Apart from the semi-structured interviews, empirical data was collected by using open-ended questionnaires and decision diary entries created by the students. Thus, the decision diary serves a double function: as a method to create communication occasions for individual competence development in the chemistry class and as an instrument for collecting empirical data. In addition to the methodological triangulation (Flick, 2017) between interviews, questionnaires and document analysis (Denzin, 2011) of the decision diaries, a theoretical triangulation should contribute to a widening of perspective. Therefore, psychological theories of decision making (Svenson, 1966), motivation (Heckhausen & Rheinberg, 1980) as well as sociological theories (Bourdieu, 2000) were triangulated.

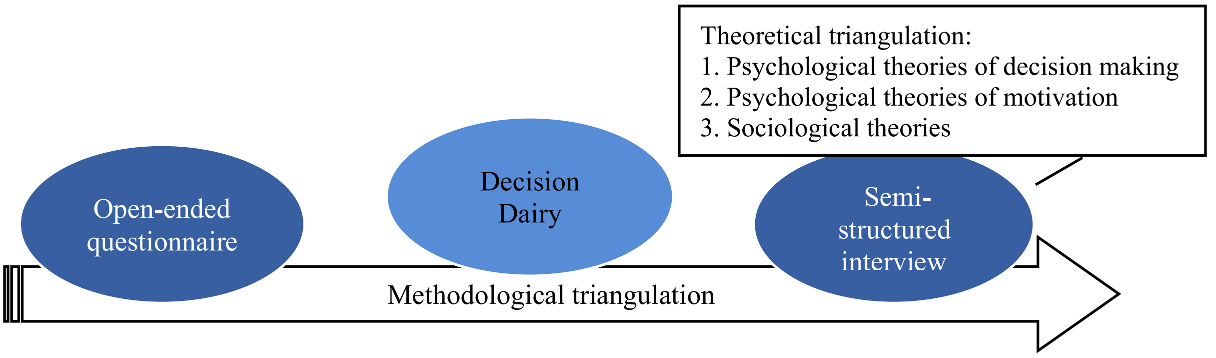

Figure 3. Study design.

So far, data of 136 decision diary entries from 53 students and semi-structured interviews (n = 9) have been analysed. The decision diaries were analysed inductively by qualitative content analysis (Mayring, 2015). The interviews were also analysed inductively and additionally a deductive category assignment based on theories of the complexity of decision situations (Pfister et. al., 2017) was applied. In this theory, a decision situation is characterised by categories "options", "level", "frequency", "information access", "consequences" and "effects" (cf. Table 2). Each of these categories is divided into a lower and a higher complexity. For example, "*Options*": The complexity of a decision situation can be reduced if the number of alternatives is already limited by external factors (*"Options given")*. It becomes more complicated for the decision maker if the options are open and have to be generated themselves (*"Options open")*. All self-chosen decision situations (n = 20) were analysed based on these categories. In the last step, the complexity was scaled from one-dimensional to multidimensional decisions. In the case of a one-dimensional decision, the students did not perceive any category as complex. In a two-dimensional decision a category with a higher complexity was described. It ends up in a multidimensional decision where all categories were perceived as complex.

Table 2. Complexity of decision situations according to Pfister et. al. (2017). Lower complexity is shown by light grey and higher complexity by dark grey.

Decision situation												
Category	*Options*		*Level*		*Frequency*		*Information access*		*Consequences*		*Effects*	
Complexity level	given	open	single	multi	repeated	unique	text-based	experience-based	certain	un-certain	personal	social

RESULTS

The analysis focuses on the processing of the task and the self-chosen decision situations of the students.

Evaluation of the decision diaries

Referring to the first sub-question (How do students work on the task of the decision diary?), three categories were identified inductively (cf. Table 3): The *information level*, on which students gather factual information and the entry does not indicate whether a decision is made. The *judgement level*, where different options are compared on the basis of a specific aspect and finally the *decision level*, where students name concrete alternatives for decision.

The Inter-Coder reliability between two coders for this category system (see Table 3) is $p_0 = 0.85$ while the coefficient κ (Brennan & Prediger, 1981) is 0.77.

The results reveal that most students argue on the *information level* (cf. Table 2). Only 39 entries show concrete decision situations with different options to choose from. This raises the question of whether the students fail to recognise a decision situation with chemical relevance in their everyday lives or whether decision situations are hidden behind *information* or *judgement level*. Therefore, it is necessary to take a closer look at the decision diaries with the interviews and ask what kind of questions are revealed.

Table 3. Number of selected processing levels per decision diary entry.

Category	**Definition**	**Representative quotes**	**Entries (n = 136)**
Information level	Entries that gather only factual information without being linked to a decision or evaluation question. Recognisable by interrogative words (how, what, where, why) and verbs like "interest" and "know".	*"Why is aluminium salt in deodorant?"*	63
Judgement level	Entries that ask for an assessment of different options according to a specific aspect, e.g. health, without necessarily leading to an action. Identifiable by better, healthier, more effective, etc.	*"Are mouth-washes with alcohol better for the teeth?"*	34
Decision level	Entries in which concrete options (alternatives) are already presented by the students and should lead to an action. To be recognised by either… or…, rather x or y, which.	*"Which drink should I buy?" (Multi-vitamin juice vs. Sprite®)*	39

Evaluation of semi-structured interviews

In order to clarify this sub-question (What kind of questions are revealed by the decision diary entries?), categories were formed inductively (Mayring, 2015) from 9 interviews with 23 decision diary entries. In total *four categories* were set up, decisions which have not yet been made (*open*), decisions already made (*taken*), no own decisions (*external*) and only one factual information question without decision-making interests (*none*). The majority of questions (cf. Figure 4) concern open decision situations in which students are still ready for new options or decision criteria. In the second most common category students have already made a decision in favour of an option on the basis of habitualised decision strategies (Bourdieu, 2000) and they just want a scientific justification.

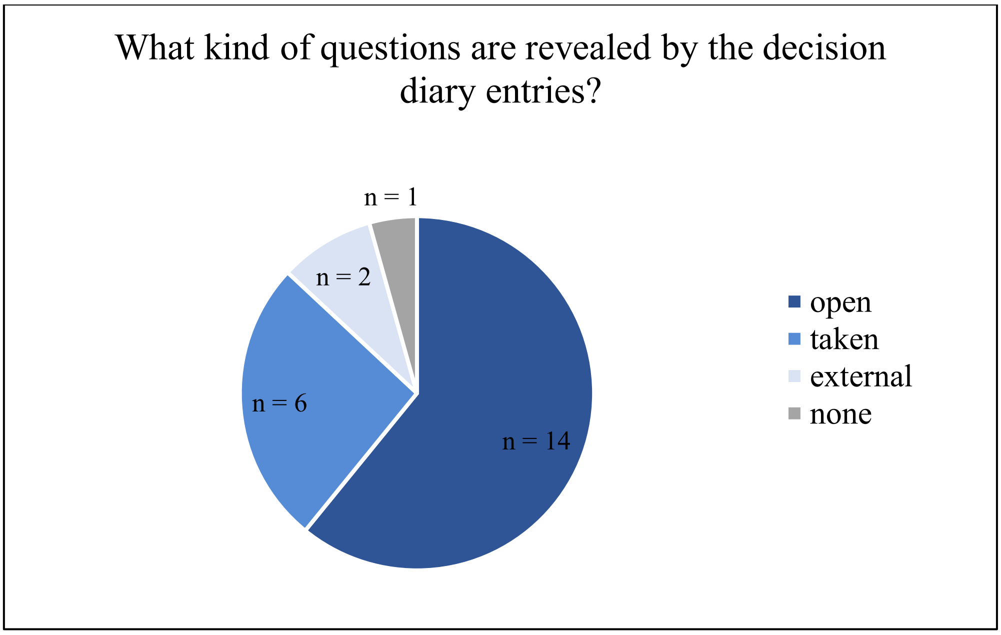

Figure 4. Analysis of 9 interviews with 23 decision dairy entries (n = 23).

After identifying student's decision making situations (*open* & *taken*), their perceived complexity was determined. Due to the task description, it can be expected that particularly *"repeated"* decision situations *(lower complexity)* will be submitted in which students are *"uncertain"* about the consequences *(higher complexity)*. As can be seen from Table 4, 19 of 20 decision situations are "*repeated"* in everyday life. In addition, in 15 of 20 situations students say that they are *"uncertain"* about the possible consequences of their decision. In many cases, students only focus on personal effects (n = 14) when making decisions in everyday life, but not on social ones (n = 6) such as sustainability or ecological considerations. As a result, neither one-dimensional (no category with higher complexity) nor multi-dimensional (all categories with higher complexity) decision situations are made tangible by the tool (see Table 5). Students perceive mainly a medium level of complexity, which can possibly protect them from being overwhelmed in "System 2" and thus from falling back into routines from "System 1" (Kahneman, 2011). In class, students can be supported in progressively becoming aware of the entire complexity of an everyday situation.

Table 4. Perceived complexity of self-chosen decision situations.

Category	*Options*		*Level*		*Frequency*		*Information access*		*Consequences*		*Effects*	
Complexity level	given	open	single	multi	repeated	unique	text-based	experience-based	certain	un-certain	personal	social
Decision situa– tions (n = 20)	18	2	14	6	19	1	6	14	5	15	14	6

Table 5. Complexity of decision situations scaled from one-dimensional to multidimensional.

	one-dimensional					multi-dimensional
Number of categories with higher perceived complexity level	0	1	2	3	4	5	6
Decision situations (n = 20)	0	3	9	7	1	0	0

The question remains whether the tool has the potential to uncover dissatisfaction with decision making situations. In 6 out of 9 interviews, the students expressed dissatisfaction with the decision situations that became tangible through the decision diary. When asked whether the students' current decision strategy is successful in achieving his or her goals, they answered for example as follows:

> "Well I think it's more 'no' than 'yes', but somehow I'm caught between, because I can't inform myself properly, because I don't know whether the gas is harmful or not." (Student, 14 years)

Here the student expresses her dissatisfaction with both her existing chemical knowledge and her competence.

CONCLUSION AND DISCUSSION

In summary, it can be stated that the decision diary leads to different levels of processing (*information*, *judgement* and *decision level*). In most cases open decision situations are submitted, which are perceived by students with a medium level of complexity. Apart from that, it turned out that the students do not perceive everyday decision situations in their entire complexity, but ignore certain aspects such as sustainability. Furthermore, the instrument seems to actually lead to uncertainty in existing decision making situations and even to dissatisfaction with one's own knowledge and competences. This promises a fruitful learning opportunity.

According to these results, the decision diary mostly seems to be an adequate instrument to make the decision situation of students tangible for teaching purposes (**Diagnosis**). However, it should be noted, that qualitative research design only permits the development of theories. The sample size does not allow any generalizable statements at this point. In the long term, quantitative methods will have to be used to support the theories developed with larger samples.

In order to clarify the overarching research questions, the next step is to examine whether the decision situations can be used in chemistry classes. This raises the question of how lessons can be planned based on the questions of the decision diaries (**Structering**) in order to provide students with the chemical knowledge they need for their decisions (**Intervention**).

REFERENCES

Aikenhead, G. S. (1985). Collective decision making in the social context of science. *Science Education*, 69(4), 453–475.

Bourdieu, P. (2000). *Pascalian meditations.* Stanford, Calif: Stanford University Press.

Brennan, R. L. & Prediger, D. J. (1981). Coefficient κ: Some uses, misuses, and alternatives. *Educational and Psychological Measurement*, 41, 687–699.

Chinn, C. A. & Brewer, W. F. (1998). An empirical test of a taxonomy of responses to anomalous data in science. *Journal of Research in Science Teaching*, 35(6), 623–654.

Denzin, N. K. & Lincoln, Y. S. (Eds.). (2011). *The Sage handbook of qualitative research* (4th ed). Thousand Oaks: Sage.

Duit, R. & Treagust, D. F. (2003). Conceptual change: A powerful framework for improving science teaching and learning. *International Journal of Science Education*, 25(6), 671–688.

Flick, U. (2017). *Doing triangulation and mixed methods* (1st ed). Thousand Oaks, CA: SAGE Publications.

Halverson, K. L., Siegel, M. A. & Freyermuth, S. K. (2009). Lenses for Framing Decisions: Undergraduates' decision making about stem cell research. *International Journal of Science Education*, *31*(9), 1249–1268.

Heckhausen, H. & Rheinberg, F. (1980). Lernmotivation im Unterricht, erneut betrachtet. *Unterrichtswissenschaft*,8, 7–47.

Heitmann, P. (2012). *Bewertungskompetenz im Rahmen naturwissenschaftlicher Problemlöseprozesse: Modellierung und Diagnose der Kompetenzen Bewertung und analytisches Problemlösen für das Fach Chemie*. Berlin: Logos.

Kahneman, D. (2011). *Thinking, fast and slow* (1st ed). New York: Farrar, Straus and Giroux.

Kahneman, D. & Tversky, A. (1979). Prospect Theory: An Analysis of Decision under Risk. *Econometrica*, 47(2), 263.

Mayring, P. (2015). Qualitative Content Analysis. Theoretical background and procedures. In A. Bikner-Ahsbahs, C. Knipping & N. Presmeg (Eds.), *Approaches to qualitative research in mathematics education. Examples of methodology and methods* (pp. 365–380). New York: Springer.

Menthe, J. & Parchmann, I. (2015). Getting Involved: Context-Based Learning in Chemistry Education. In *Affective Dimensions in Chemistry Education* (pp. 51–67). Heidelberg: Springer.

OECD. (2007). *PISA 2006: Science competencies for tomorrow's world.* (Vol. 1). Paris: OECD.

Pfister, H.-R., Jungermann, H. & Fischer, K. (2017). *Die Psychologie der Entscheidung: eine Einführung* (4th ed). Berlin Heidelberg: Springer.

Sadler, T. D. & Zeidler, D. L. (2009). Scientific literacy, PISA, and socioscientific discourse: Assessment for progressive aims of science education. *Journal of Research in Science Teaching*, 46(8), 909–921.

Sander, H. & Höttecke, D. (2016). Students' decision-making on issues of sustainability – beyond rational choice theorey. In J. Lavonen, K. Juuti, J. Lampiselkä, A. Uitto & K. Hahl (Eds.), *Science Education Research*: Engaging Learners for a Sustainable Future (Proceedings of ESERA 2015) Part 7, Strand 7, Discourse and argumentation in science education, 1004–1011.

Svenson, O. (1996). Decision Making and the Search for Fundamental Psychological Regularities: What Can Be Learned from a Process Perspective? *Organizational Behavior and Human Decision Processes*, 65(3), 252–267.

Uskola, A., Maguregi, G., & Jiménez-Aleixandre, M. (2010). The Use of Criteria in Argumentation and the Construction of Environmental Concepts: A university case study. *International Journal of Science Education*, 32(17), 2311–2333.

ANALYZING EPISTEMOLOGICAL, ONTOLOGICAL AND AXIOLOGICAL COMMITMENTS IN STUDENTS' SPEECHES AS THEY DISCUSS ON MEDICINES AND SELF-MEDICATION

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This work is part of a broader doctoral research which aimed to identify and understand relations among contexts, common sense and scientific knowledge in studies on socio-scientific issues (SSI). *Here, we focused our analysis on epistemological, ontological and axiological commitments implied in the students' speeches as they are engaged in an SSI approach on medicines and self-medication, in chemistry classes. Research on SSI was considered to plan a teaching and learning sequence (TLS) on the theme and the theory of conceptual profile supported data analysis looking for the heterogeneity of thinking in the students' speeches. A chemistry teacher and 32 students (year 11), in a Brazilian public high school, participated in this investigation. The students were engaged in TLS activities, such as: reading, solving cases, discussing in small groups, analyzing package inserts and responding questions. Eight classes (100 minutes each one) were audio and video recorded, relevant episodes were extracted from the classes and transcripts were analyzed in order to identify thematic items, semantic relations among them and to characterize epistemological, ontological and axiological commitments implied in students' speeches. In this work, we present data from episode 7.2, extracted from the class 7. Results pointed that scientific knowledge was predominant in the students' speeches, in the two last classes, and they did not make position in favor of self-medication, but they considered exceptions in this practice for people who has no easy access to medical assistance, bringing together epistemological and axiological commitments. Different thematic items related to self-medication and medicines were connected by different semantic relations, for instance, medicines/therapeutic action, medicines/side effects, medicines/substance, medicine/active component, self-medication/ needs, self-medication/medical assistance access, self-medication/overdose and others. Despite scientific knowledge was predominant in the students' speeches, it did not seem to be a guarantee for the use of epistemological commitments to guide their positions as most of them declared to practice self-medication. Different ways of thinking emerged in the students' speeches and it can be representative of their heterogeneity of thinking and they assumed different commitments as faced to diverse aspects of the SSI. Common sense or scientific knowledge seemed to be applied by the students depending on the context in which the ideas or models are more appropriated.*

Keywords: socio-scientific issues, heterogeneity of thinking, medicines and self-medication

INTRODUCTION

In this work, we aimed to analyze epistemological, ontological and axiological commitments implied in students' speeches as they engaged in discussions on medicines and self-medication in chemistry classes. The theory of conceptual profile supported the identification of epistemological, ontological and axiological commitments implicated in different modes of thinking, expressed by students in the classroom discussions, which enable us to characterize the heterogeneity of thinking in science classrooms. Research on SSI help us to plan specific strategies to address the theme on medicines and self-medication considering scientific, social and cultural aspects, among others, according to requirements for an SSI approach.

According to the conceptual profile theory (Mortimer et al, 2014), an individual can present different modes of thinking and ways of speaking on a specific concept, which are represented by zones constituted from different epistemological, ontological and axiological commitments. The conceptual profiles zones can be considered as a pool of ideas that characterize distinct worldviews, which are used to understand and to represent the reality. Each zone can be associated with specific contexts in which they make sense. From this perspective, science classrooms are a complex social place of interactions between individuals, who bring social discourses circumscribed in diverse contexts, constituting the heterogeneity of verbal thinking (Tulviste & Hall, 1991; Wertsch, 1988) as a starting and arrival point for plurality in science classes. According to Tulviste & Hall (1991), the heterogeneity of verbal thinking implies that in any culture, for any individual, there are not only a unique, homogeneous ways of thinking on a specific concept. Wertsch (1988) argued that different ways of thinking are somehow articulated to the genetic domains (phylogenesis, sociocultural and ontogenesis) proposed by Vygotsky, considering the influence of the context in the development of ideas and concepts by individuals. According to Mortimer et al (2014), the heterogeneity of thinking is inevitable as teachers and students are engaged in teaching and learning scientific concepts in the classroom and it should be expressed in different ways of speaking on content addressed in classes.

In this work, even though we did not make a proposal of specific zones for a conceptual profile, according to the methodological requirements from the theory, different ways of thinking on the studied theme were identified and characterized by epistemological, ontological and axiological commitments. This could be a start point to propose a conceptual profile in further work, considering conceptual profiles as models of different modes of seeing and conceptualizing the world used by individuals to signify their experience (Mortimer & El-Hani, 2014). In science classrooms, different ways of thinking and speaking emerge in the discussions, and teachers could recognize some culturally relevant ideas, which are appropriate in contexts and spheres of life for students and include these ideas in the making meaning process for scientific concepts. In putting together ideas from social and scientific contexts, teachers address not only problems, solutions and knowledge associated to each context, but they also bring all motivations, values and goals related to the activities addressing scientific subjects, and epistemological, ontological and axiological commitments could be identified in the students' speeches (RODRIGUES, 2009, p. 24).

In school context, the process of meaning making for scientific knowledge should help students to represent and to understand reality in its complexity by coming across different senses and meanings that scientific concepts can acquire in different contexts. Students could be invited to establish relationships among different forms of knowledge and to deal with diverse perspectives on situations and phenomena. We consider that socio-scientific issues (SSI) can be part of didactic strategies that aim to broaden the classroom discussion about scientific knowledge considering the emergence of different ways of thinking that they could make to arise. According to Martinez Pérez (2012), SSI include themes and controversies related with scientific and/or technological knowledge that promote impacts on society. Socio-scientific issues are controversial social issues with conceptual and/or procedural links with science. They can be characterized as open problems without clear solutions, with multiple possibilities of resolution (Sadler, 2004). These issues cover the formation of personal and social opinions and judgments, in decision-making processes that imply in the development of values and ethical aspects and are related to social problems in local, national and global levels (Ratcliffe and Grace, 2003). According to the authors, an SSI approach has potential to explore different contexts in classrooms by addressing political, ideological, cultural and ethical aspects that involve contemporary science. In an SSI approach, it could be considered aspects related with the nature of science and technology, decision making, ethical-moral reasoning, socio-critical reconstruction and actions adjacent to the interactions of the STS movement, for example, formation for citizenship. In this way, we argue that SSI can support teachers to explore different dimensions of human life as they are teaching scientific contents, provoking students to express ideas implicated with their personal experience, in which they assume different epistemological, ontological and axiological commitments.

An SSI approach could enable teachers to contextualize scientific concepts marking different position to the traditional school teaching, in which scientific concepts are presented as unquestionable constructs that could be applied to any context as hegemonic response to questions and challenges faced by the students. We believe that SSI could lead teachers and students to search and discuss scientific models and social experiences that are not necessarily reproducible for any situation, considering the contexts to approach and solve problems. In this way, science learning would involve exploring and understanding different perspectives and views on concepts and how they could be useful to explain and solve situations and problems in diverse context. According to Rodrigues & Mattos (2007), it is important to point out the domains of validity and limits of scientific knowledge when it often does not replace common sense. The complex relations between scientific concepts and contexts open space for the expression of the heterogeneity of thinking, and different modes of thinking can be identified from different epistemological, ontological and axiological commitments assumed by the individuals.

In this investigation, we consider that science teaching and learning implies to be involved in a dynamic interrelationship between common sense, cultural and personal beliefs/ideas and scientific concepts. It does not mean that we expect to convert one into the other, or substitute one by the other, rather we look for promoting dialogue, an articulation between different points of view, in order to establish relations among different ways of thinking, contributing to build a plural knowledge. We believe the conceptual profile theory can help us to understand the process of conceptualization in science teaching and learning by constituting relations among different forms of knowledge. In this sense, the students were invited to study and discuss on medicines and self-medication in chemistry classes, bringing an important social issue present in their lives. Different ways of thinking on medicines, substances, and self-medication, side effects, among others were discussed in the classes, and epistemological, ontological and axiological commitments were identified in the students' speeches.

METHODOLOGY

This work is a qualitative research, part of a broader doctoral research which aimed to identify and understand relations among contexts, common sense and scientific knowledge in studies on socio-scientific issues (SSI). In this work, the purpose was to analyze epistemological, ontological and axiological commitments implied in the students' speeches as they are engaged in an SSI approach on medicines and self-medication, in chemistry classes. Research on SSI was considered to plan a teaching and learning sequence (TLS) on medicines and self-medication and the theory of conceptual profile supported data analysis focused in the heterogeneity of thinking in the students' speeches.

The investigation involved one chemistry teacher and 32 students (aged 16-18), in year 11, in a Brazilian public high school. After short discussions on SSI approaches, a TLS was planned by the teacher with support of the first author in this paper. The students were engaged in activities such as: reading, solving cases, discussing texts and situations in small groups, analyzing package inserts and responding questions, as showed in the table 1.

Table 1: TLS Design according to the 5Es model proposed by Patro (2008)

Teaching and Learning Sequence - Medicines and self-medication		
Content: Organic Chemistry – Functional groups - identification of compounds and molecular structure.		
Aims: Characterizing functional groups from studies on the theme. Analyzing medicines composition, presence of substance in generic, similar, original and natural medicines. Understanding different types of medicines and drugs. Analyzing controversial issues involving medicines and self-medication.		
SSI proposed: Is self-medication a public health problem or a solution in face to public health precariousness? Are there controversies regarding the use of generic, manipulated, natural or original medicines?		
Phases (5Es)	**Activities**	**Classes**
Engagement	Questionnaires to raise initial conceptions and the introduction of the theme	Class 1
Exploration	Video exhibition and debate: The intelligence pill. Questions for debate: is it right to take medicines on your own, even though it promises benefits as we saw in the video? Is it possible that you take the "intelligence pill", in some occasion? Why? What would be the benefits and risks? Do all medicines bring benefits or healing to humans? What are substances? And what are molecules? After video, the students read a report on British BBC journalist who used the intelligence pill to test it.	Class 2 (Episode 2.1)
Explanation	Expositive classes to discuss on chemical concepts - substance, molecule, drug, medicine, active ingredient, origins of medicines. Reading the text: "On the Chemistry of Medicines, Drugs and Remedies" (Barreiro, E.J.; Rodrigues, C.R., 2001). Identification of functional groups and structural formulas in medicines often used by the students.	Classes 3, 4, 5
Elaboration	Group activity: reading package inserts of generic, similar and original medicines and draw up a panel with the main information about them - among others, active components, substances and functional groups. Question for debate: are there differences between original, generic or similar medicines? What? Presentation of the results with the large group.	Class 6
Evaluation	Students working in small groups: solving a case study – Bianca's case. Resolution of the two questions addressing SSI.	Classes 7-8 (Episodes 7.2-8.3)

An overall of 8 classes (100 minutes each) were audio and video recorded and transcripts were analyzed from episodes. Three relevant episodes were extracted for analysis: [2.1] Introducing discussion on self-medication after exhibition of the video "The Intelligence Pill"; [7.2] Discussion on self-medication using a case study and [8.3] Discussion on chemical characteristics and properties of medicines and human health. In this work, we present the analysis and discussion of data extracted from episode 7.2.

The students' speeches were analyzed starting from the identification of thematic items and semantic relations (Lemke, 1997) established among them by the students, and epistemological, ontological and axiological commitments were identified from semantic relations. From the ways of speaking, we identify modes of thinking, taking into account ideas from Mortimer and Wertsch (2003). The authors considered that different modes of thinking are interwoven with different ways of speaking characterized in terms of social languages and discourse genres (Bakhtin, 1981, 1986). They refer to Bakhtin as he states that heterogeneity of speech is related to discourses comprising different social voices. The voices are considered as specific points of view about the world, the ways of conceptualizing the world in words, specific perspectives of the world - each one characterized by its own objects, meanings and values. As such, they can all be juxtaposed to one another and coexist in the consciousness of real people. To identify commitments assumed by the students, we considered scientific or formal knowledge (epistemological), the nature of objects addressed by them (ontological), values and emotional features (axiological) implicated in their speeches as they discuss the SSI.

RESULTS AND DISCUSSION

In general sense, during the classes, we observed most of the students became progressively aware on chemicals aspects related to medicines and they engaged positively in discussions on self-medication, among others. In data analysis, our main point was to capture movements in the students' speeches that could evidence changes in commitments assumed by them as they expressed ideas or positions on the theme. In the beginning of TLS, the students discussed on medicines and self-medication and expressed ideas related to their personal experiences (classes 1-2, see table 1). Most of their ideas were expressed using everyday language, mainly supported by commonsense knowledge, and/or they reproduced information on the theme broadcast by communication media, and axiological commitments were more evident in the students' speeches. In this occasion, we realize that students did not have a well-built opinion about the risks involved in self-medication, as they considered as natural to take medicines by their own. In the classes 3, 4, 5 and 6, the students were engaged in activities to read texts, discuss and solve questions considering chemical and human health aspects related to this theme. In the classes 7 and 8, they brought together different ways of thinking in order to solve a case and questions posed by the teacher.

In class 7, in small groups with mediation of a preservice teacher acting as research assistant, the students were asked to solve a case study which brought the follow situation, in summary:

A young student, Bianca, was immersed in a hard routine of studies for exams. She often felt headaches, a problem that she had since early childhood. She had no time to seek for medical assistance and always took medicines without medical consultation (self-medication). Then, she always sorted and took medicines on their own considering publicity, friends advice or commonsense knowledge (Neosaldina®,

Sonridor®, Tylenol®, dipyrone), and her health problem never has been solved, instead of, headaches have become more frequent.

The students were invited to analyze and discuss the case guided by questions such as: what chemical substances and properties are present in some popular medicines used by Bianca? Are these medicines efficient to relieve headaches? Are they efficient to everyone indistinctly? Are you in favor of self-medication? If positive, in which situations or conditions it could be useful? Do you think there are benefits and risks involved in self-medication? The case brings a situation in which students could be involved in everyday life. Self-medication is a social problem in Brazil as in other places around the world. To support groups' discussion, the students were asked to read a text entitled "What is self-medication: causes and consequences", and the teacher made available cards, elaborated by the researcher (first author), with information on different commercial medicines often used for headaches, and infographics extracted from advertisement on medicine for relieving headache. It was requested that groups discussed ideas in order to answer the questions and make position about Bianca's case. Below, we show a piece of Episode 7.2, with discussion involving the preservice teacher (PT) and the students (S1, S2, S4), in a small group.

Episode 7.2 (piece) **:** Discussion on self-medication using a case study

1	S1: Other question we have here is ... Bianca has no time to seek medical help, in such case self-medicating would be correct? Why?
2	PT: Now, let's look at self-medicating in the texts you have read, the question is...
3	S1: In this case, self-medicating would be a solution or a problem?
4	PT: Come on, for Bianca is self-medication a solution or a problem?
5	S2: It would be a problem
6	S4: In her situation, if she doesn't have an easy access to a hospital or health clinic, for her, (self-medication) would be a solution because it would solve her problem.
7	PT: But let's see, she's been self-medicating for a while.
8	S2: Since her childhood
9	PT: So, in this case, self-medicating by taking Tylenol® or something else would be a solution? It works?
10	S4: It would be a problem, in my opinion, it would be a problem, because she already ...
11	PT: Tylenol is another medicine, let's look now at Neosaldina®, Sonridor® and dipyrone sodium, let's see the active ingredient to check the medicines she was taking, if they have the same active ingredient - is it the same or not?
12	S4: The active ingredient in Tylenol is acetaminophen. The active ingredient of dipyrone is itself.
13	S1: The active ingredient in Sonridor® is acetaminophen and caffeine.
14	S4: In Neosaldina® the active ingredient is dipyrone, caffeine and isometheptene mucate and for Sonridor ® is paracetamol and caffeine, and Tylenol® is just paracetamol.
15	PT: Can you guys see if you have the same active ingredients?
16	S1/ S4: Neosaldina® and Sonridor® have caffeine but none of the others (has).
17	PT: Let's look at the functional group, because we need to see if they have some components or not, if their active component is the same. There are four, Neosaldina®, Sonridor®, Sodium Dipyrone, and Tylenol®. We need to see if they are the same medicine or not, if they have the same active component.
18	S4: They are not the same medicine. They do not have the same active principle
19	S1: So that's why in my opinion it (self-medication) wouldn't be a solution for her, because she was already going to have taken three (different) medicines.
20	S4: They don't have the same active ingredient, but the classification or action is the same for them, which is to reduce fever, analgesic... I say an antipyretic that reduces the...
21	S2: Reducing body temperature
22	S4: Analgesic, in case, relieves pain but not fever
…	(…)
54	S1: So everyone comes to a consensus that she self-medicated would be a problem. Because it would be the accumulation of another medicine with the same active ingredient.
55	All: Yes

56	S1: So, it would be a problem, it wouldn't be a solution

In episode 7.2, the students used scientific arguments to analyze the case, going beyond personal experiences, and they considered that self-medication could be a problem that involves risks. It is interesting to highlight the two different positions assumed by the student S4, as he considered self-medication as a solution (turn 6) and then as a problem (turn 10) for Bianca. In general sense, we verified that students were able to identify chemical substances and active components in the medicines taken by Bianca, and they used scientific knowledge to understand relations between properties and therapeutic effects for them, in order to decide about self-medication as solution or problem for her case. Their conceptions on self-medication seemed to be wider in comparison to they expressed in episode 2.1, as self-medication was considered as something natural. In episode 7.2, the students seemed to assume epistemological commitments to make final decision on the questions proposed in the case (turns 54-56), although axiological commitments also were assumed considering controversial aspects related to the studied case involving Bianca's needs, conditions and health.

During classes 7 and 8, the students improved their speeches by using thematic items such as: self-medication risks, access to medicines, substances accumulation in the body, side effects, dosage, efficacy, adaptation; active component in medicines, medicines composition, substances, therapeutic action, and others. We collected different thematic items and characterized semantic relations among them, in the two episodes extracted from classes 7 and 8, and some of them, related to medicines and self-medication. The most frequent semantic relations between thematic items, as established by the students, were: process/reason (self-medication/needs), identified/identifier (medicines/active component), thing/attribute (medicines/ therapeutic action), cause/consequence (medicine/side effects), whole/part (medicine/substance) and others, are showed in the table 2. In the semantic relations, categories placed before the bar (/) is related to the item in the first column, followed by the categories related to the subsequent item in the third column.

Table 2: Systematization of semantic relations present in students' speech in episode 7.2

Thematic Item	Semantic Relations	Thematic Item
Self-medication	Thing/Attribute	Problem
Self-medication	Process/Reason	Needs
Self-medication	Action/Motivation	Difficulty for medical assistance
Self-medication	Action/Motivation	Access/needs in rural areas
Self-medication	Cause/Consequence	Body adaptation (loss of effect)
Self-medication	Cause/Consequence	Overdose
Self-medication	Cause/Consequence	Allergic reactions
Self-medication	Cause/Consequence	Unexpected reactions
Medicines	Thing/Attribute	Therapeutic action
Medicines	Cause/Consequence	Side effects
Medicines	Whole/Part	Substance
Medicines	Identified/Identifier	Active component

From the table 2, we considered that semantic relations pointed for different ways of thinking on self-medication and medicines, considering they addressed different aspects related to these two concepts – scientific and social ones - and assumed different commitments to express their ideas. We organized these ways of thinking, such we showed below:

Ways of thinking on self-medication	Ways of thinking on medicines
[1] Self-medication as a problem	[5] Medicines as material thing causing problem
[2] Self-medication as process leaded by needs	[6] Medicines as material thing healing diseases
[3] Self-medication as action motivated by difficulties in the access to medical assistance	[7] Medicines constituted by substances
[4] Self-medication as cause for risks and consequences – side effects, loss of therapeutic effect, overdose, unexpected reactions	[8] Medicines identified by active component

From the students' ideas on self-medication, we characterized ways of thinking associated to social and emotional aspects (1, 2, 3), as they raised up possible causes for people practicing self-medication, which suggest axiological commitments guiding their speeches. They applied scientific knowledge to explain consequences for self-medication (4), assuming epistemological commitments. For self-medication, different ontological commitments were identified: process, concrete action (materialized) and cause (abstraction). From the students' ideas on medicines, we find only one ontological commitment – medicines as something material, sometimes addressed from their properties (healing or causing problems – 5, 6), other times explained medicines considering composition or active components (7,8). These ways of thinking and speaking seemed to characterize a heterogeneity of thinking as we put together a topic closely related to chemical aspects (medicines) and a social issue associated to it (self-medication).

To solve Bianca's case, the students looked for differentiating chemical substance (active components) in medicines, seeking for scientific bases to support their positions and they considered social aspects leading to the practice of self-medication. In this sense, they were not in favor of self-medication, considering that medicines can bring undesirable consequences, if it is taken without appropriate indication. However, they make exceptions to this practice considering social conditions of the individuals – no easy access to medical assistance and personal needs. In this sense, it is important to highlight that a meaningful number of students declared to practice self-medication, at different moments, in TLS. In episode 7.2, we realized that scientific knowledge was predominant in classroom discussions, but it did not seem to guarantee that students assumed only epistemological commitments in their positions.

FINAL COMMENTS

In general, in this work, we verified that students associated scientific knowledge with ideas built in their personal experience, in the classroom discussions, in order to understand the SSI from the point of view of science. Texts, videos, lectures, discussions and other didactic materials helped the students to make meaning for chemical content as they were asked to solve questions related to the SSI on self-medication. We realized a movement from predominant axiological commitments assumed by the students, in the beginning of TLS, to more elaborated ideas in which was also implied epistemological and ontological commitments. We believe that students enriched their repertoire of ideas on the theme both in scientific and social view, and it could be fruitful for a meaningful science learning and the development of values, motivations for actions in their lives. In this way, we realized that scientific knowledge gained relevance for students considering that it was applied to understand an important issue present in social context.

The pragmatic value for scientific knowledge seemed to be materialized as the students implicitly or explicitly bring together their epistemological, ontological and axiological commitments, which could favor the expression and articulation of diverse ideas and positions on the theme. In science classes, SSI approach can contribute to make meaning for scientific knowledge in order to understand and signify experiences lived in everyday life. Different ways of thinking can be addressed from a pragmatic value, in an integrative perspective and not for replacing one by the other. The heterogeneity of verbal thinking reflects the existence of different forms of knowledge that constitute the diversity of representations for the world and reality, which can emerge in contextualized educational practices.

ACKNOWLEDGEMENT

CNPq and CAPES – Brazil for research grants. To the teacher and students for collaboration.

REFERENCES

Bakhtin M., (1981), *The dialogic imagination*, in Holquist M. (ed.), Austin: University of Texas Press.

Bakhtin M., (1986), *Speech genre and other essays*, Austin: W. McGee.

Lemke, J. (1997). *Aprender a Hablar Ciência. Lenguaje, Aprendizaje y Valores*. 1. Ed. Barcelona: Paidós.

Martínez Pérez, L. F. M. e Carvalho, W. L. P. (2012). Contribuições e dificuldades da abordagem de questões sociocientíficas na prática de professores de ciências. *Educação e Pesquisa*, 38 (3), p. 727-741.

Mortimer E. F. and Wertsch J. V., (2003), *The architecture and dynamics of intersubjectivity in science classrooms, Mind, Culture, and Activity,* vol. 10, pp. 230–244.

Mortimer, E. F., & El-Hani, C. N. (Eds.). (2014). *Conceptual profiles: A theory of teaching and learning scientific concepts* (Vol. 42). Springer Science & Business Media.

Mortimer, E. F.; et. al. (2014). Conceptual Profiles: Theoretical-Methodological. In: *Bases of a Research Program Conceptual Profiles:* A Theory of Teaching and Learning Scientific Concepts. New York: Spriger, 2014.

Patro, Edward T. Teaching aerobic cell respiration using the 5 Es. *The American Biology Teacher*, v. 70, n. 2, p. 85-87, 2008.

Ratcliffe, M.; Grace, M. (2003). *Science education for citizenship*: Teaching socio-scientific issues. McGraw-Hill Education (UK).

Rodrigues, A. M. (2009). *Redimensionando a noção de aprendizagem nas relações entre perfil conceitual e contexto: uma abordagem sócio-cultural-histórica* (Doctoral dissertation, Universidade de São Paulo).

Rodrigues, A.M.; Mattos, C.R. (2007). Reflexões sobre a noção de significado em contexto. *Indivisa, Boletín de Estudios e Investigación*, 7, p. 323-333.

Sadler, T. D. (2004). Informal reasoning regarding socioscientific issues: A critical review of research. *Journal of Research in Science Teaching*: The Official Journal of the National Association for Research in Science Teaching, 41(5), 513-536.

Tulviste, P., & Hall, M. J. T. (1991). *The cultural-historical development of verbal thinking*. Nova Science Publishers.

Wertsch, J.V. (1988). *Vygotsky and the social formation of mind.* Cambridge: Harvard University Press.

PART 9: STRAND 9

Environmental, Health and Outdoor Science Education

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CONTENTS

STRAND 9: INTRODUCTION

ENVIRONMENTAL, HEALTH AND OUTDOOR SCIENCE EDUCATION

Strand 9 includes a number of areas of education including the following: ecological and environmental education; education for sustainable development; environmental health, health education and health promotion; lifestyles and attitudes towards health and the environment; and, developing and evaluating the impact of programmes and experiences outside classrooms, including those organised by institutions other than schools. On first inspection, this grouping might seem to lack the coherence of other strands, however, when viewed from the perspective of the challenges facing the planet and everything that lives on it in 2020, things fall into place.

The Coronavirus pandemic has exposed the failure of science education to adequately prepare scientifically literate citizens (Dillon & Avraamidou, 2020). The strength and depth of the anti-vaccination movement coupled with more general misunderstandings of risk and health should sound a wake-up call to policy-makers, educators and education researchers. Not that some policy-makers seem to appreciate the science, either – few world leaders appear to understand some basic ideas and risk the lives of their populations as a result.

While the global health crisis has dominated the media and the public consciousness, the potentially greater threats of biodiversity loss, food/water security and climate change remain. These wicked problems cannot be solved in the conventional sense, and no amount of inquiry-based or problem-solving approaches are going to prepare students for the values-based decisions they will have to make in their lives.

Part of the problem that has been exposed by recent and longer-term challenges is a widespread lack of engagement with the environment and the outdoors. Enforced lock-down has made people aware, if they weren't already, of the mental and physical health benefits of engagement with the environment. This interrelationship between science, the environment and health underpins ESERA Special Interest Group 4 "Science|environment|health" (Zeyer & Dillon, 2019)

We see science as a both a body of evolving (and established) facts and theories and a way of making knowledge; the environment can be regarded as nature or the natural world; health reflects the physical and mental aspects of well-being. We acknowledge, of course, that all three terms are contested. The fact that they represent different ontological categories does not deny their interrelationship in our lived experience.

Twelve papers constitute this chapter. The 39 authors come from around the world, reflecting the diversity of ESERA and the global nature of research in these topics. Some, like Alexandros Amprazis and Penelope Papadopoulou, address longstanding challenges faced by teachers, such as plant blindness, in their case through a cross-age study of Greek students. Another Greek study, this time by Athanasia Papadopoulou, Dimitrios Charalambous, Alexandros Georgopoulos and Georgios Malandrakis, reports on an exploration of primary students' intention of consuming seasonal, organic and local fruits. The seven-month intervention the authors report on, might offer a way of raising students' awareness of the role of plants in our lives.

Three contributions focus on studies involving pre-service teachers. Elías Amórtegui, Olga Mayoral and Valentin Gavidia report on a successful Colombian study of the development of the pedagogic content knowledge necessary to teach biology fieldwork. Lidia Caño and Oihana Barrutia report on the development of a scale to test environmental literacy and to predict environmental responsible behaviour of Spanish pre-service teachers. As with most studies of pre-service teachers' knowledge, the results were quite disappointing. Anthoula Maidou, Katerina Plakitsi and Hariton Polatoglou present a study which involved introducing pre-service early childhood teachers to education for sustainable development using an approach they call Socrates' House.

Another energy-related study is reported by Shih-Yeh Chen and Shiang-Yao Liu, from Taiwan, who interviewed students three years after they had taken a science-informed energy course. This unusual approach begins to address the challenges of programmes that focus on issues of sustainability – if there's no long-term impact, they probably haven't worked. In a related paper, Maria-Christina Kasimati and Marida Ergazaki, from Greece, look at a neglected area – early-childhood education for education for sustainability; you can never start too young, it seems.

Two studies focus on novel pedagogic strategies. Japanese researchers, Shiho Miyake and Asami Ohnuki, report on the use of a card-type game aimed at providing an opportunity to consider the ethical perspectives of science in students future decision-making related to health and wellbeing.

Another Japanese study, by Emoto Arisa, Hisano Arata, Kawabata Itsuki, Kusunoki Fusako, Inagaki Shigenori, Hanaki Kumiko, Atake Noriko and Nogami Tomoyuki, used augmented reality to help students visiting a zoo to develop their observational skills with a focus on animal skeletons and their movements. While limited in its success, the approach offers huge potential for the future.

Another use of technology in education is provided by Shota Asahina, Shigenroi Inagaki, Yoshiaki Takeda, Etsuji Yamaguchi, Hiroshi Mizoguchi, Fusako Kusunoki, Hideo Funaoi and Masanori Sugimoto from Japan. They present an evaluation of a simulation game focussing on succession as part of forest management – a major issue worldwide.

Gonzalo Guerrero reports on a study involving in-service science teachers learning about science outside the classroom on a Chilean Master's degree programme. This innovative study involved research-practice partnerships and has some salutary lessons about how much teachers can be expected to take on in such situations.

Finally, Christin Sajons and Michael Komorek, from Germany, report on complementary networking of out-of-school learning environments. They describe how the learning and engagement with key environmental issues and ideas can be reinforced by collaborations between schools and institutions such as museums, botanic gardens and environmental centres.

We commend these papers to you as examples of the breadth of research interests with Strand 9 and of the commitment to addressing the key challenges facing the planet now and in the future.

Albert Zeyer and Justin Dillon

References

Dillon, J., & Avraamidou, L. (2020). Towards a viable response to COVID-19 from the science education community. *Journal for Activist Science and Technology Education*, *11*(2), 1–5. https://doi.org/10.33137/jaste.v11i2.34531

Zeyer, A., & Dillon, J. (2019). Science|Environment|Health – the emergence of a new pedagogy of complex living systems. *Disciplinary and Interdisciplinary Science Education Research,* 1:9. doi:10.1186/s43031-019-0014-9

PLANT BLINDNESS INTENSITY THROUGHOUT THE SCHOOL YEARS: A CROSS-AGE STUDY

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It is really interesting, that even though plants contribute essentially to human life, people don't seem to find them interesting. Humans prefer animals and rarely notice the flora around them. This phenomenon is called plant blindness and the reasons behind it can be found in education, in the cultural framework and in human biology. Apart from being a cause, the educational context can be also a solution to plant blindness as educational activities can elucidate plants' importance and make them more interesting to humans. Above all, plant blindness should be examined as an important issue that can be related to environmental awareness and to Sustainable Development Goals (SDGs). In this study we seek to examine plant blindness' presence in the Greek student population. Moreover, aim of this study is to clarify through a cross age study whether the phenomenon's intensity change throughout the school years. One thousand thirteen (1013) primary, junior and senior high school Greek students participated in this research. Their attitudes towards plants or animals were assessed through a questionnaire with five-point likert-type scale items. According to the results, Greek students do show greater preference for animals comparing to plants. Additionally, as the students get older, they lose interest in flora. Our results highlight plant blindness' presence in the school population and enhance the general concern about the reduced emphasis on plant life in educational systems worldwide. Hence, a need emerges for revising curricula and promoting the education for plants during school life.
Keywords: environment, biology education, society and environment education

INTRODUCTION

"Plant Blindness" refers to humans' tendency to ignore and underestimate plants, especially comparing to animals (Amprazis, Papadopoulou, & Malandrakis, 2019; Wandersee & Schussler, 1999). It is a phenomenon that was firstly assigned during mid 80s (Wandersee, 1986) and since then has received much attention by researchers. Deficiencies in the educational systems, humans' brain function and the characteristics of plants are listed among the causes of this phenomenon (Hersey, 1996). Examining the Greek curriculum for example, it is noteworthy that there is a focus mainly on the plant biology context while references to plants importance in general are lacking (Amprazis & Papadopoulou, 2018). In general, plant blindness seems to be a complex phenomenon that is also affected by cultural aspects (Balding & Williams, 2016). Initially, researchers assessed this phenomenon mainly as a differentiation in preference regarding plants and animals. Recent findings however, point out possible correlations between plant blindness and important issues such as biodiversity loss, sustainable development and a lack of scientific literacy (Kaasinen, 2019; Sharrock & Jackson, 2017). Plants are involved in nutrition, climate issues, air pollution, soil quality, medicine production, habitat provision and human well-being. All the above are top priorities in the Sustainable Development Goals' (SDGs) declaration (Fukuda-Parr, 2016; United Nations, 2015). In that sense, ignoring flora can be an opposing factor to environmental balance and hinder the SDGs' achievement. Plants' preservation is directly integrated in the thirteenth, (Climate Action), fourteenth (Life below

Water) and fifteenth (Life on Land) SDG, but more indirect relationships can be traced out to the other SDGs too.

According to researchers, educational activities can be an effective way to reduce this phenomenon's intensity (Krosnick, Baker, & Moore, 2018; Stagg & Verde, 2018). Assiduously designed educational projects seem to be able to stimulate students' interest in plants (Borsos, 2019; Kissi & Dreesmann, 2018). Outdoor activities, intersectional perspectives and the context of education for sustainability can be effective options for reversing the limited preference for plants during the school years (Cil, 2016; Veiga Ávila et al., 2018).

Considering all that have been mentioned before, it is meaningful to examine plant blindness' intensity in a country that has not been examined before and assess its intensity throughout the school grades. Knowing that, we can have more clues in order to design educational intervention programs that will enhance students' interest in plants during the primary and high school years, the main era to construct knowledge in the typical educational systems worldwide. Aim of this study is to assess Greek students' attitudes towards flora and moreover, examine the development of the plant blindness phenomenon as students move from the primary to the secondary school. The research questions we address here are as follows:

1. What are Greek students' attitudes towards plants, especially comparing to their attitudes towards animals

2. How does the phenomenon's intensity changes as the students move from primary to junior and senior high school

It is noteworthy to mention that no cross age studies exist regarding the plant blindness phenomenon.

METHODOLOGY

The participants of our study were one thousand thirteen Greek students (1013). In particular, 349 students were from the primary school's sixth grade (12 years old), 334 were from the junior high school's third grade (15 years old) and 330 were from the senior high school's third grade (18 years old). In order to clarify whether students of different grade levels share or do not share the same understandings and attitudes, cross-age and longitudinal studies are suggested (Creswell, 2012). Taken under consideration the disadvantages of the longitudinal approach (Schmidt & Teti, 2005), a cross-age study was chosen for our research. A questionnaire was used to assess students' attitudes towards plants. Participants' attitudes were assessed through five-point likert-type scale questions, e.g., "How much do you like plants" - Not at All / Slightly / Moderately / Very / Very Much. The research instrument was constructed according to the basic principles of the quantitative methodology (Creswell, 2012; Kaplan, 2004). After determining the theoretical framework and conducting a number of exploratory semi structured interviews with students, the first edition of our research instrument was formed. The questionnaire was tasted through three pilot implementations. School teachers assessed it in regard to its comprehension and its adequacy. The wording of each grade's questionnaire was based on the different level of comprehension and scientific literacy that older students have comparing to the younger ones. The questionnaire's validity was established by a group of experts in biology education. The instrument's internal consistency was also measured and the value of Cronbach's Alpha was 0.845. Data analysis was performed by using the version 23.0 of the Statistical Package for Social Sciences (SPSS). A Principal

Components Analysis (PCA) was conducted. Four factors (*"Preference in Flora", "Preference in Fauna", "School Knowledge about Flora" and "Plants' Presence & Importance"*) explained 60.96% of the variance. Descriptive statistics were calculated in order to summarize students' answers to the all factors' items

All ethical principles were taking under consideration during the design of the research. The instrument was constructed by considering values such as respect, beneficence and dignity. An authorization was granted by the Greek Ministry of Education before the final implementation. The research instrument was given to the participants during the middle of the school day (between 11.00 and 12.00) as this seems to be the more effective period regarding attention and achievement (Klein 2004). In general, implementing the questionnaire was seamless and trouble free for the vast majority of the schools that participated in the survey.

RESULTS

By reference to Figure 1, we can see the results regarding the main instrument's questions comparing preference for flora and fauna (*"How much do you like plants"; "How much do you like animals"*). Regarding the "Very" and the "Very much" response options, there is a significant gap between plants and animals as 90.1% of our participants claimed that they like fauna "Very" or "Very much", while the respective percentage for flora was only 63.7%. In order to confirm statistically that our students do prefer animals more than plants, we conducted a Wilcoxon Signed-Ranks Test comparing the scores in all items of the factors "*Preference in Flora*" and "*Preference in Fauna*".

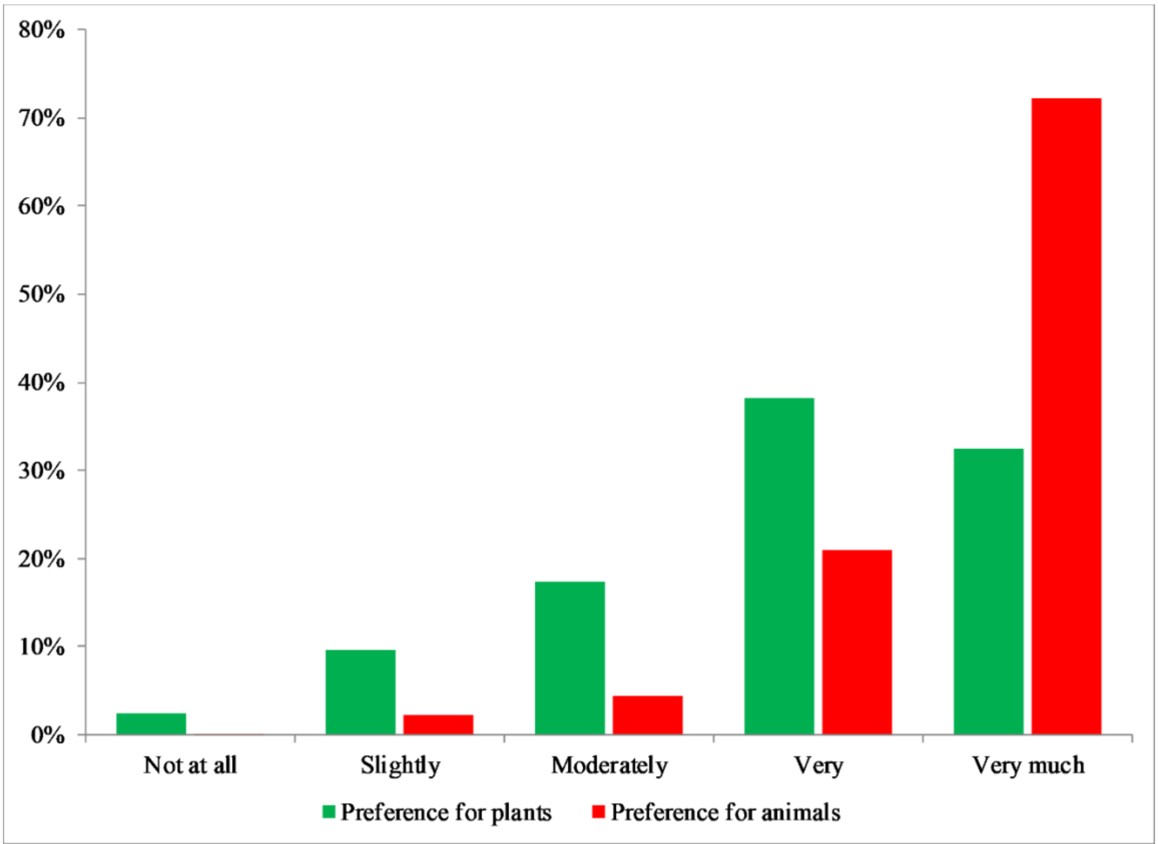

Figure 1. Percentages of students' answers to questions recording preference in plants and animals.

The Wilcoxon Signed-Ranks Test indicated that students' scores regarding preference for animals were statistically significantly higher than their scores regarding preference for plants, Z=-19.01, p<.000. It is also noteworthy that the effect size of this statistical test was large, r=.64.

Regarding our participants' age, a Kruskal-Wallis H test was conducted to clarify whether there is a statistically significant difference in the "*Preference in Flora*" factor among the three age groups of our participants. The test was significant [$X^2(2, n=1013)= 38.82, p<.05$] with a mean rank score of 405.7 for the twelve years old group, 306.5 for the fifteen years old group and 313.3 for the eighteen years old group (Table 1). Follow-up Mann-Whitney U tests were conducted to evaluate pairwise differences among the three groups. The age group of twelve years old recorded the most positive answers regarding preference in flora.

Table 1. Kruskal-Wallis H test results regarding students' age effect on their preference for plants (N=1013)

Students' Grade	N	Mean Ranks	x^2	df	Asymp. Sig
Primary school (12 years old)	349	405.7	38.82	2	.000
Secondary school (15 years old)	334	306.5			
High school (18 years old)	330	313.3			

Descriptive statistics were calculated for the other plant blindness definition aspects, i.e. noticing the flora around and appreciating flora's role for the life phenomenon upon earth. For both these aspects, primary school students appear to be more related to plants. High school students seem to notice flora around them less often (Figure 2) and do not seem to recognize plants importance as much as younger children do (Figure 3). For both these research questions Kruskal-Wallis H tests were conducted and confirmed a statistical significance in regard to these differences.

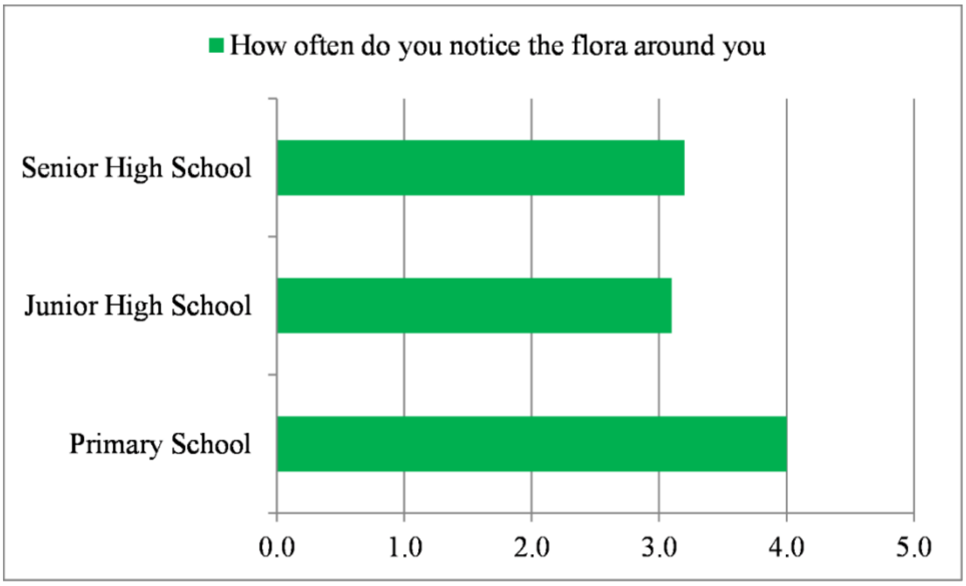

Figure 2. Students' tendency to notice the flora around them

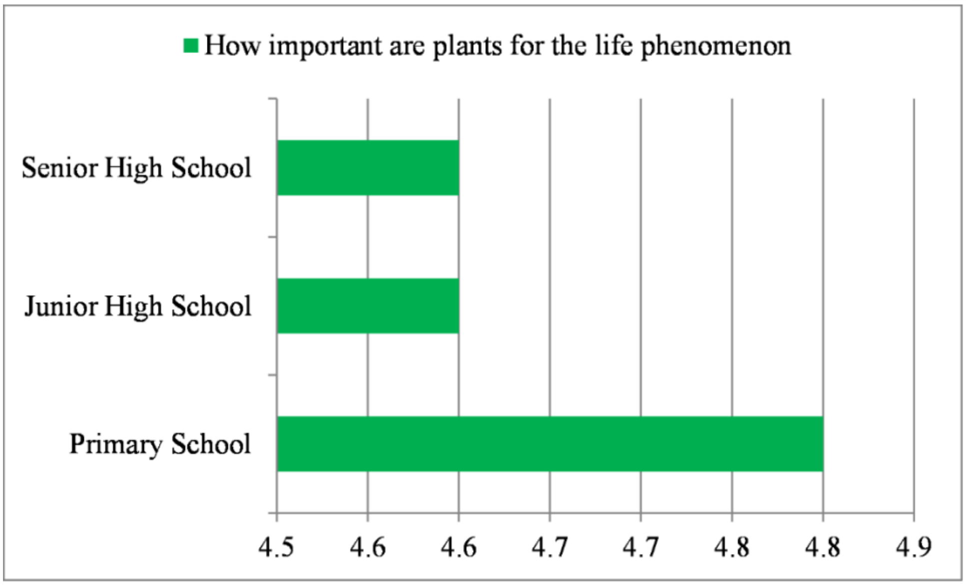

Figure 3. Students' assessment of flora's importance

In order to examine how the other characteristics, affect students' preference for plants, Kruskal–Wallis H and Mann–Whitney U tests were conducted. Regarding the place of residence variable, a Kruskal–Wallis H test was conducted to clarify whether there is a statistically significant difference in the "*Preference in Flora*" factor among the students that come from urban, rural areas and semi-rural areas. The test was significant [$X^2(2, n = 1013) = 9.138, p < .05$] with a mean rank score of 541.87 for the rural, 466.48 for the semi rural and 482.55 for the urban areas (Table 2).

Table 2. Students' characteristics affecting their preference for plants (N=1013)

Students' characteristics		Mean Ranks	x^2	df	Asymp. Sig
Place of residence	Rural	541.87	9.138	2	.010
	Semi rural	466.48			
	Urban	482.55			
Students' characteristics		**Mean Ranks**	**U**	**z**	**Asymp. Sig**
Gender	Boys	419.8	87561	-4.41	.000
	Girls	496.9			
Environmental education projects	Yes	307.9	27968.5	-2.90	.004
	No	261.2			

Follow-up Mann–Whitney U tests were conducted and indicated that the rural group recorded the most positive answers regarding preference in flora.

A Mann–Whitney U test was conducted to evaluate difference among boys and girls regarding their preference in flora. A significant difference was revealed [$U = 87561, z = -4.41, p < .05$] between boys (Md = 419.8) and girls (Md = 496.9) as girls seem to be more interested in plants.

Respectively, a Mann–Whitney U test was conducted in order to highlight any difference in preference in plants of students that have participated in environmental education projects and those who have not. A significant difference was also revealed [$U = 27968.5$, $z = -2.90$, $p < .05$] and indicated that environmental education projects do can enhance students' interest in flora (Table 2).

CONCLUSIONS

Our findings support the general idea of greater preference in animals than plants and overlap with the conclusions of other analogous studies which also indicate low interest rates regarding plant life (Fančovičová & Prokop, 2011; Strgar, 2007). The strong effect size of our statistical analysis leaves no room for doubt whether children aged between twelve and eighteen years old are more interested in plants or animals. Regarding students' characteristics affecting their preference in plants, greater preference for plants has been recorded by girls, by students coming from rural areas and by students that have participated in environmental education projects. The most remarkable result to emerge from the data has to do with plant blindness' incremental development. Our participants seem to lose their interest in flora as they get older. A possible explanation about this finding can be that during adolescence children seldom show interested in issues such as the environment, as they are more focused on themselves.

Plant blindness doesn't seem to be a philosophical issue. It is rather a well-documented phenomenon with a growing body of literature. If we want to prevent plant blindness, we need to create a new learning direction regarding plant life. We have to move out the strict biology framework and highlight plants' importance through every school subject. This need becomes more obvious during the junior and the senior high school years that seem to be the more intense period for this problem. Towards this direction, the role of education for sustainability should be enhanced as this educational context can offer the opportunity to highlight the importance of plants for human wellbeing and for the life phenomenon in general. Bringing flora in the limelight can lay the foundations of environmental awareness, nurture the concept of environmental citizenship and above all, contribute to the achievement of the Sustainable Development Goals. In that sense, education for sustainability seems an ideal framework for providing comprehensive scientific literacy about plants that will establish flora as an utterly important natural resource in students' consciousness.

Relatively to future research suggestions, there is no doubt that more cross age studies are required in order to draw complementary conclusions about the phenomenon's intensity in other countries. Any similar future inquiries concerning students' attitudes towards plants throughout their education years could be a comprehensive guide for changes in the curriculum, enriching textbooks with plant science and implementing long lasting educational projects. Studies focusing on restricting plant blindness' intensity specifically through education for sustainability could also be highly valued.

REFERENCES

Amprazis, A., & Papadopoulou, P. (2018). Primary school curriculum contributing to plant blindness: Assessment through the biodiversity perspective. *Advances in Ecological and Environmental Research, 3*(11), 238-256.

Amprazis, A., Papadopoulou, P., & Malandrakis, G. (2019). Plant blindness and children's recognition of plants as living things: A research in the primary schools' context. *Journal of Biological Education*, 1-16.

Balding, M., & Williams, K. J. (2016). Plant blindness and the implications for plant conservation. *Conservation Biology, 30*(6), 1192-1199.

Borsos, E. (2019). The gamification of elementary school biology: a case study on increasing understanding of plants. *Journal of Biological Education, 53*(5), 492-505.

Çil, E. (2016). Instructional integration of disciplines for promoting children's positive attitudes towards plants. *Journal of Biological Education, 50*(4), 366-383.

Creswell, J. W. (2012). Educational research: Planning, conducting, and evaluating quantitative and qualitative research (4th ed.). Boston, MA: Pearson.

Fančovičová, J., & Prokop, P. (2011). Plants have a chance: outdoor educational programmes alter students' knowledge and attitudes towards plants. *Environmental Education Research, 17*(4), 537-551.

Fukuda-Parr, S. (2016). From the Millennium Development Goals to the Sustainable Development Goals: shifts in purpose, concept, and politics of global goal setting for development. *Gender & Development, 24*(1), 43-52.

Hershey, D. R. (1996). A historical perspective on problems in botany teaching. *The American Biology Teacher, 58*(6), 340-347.

Kaasinen, A. (2019). Plant Species Recognition Skills in Finnish Students and Teachers. *Education Sciences, 9*(2), 85.

Kissi, L., & Dreesmann, D. (2018). Plant visibility through mobile learning? Implementation and evaluation of an interactive Flower Hunt in a botanic garden. *Journal of Biological Education, 52*(4), 344-363

Kaplan, D. (2004). *The Sage handbook of quantitative methodology for the social sciences*. Thousand Oaks, CA: Sage.

Klein, J. (2004). Planning middle school schedules for improved attention and achievement. *Scandinavian Journal of Educational Research, 48*(4), 441-450.

Krosnick, S. E., Baker, J. C., & Moore, K. R. (2018). The Pet Plant Project: Treating Plant Blindness by Making Plants Personal. *The American Biology Teacher, 80*(5), 339-345.

Schmidt, K. R. T., & Teti, D. M. (2005). Issues in the use of longitudinal and cross-sectional designs. *Handbook of Research Methods in Developmental Science*, 3-20.

Sharrock, S., & Jackson, P. W. (2017). Plant Conservation and the Sustainable Development Goals: A Policy Paper Prepared for the Global Partnership for Plant Conservation. *Annals of the Missouri Botanical Garden, 102*(2), 290-303.

Stagg, B. C., & Verde, M. F. (2018). Story of a seed: educational theatre improves students' comprehension of plant reproduction and attitudes to plants in primary science education. *Research in Science & Technological Education*, 1-21.

Stewart, F. (2015). The sustainable development goals: A comment. *Journal of Global Ethics, 11*(3), 288-293.

Strgar, J. (2007). Increasing the interest of students in plants. *Journal of Biological Education, 42*(1), 19-23.

United Nations. (2015, September 25). *Sustainable Development Goals*. Retrieved from http://www.undp.org/content/undp/en/home/sustainable-development-goals.html

Veiga Ávila, L., Rossato Facco, A. L., Bento, M. H. D. S., Arigony, M. M., Obregon, S. L., & Trevisan, M. (2018). Sustainability and education for sustainability: An analysis of publications from the last decade. *Environmental Quality Management, 27*(3), 107-118.

Wandersee, J. (1986). "Plants Or Animals – Which Do Junior High School Students Prefer To Study?" *Journal of Research In Science Teaching, 23*(5), 415-426.

Wandersee, J. H., & Schussler, E. E. (1999). Preventing plant blindness. *The American Biology Teacher, 61*(2), 82-86.

EXPLORING GREEK PRIMARY STUDENTS' INTENTION OF CONSUMING SEASONAL, ORGANIC, LOCAL FRUITS

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Food production, transport and consumption are linked with various environmental issues, including, among other, the greenhouse gases emissions. Food consumption in the western world has been estimated to be responsible for approximately the 20-30% of the total environmental impact. In order to achieve a more sustainable diet, one of the major dietary changes proposed is the consumption of more seasonal and locally produced food, especially fruits and vegetables. Present study explores Greek primary students' intention to consume seasonal, locally produced and organic fruits before and after experiential teaching intervention. Participants were 82 third grade students (8-9 years old) from schools located at the east and the west of the greater metropolitan area of Thessaloniki, Greece. Data collected with the use of a closed-form questionnaire consisted of fourteen questions. Analysis was primarily quantitative and focused, beyond descriptive, on significant differences in students' answers before and after teaching intervention. Results indicate that before the experiential teaching, students' intention of consuming seasonal, organic fruit was medium ($Mean_{SEAS\text{-}pre}=1.02$*, theoretical maximum=2), and also medium was their intention of consuming local fruits (*$Mean_{.LOC\text{-}pre}=1.07$*, theoretical maximum=2). After intervention, statistically significant differences in students' answers were recorded in both variables under study (*$Mean_{SEAS\text{-}post}=1.73$*, *$p=0.000$*, *$Mean_{LOC\text{-}post}=1.73$*, *$p=0.000$*). The seven-month, experiential teaching intervention triggered the interest, engagement and enjoy of students at every phase of the learning process, especially at the phase of the creation of the organic school garden, leading to fruitful outcomes.*

Keywords: experiential learning, primary school, outdoor learning

INRODUCTION

Nowadays, globalization has permitted the whole-year availability of a wide variety of fruits and vegetables. Southern produced products can easily reach northern hemisphere and vice versa. Consumption has become independent from seasons. The use of new technologies caused the intensification of agriculture and the extension of natural production and growing seasons, and also increased the international trade. This caused a food culture with variety of foods in a lot of countries otherwise this couldn't be possible. (Macdiarmid, 2013). Unfortunately, this was made with a high environmental cost, including the need of more energy, and the change in land use that resulted to the loss of environmental biodiversity and loss of species. Moreover, it required the increased use of monocultures in agriculture (DeClarke, 2013).

Food production, transport and consumption are linked with environmental problems such as greenhouse gases emissions (Tukker & Jansen, 2006). In the western world, food consumption has been evaluated to account for approximately 20-30% of total CO_2 environment impact. In order to achieve a more sustainable diet, one of the dietary changes proposed is the consumption of more seasonal and locally produced food, especially fruits and vegetables (Garnett, 2008).

For some, seasonally produced food doesn't have geographical limits and incorporates any food that is produced in the natural production season but consumed anywhere in the world. For others, seasonality is linked with locally produced food, produced in the natural production season and consumed within the same climatic zone (Brooks, Foster, Holmes & Wiltshire, 2011). However, although there is not a universally accepted definition for seasonality, there is a common point among the various approaches, stressing that the food need to be produced in its natural growing season, outdoors, and without the use of additional energy, having as a result that no additional greenhouse gas emissions are released (Macdiarmid, 2014).

One of the benefits of consuming seasonal food that is produced outdoors, is the reduction of greenhouse gases emissions because of no artificial heating or lightening required. Studies have shown that open-field produced food, grown and consumed in season in the same country-region, in general have lower energy requirements and carbon footprints per unit of product in contrary with food produced under protection, stored or even imported (Edwards-Jones, 2010). The term 'food miles' introduced in the early 1990's by Professor Tim Lang (Lang, 2006) to describe the distance our groceries have to travel to reach us. Although that originally the concept was not used as a measure of the environmental impact, in nowadays, we mean the distance that the food is transported from the place and time of its production until it reaches the consumer (DEFRA, 2005). However, food miles is a very controversial concept because it focuses primarily or even exclusively to the distance that the food travels (Wynen & Vanzetti, 2008), and there is no distinction about the transportation type used that can have very different emissions (Coley, 2011).

Different transportation types produces different amounts of greenhouse gases emissions, so it is reasonable to assume that consumption of locally produced food can reduce greenhouse gases emissions (Edwards-Jones et al., 2008). But this is not quite true. In the case that the local transport is inefficient (e.g. with vans), the greenhouse gases emissions can exceed those from imported foods (Mundler & Rumpus, 2012). So, locally produced food compared with imported products, does not always have lower greenhouse gases emissions but it depends on the way that food is transported.

Organic agriculture is a holistic production management system which promotes and enhances agro-ecosystem health, including biodiversity, biological cycles, and soil biological activity. It emphasizes the use of management practices in preference to the use of off-farm inputs, taking into account that regional conditions require locally adapted systems (FAO/WHO Codex Alimentarius Commission, 1999). Moreover, regenerative organic agriculture and its management practices are potentially significant means to sequester more than current global annual emissions and to reverse the greenhouse effect (Rodale Institute, 2014).

In the field of education, there are many benefits of incorporating school garden in teaching, including the social, academic and emotional development of children, the deepen and enrichment of classical teaching by enhancing interdisciplinarity, and providing the basis for scientific and research thinking (Passy, 2014). Moreover, school gardens are considered as among the best tool for experiential learning, and they have also been reported as positively influencing children's eating habits (Parmer, 2009). Experiential learning asserts that learning is built on our emotions and emphasizes on the experience, promoting the active participation of students in a teaching approach in which teachers are just facilitators of learning (Georgopoulos, 2014).

Also, experiential learning as a teaching innovative approach, offers significant benefits. The use of outdoor classroom and school gardens, contrary to the traditional schooling that takes place within walls, engages students in experiential lessons that deepen understanding and accelerates learning (McCarty, Ford & Ludes, 2018). School gardens as a component of nutrition education can increase fruit and vegetable knowledge and can facilitate behavior change among children towards more sustainable and healthy consumption patterns (Parmer, Salisbury-Glennon, Shannon & Struempler, 2009)

Given the above, the goal of the present study is to explore the learning gains in elementary Greek students, produced from the use of school gardens in teaching sustainability issues related to the consumption of seasonable, organic, local fruits. This study is part of a doctoral research which focuses on changing students' knowledge, perceptions and eating habits towards more healthy and sustainable choices that include, among other, more frequent vegetable and fruit consumption. In order to explore the above, an experiential teaching intervention, accompanied by the creation and implementation of a biological school garden took place. This paper pays attention on changes in students' intentions to consume seasonal, local and organic fruits after their participation to the project.

METHOD

The teaching intervention took place for seven months during the 2017-'18 school year, with weekly meetings between the main researcher and the students, each one lasting two hours. The main researcher (first author) was delivered the module to students, but she was not the teacher of the classes participating to the project. The theoretical aspects of the course were mostly covered by experiential activities, while the major teaching approach was the creation of an organic school garden. By that, we tried to maximize the learning outcomes of the educational process and trigger the interest, participation, engagement, and enjoyment of students at every stage of the learning process.

Participants were 82 third grade students (41 males and 41 females, 8-9 years old) from four classes of four public, elementary schools from the east and west greater metropolitan area of Thessaloniki, Greece. East Thessaloniki is considered as an area of medium to high socio-economic level, whereas west Thessaloniki is considered as an area having medium to low socio-economic level.

The data collection tool was a closed-type questionnaire comprised of 14 questions, completed before and about two weeks after the end of the project. Its completion time was 20-25', and the collected data were mainly subjected to quantitative analysis using the SPSS v.24.

RESULTS

Intentions to consume seasonable organic fruits

According to Table 1, before the intervention, students' intention of consuming seasonal, organic fruits was medium (*Mean=1.02, SD=0.72*, theoretical maximum=2). However, after intervention, their scores were significantly increased (Mean=1.73, p=0.000). Significant testing was also implemented based to the two independent variables under study, i.e., students' gender (boys and girls) and school location (east and west Thessaloniki). Through the analysis we also found significant differences before and after the intervention for the boys *(Mean $_{BOYS.BEF}$=0.90, Mean $_{BOYS.AFTER}$=1.78, p=0.000),* and for the girls *(Mean $_{GIRLS.BEF.}$=1.15, Mean $_{GIRLS.AFTER.}$=1.68, p=0.000),* but not between boys and girls either before or after the intervention.

Table 1: Students' intention to consume **SEASONAL, ORGANIC FRUITS** based to **GENDER**

		Before		After		1 year after	
	N	*Mean*#	*SD*	*Mean*#	*SD*	*Mean*#	*SD*
Boys	**41**	0.90	*0.77*	1.78***	*0.42*	1.66	*0.53*
Girls	**41**	1.15	*0.65*	1.68***	*0.47*	1.56	*0.55*
Total	**82**	**1.02**	***0.72***	**1.73*** **	***0.45***	**1.61**	***0.54***

#Theoretical min= 0, theoretical max=2
**p <0.05, **p<0.01, ***p<0.001 (based on Sign Test)*

Table 2: Students' intention to consume **SEASONAL, ORGANIC FRUITS** based to **SCHOOL AREA**

		Before		After		1 year after	
	N	*Mean*#	*SD*	*Mean*#	*SD*	*Mean*#	*SD*
East Thessaloniki	**37**	1.08	*0.80*	1.76***	*0.44*	1.62	*0.55*
West Thessaloniki	**45**	0.98	*0.66*	1.71***	*0.46*	1.60	*0.54*
Total	**82**	**1.02**	***0.72***	**1.73*** **	***0.45***	**1.61**	***0.54***

#Theoretical min= 0, theoretical max=2
**p <0.05, **p<0.01, ***p<0.001 (based on Sign Test)*

In respect of the school location, according to Table 2, we found significant differences between before and after the intervention for the schools of East Thessaloniki *(Mean$_{EAST.BEF..}$=1.08, Mean $_{EAST.AFTER}$=1.76, p=0.000),* and for the schools of West Thessaloniki *(Mean $_{WEST.BEF.}$=0.98, Mean $_{WEST.AFTER.}$=1.71, p=0.000),* but not between the school locations either before or after the teaching.

Intentions to consume local fruits

According to Table 3, before the intervention, students' intention of consuming local fruits was medium (*Mean=1.07, SD=0.75*, theoretical maximum=2). However, after intervention, students' scores were significantly increased (Mean=1.73, p=0.000). We also found significant differences before and after the intervention for the boys *(Mean$_{BOYS.BEF.}$=1.17, Mean $_{BOYS.AFTER}$=1.80, p=0.000),* and for the girls *(Mean $_{GIRLS.BEF.}$=0.98, Mean $_{GIRLS.AFTER.}$=1.66, p=0.000),* but not between boys and girls either before or after the teaching.

Table 3: Students' intentions to consume **LOCAL FRUITS** based to **GENDER**

		Before		After		1 year after	
	N	*Mean*#	*SD*	*Mean*#	*SD*	*Mean*#	*SD*
Boys	**41**	1.17	*0.74*	1.80***	*0.40*	1.66	*0.53*
Girls	**41**	0.98	*0.76*	1.66***	*0.48*	1.61	*0.59*
Total	**82**	**1.07**	***0.75***	**1.73*** **	***0.45***	**1.63**	***0.56***

#Theoretical min= 0, theoretical max=2
**p <0.05, **p<0.01, ***p<0.001 (based on Sign Test)*

In respect of the school location, according to Table 4, we found significant differences between before and after the intervention for the schools of East Thessaloniki *($Mean_{EAST.BEF..}=0.89$, $Mean_{EAST.AFTER}=1.84$, $p=0.000$)*, and for the schools of West Thessaloniki *($Mean_{WEST.BEF.=}1.22$, $Mean_{WEST.AFTER.}=1.64$, $p=0.000$)*, but not between the two school locations either before or after the intervention

Table 4: Students' intentions to consume **LOCAL FRUITS** according to **SCHOOL AREA**

		Before		After		1 year after	
	N	*Mean*#	*SD*	*Mean*#	*SD*	*Mean*#	*SD*
East Thessaloniki	**37**	0.89	*0.74*	1.84***	*0.38*	1.68	*0.58*
West Thessaloniki	**45**	1.22	*0.74*	1.64**	*0.48*	1.60	*0.54*
Total	**82**	**1.07**	***0.75***	**1.73*** **	***0.45***	**1.63**	***0.56***

#Theoretical min= 0, theoretical max=2
*p <0.05, **p<0.01, ***p<0.001 (based on Sign Test)

Furthermore, for both variables under study (i.e., students' intention of consuming seasonal, organic fruits and students' intention of consuming local fruits) and for the two independent variables (i.e., gender and school location) no statistically significant differences were observed between the end of the teaching and one year after. That means all variables were significantly increased after teaching and remained high even one year after.

DISCUSSION

In our study, students' intention to consume seasonable and local fruits, before teaching, was medium. This is consistent with the findings reported by Tamurro et al., (2017) where student-teachers' knowledge about seasonal food was inadequate, as they were unable to correctly identify the seasonal period of strawberries (April-August, 62%) and correctly identify the seasonal period of kiwi fruit (November-May, 48%). Moreover, our results are in line with those reported by Kemp et al. (2010) in which only the 19% of them correctly knew the place of origin of their chosen food item (food miles), and only the 17% stated that this knowledge had influenced their purchase decision. Ozer (2007) reports that garden-based experiences and programs provide a context that helps the understanding of seasonality, add a great impact on learning approach, and foster a better understanding of how the natural world is sustained and where food comes from.

ACKNOWLEDGMENT

The research work was supported by the Hellenic Foundation for Research and Innovation (HFRI) and the General Secretariat for Research and Technology (GSRT), under the HFRI PhD Fellowship grant (GA. no. *129*).

REFERENCES

Brooks, M., Foster, C., Holmes, M., & Wiltshire, J. (2011). Does consuming seasonal foods benefit the environment? Insights from recent research. *Nutrition Bulletin*, *36*(4), 449-453. doi: 10.1111/j.1467-3010.2011.01932.x

Coley, D., Howard, M., Winter, M. (2011). Food miles: time for a re-think? *British Food Journal*, *113(7),* 919–934.

DeClarke, F. (2013). *Harnessing biodiversity: from diet to landscapes. In Diversifying Food and Diet* (pp. 17-44). Oxon, UK: Fanzo J., Hunter D., Borelli T., Mattei, F.

Department for Environment, Food and Rural Affairs, (2012). Understanding the environmental impacts of consuming foods that are produced locally in season-Project FO0412. Retrieved from http://randd.defra.gov.uk/Default.aspx?Module=More&Location=None&ProjectID=16390

Edwards-Jones, G. (2010). Vulnerability of exporting nations to the development of a carbon label in the United Kingdom. *Environmental Science & Policy*, *12(4),* 479-490.

Edwards-Jones, G., Milà i Canals, L., Hounsome, N., Truninger, M., Koerber, G., & Hounsome, B. et al. (2008). Testing the assertion that 'local food is best': the challenges of an evidence-based approach. *Trends In Food Science & Technology*, *19*(5), 265-274. doi: 10.1016/j.tifs.2008.01.008

Garnett, T. (2008). Cooking Up a Storm: Food, Greenhouse Gas Emissions and Our Changing Climate. Surrey: University of Surrey, Food Climate Research Network, Centre for Environmental Strategy.

Georgopoulos, A. (2014). *Environmental education. Identity issues.* Greece, Thessaloniki: Gutenberg. (In Greek).

Kemp, K., Insch, A., Holdsworth, J., Knight, G. (2010), Food miles: Do UK consumers actually care? *Food Policy, 35(6),* 504-513.

Lang, T. (2006). Locale / global (food miles), Slow Food (Bra, Cuneo Italy), 19 May, pp.94-97.

Macdiarmid, J. (2014). Seasonality and dietary requirements: Will eating seasonal food contribute to health and environmental sustainability? *Proceedings of The Nutrition Society*, *73(3),* 368-75

McCarty, J., Ford, V., & Ludes, J. (2018). Growing Experiential Learning for the Future: REAL School Gardens. *Childhood Education*, *94*(2), 47-55. doi: 10.1080/00094056.2018.1451690

Mundler, P., & Rumpus, L. (2012). The energy efficiency of local food systems: A comparison between different modes of distribution. *Food Policy*, *37*(6), 609-615. doi: 10.1016/j.foodpol.2012.07.006

Ozer, E. (2007). The effects of school gardens on students and schools: conceptualization and considerations for maximizing healthy development, *Health Education Behavior 24,* 846–863.

Parmer, S.M., Salisbury-Glennon, J., Shannon, D., Struempler, B. (2009). School Gardens: An Experiential Learning Approach for a Nutrition Education Program to Increase Fruit and Vegetable Knowledge, Preference, and Consumption among Second-grade Students. *Journal of Nutrition Education and Behavior, 41(3),* 212–217.

Passy, R. (2014). School gardens: teaching and learning outside the front door, *Education 3-13: International Journal of Primary, Elementary and Early Years Education, 42(1)*, 23-38

Rodale Institute Regenerative Organic Agriculture and Climate Change. (2014). A Down-to-Earth Solution to Global Warming, Retrieved from https://rodaleinstitute.org/wp-content/uploads/rodale-white-paper.pdf

Tamurro, M., Ripabelli, G., Forleo, M.B., Sammarco, M.L. (2017). Dietary behaviours and awareness of seasonal food among college students in central Italy, *Italian Journal of food science, 29(4),* 667-680.

Tukker, A., Jansen, B. (2006). Environmental impacts of products: A detailed review of studies. *Journal of Industrial Ecology*, *10(3),* 159–182.

Wynen, E., &. Vanzetti, D. (2008). No Through Road: The Limitations of Food Miles. ADBI Working Paper 118. Tokyo: Asian Development Bank Institute. Retrieved from http://www.adbi.org/working-paper/2008/10/30/2735.limitations.food.miles/

WHAT DO THE FUTURE TEACHERS TEACH WHEN MAKING A BIOLOGY FIELD TRIP? A STUDY IN SOUTHERN COLOMBIA

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Field Works are fundamental in the teaching-learning of biology, facilitate the understanding of the dynamic nature as a network of relationships, the acquisition of scientific skills and the generation of attitudes on the conservation of ecosystems and the protection of the natural heritage. However, teacher training does not seem to address what and how to teach in natural environments. We conducted a research in the context of southern Colombia (Neiva-Huila), with 27 future teachers of the Degree Program in Natural Sciences and Environmental Education of the Universidad Surcolombiana. Based on a mixed approach (qualitative and quantitative) and using questionnaires, participant observations, conducting a training seminar and monitoring the development of field practices with secondary school students, we approached the conceptions of pre-service teachers about the consubstantial elements of Field Works. The evolution of their initial reductionist ideas towards more complex and desirable conceptions, in accordance with the research in Science Didactics, were also addressed.

Keywords: Teacher preparation, Outdoor education, Secondary school.

INTRODUCTION

There is the idea, socially underlying, that in order to teach it is enough to have a deep theoretical knowledge of what is taught, in this case Biology; as education professionals we know that teachers have specific knowledge that, in addition to including content knowledge, has didactic, pedagogical, and curricular aspects, among others, that allow them to carry out didactic transposition processes in an appropriate manner (Mellado, 2011). This has been called Professional Teacher Knowledge (Shulman 1986; Gess-Newsome, 2015).

In other hand, Field Work offers educational opportunities of unquestionable value, related to the affective, cognitive and environmental dimension, and is essential in the interest and valuation of biodiversity, the generation of attitudes in favor of the conservation of living beings, the acquisition of skills of the scientific work and direct contact with natural environments (Gavidia & Cristerna, 2000; Hamilton-Ekeke, 2007; Rennie, 2014). In this sense, Field Work acquires a special value in the teaching and learning of Biology because it promotes the students to approach "the living", as close as possible to their natural conditions, with a systemic and holistic perspective. Authors like Morag & Tal (2012) and Morag, Tal & Rotem-Keren (2013), show that natural environments and field practices differ in several characteristics in relation to visits to museums, planetariums or science centers, because they allow direct experience with the real phenomena of nature, more than any other activity outside the school.

According to Behrendt & Franklin (2014) teachers do not have enough training on how to teach in nature, because neither the initial training courses nor the ongoing training courses have allowed them to develop an adequate knowledge of the content and competences needed to teach outside the school in natural environments that is, how to design and carry out field practices. For Lavie Alon & Tal (2016) the research on the role of the teacher in field practices has shown that in most cases they prefer not to play an active role and be fully involved in the outputs and their preparation, and give all the didactic acting to professionals external to the school and in charge of the activity (guides, instructors). Generally the teachers in their initial training have participated as students in Field Trips, without having experiences in which they should plan and teach outside the classroom (Tal & Morag, 2009). Our main research goal was to analyze the contribution of Field Work to the construction of Professional Knowledge in future teachers of Natural Sciences at the Universidad Surcolombiana.

RESEARCH DESIGN AND METHOD

We conducted a mixed -quantitative and qualitative- study, in order to capture with greater effectiveness, the various components of the Professional Teacher Knowledge and specifically the contributions of field practices in teacher training. Our study was also a longitudinal prospective type, with the aim of highlighting the progression of the teachers' own professional learning. The sample is formed by 100% of the students who took the "Didactic I" course (sixth semester) of the Degree Program in Natural Sciences and Environmental Education at the Universidad Surcolombiana (Huila-Colombia). This university is public and the only one that has a teacher training program in the region. The data collection occurred during the second semester of 2016 (July to December). The group consisted of 27 students, of which 21 female and 6 male, the ages of these future teachers ranged between 19 and 23 years old. To obtain data, we chose to implement a questionnaire (applied at the beginning and end of the training process), enriching the research with participant observation (through the video recording of the development of the didactic intervention) and the follow-up of the development of the seminar "Field Work in the teaching of biology and teacher training". The questionnaire consists of two large sections: the first six questions focus on general elements on Field Work, while in the second section a hypothetical scenario is presented in which the participants find themselves as teachers of an educational institution of Huila and must perform Field Work. We have systematized the information based on the content analysis (Álvarez & Jurgenson, 2003) through the Software Atlas.Ti 7.0 and for the case of the questionnaire we have applied a t-student, following the guidelines of Cohen, Manion & Morrison (2011).

Finally, we emphasize that the instrument designed consists of a system of categories and subcategories that have considered the main characteristics of Field Work. These categories are based on a study by Amórtegui and Correa (2012) and expanded by an extensive literature review, from which we propose to add the categories Field Work Nature, Planning and Difficulties. The resulting instrument is presented in Table 1.

Table 1. Categories system for the analysis of field work in biology teaching and teacher training

FIELD WORK NATURE	Going out Experience Teaching strategy Professional development
LEARNING PURPOSES	Concepts Processes Attitudes
PLANNING	Teaching model Field guide Previous ideas Students motivation Preparation (place, subject, materials, cost, permission)
DIFFICULTIES	School culture Teachers Preparation (place, subject, materials, cost, permit, risk) Students behavior Understanding the subject
CONTRIBUTION TO TEACHER TRAINING	Biology Learning Teaching experience Teaching Biology Professional development
5 Categories	21 subcategories

To develop our seminar, the pre-service teachers, were organized five groups with specific biological themes and focused on specific courses: ecosystems and trophic networks (G1-8th grade students), insects and their environments (G2-8th grade students), plants (G3-7th grade students), arthropods (G4-6th grade students) and insects (G5-6th grade students). The ages of the students to whom the Practices were directed ranged between 10 and 15 years old.

All the groups had one or two sessions (of 2 hours each one) prior to classroom preparation with secondary students, one morning for their application in the field (3-4 hours) and one or two sessions for the conclusion again in the classroom (2 hours each one). Field Practices were carried out in the following way: in two cases in the forest of the educational institution itself (G3, G5); in two other cases in a forest that contained a stream outside the school, although close to it, so that it was possible to walk from school (G1, G2); finally, a group in a wetland on the outskirts of the city and therefore had to be transported by bus (G4).

RESULTS AND DISCUSSION

Given the volume of results of our research and the extension limitations of this paper, we will focus on the following aspects: a) address some of the findings at the beginning of the training process (pretest) and b) the progression in the future teachers' conceptions after the development of a sequence of learning as a seminar (posttest). Among all the categories of analysis we address five of them: *Field Work Nature; Learning purposes*, *Planning*, *Difficulties* and *Contribution to teacher training.*

The categories have been grouped considering whether they refer to the A) initial conceptions or B) final conceptions. Within each category, after the heading, a word or sentence that synthesizes the major perception of the students is included in italics. Included in brackets, in the next line is the question that addressed the issue along with a representative response by the students.

A) Initial Conceptions

According to Field Work Nature: *Going out*
{From your point of view, what is a Field Work activity?} *"... It is an activity where the student is taken to a specific place..."*

15 students (55.5%) consider that Field Work refers only to the fact of going out of school. In some cases, reference is made to spaces of formal education (as to other universities) and in others to non-formal spaces (technological centers, scientific studies, among others). It is striking that in these cases there is no reference to a natural place such as an ecosystem, forest, among others. Similarly, future teachers do not consider didactic elements of this teaching strategy, for example their learning purposes, their evaluation, the working roles or their planning. We consider that this type of conceptions can reaffirm the difficulty posed by Morag and Tal (2012) and Dourado and Leite (2013), about the diversity of meanings, both in Spanish and in English, that the literature report on the term of Field Work, including field activities, educational field activities, field trips, study visits out of school, excursions, experiential education, environmental interpretation, among others. On teachers' conceptions, Glackin (2016) states that teachers who identify with traditional teaching approaches tend to have conceptions in which Field Practices are considered exclusively as fun activities.

According to Learning purposes: *Concepts*

{What do you think the students learn when they go on a Field Work?} *"... The students would consolidate their knowledge and help them to a better understanding of the topics...."*

For 21 future teachers (77.7%), Field Work is carried out so that the students confirm the concepts and definitions that the teacher previously taught in the classroom. They specify that students learn concrete and particular objects and themes, for example about plants, animals, natural environments, biotic, abiotic factors, etc.

From this perspective where conceptual contents predominate, Field Work is not usually framed within a problem, nor in a specific context. Field Work only shows secondary school students a phenomenon, in this case biological, as something finished as an absolute truth, so there is no space for discussion or construction.

From this approach, no manipulation or intervention on the object of study is evident, therefore it is enough to merely observe the phenomenon (Dourado and Leites, 2013) and it is not necessary to develop research skills and abilities.

According to Planning: *Logistics preparation*

{What would you consider in order to carry out a Field Work activity?} *"... To carry out field practice, the first thing that must be taken into account is that there is consent on the part of the parents ..."*

Taking the elements that the future teachers would consider when planning Field Work, we highlight that 23 pre-service teachers (85.2%) affirm that it is enough with adequate logistical preparation for the development of the activity. Thus, the teacher must be responsible for specifying the subject to be treated, establishing the place of development of the activity, specifying the duration of the output, getting the transport, the materials, etc. Didactic aspects, such as the *Field Guide* (2 students-7.4%), *Students motivation* (5 students-18.5%) and *Previous ideas* (6 students-22.2%) are hardly contemplated. Considering that logistical aspects are enough to plan the field practice, could be related to traditional teaching approaches, in which the field activity is focused on the teacher and therefore the degree of student participation is minimal. Pedrinaci (2012) considered this approach, as the most frequent field activity.

According to Difficulties: *School Culture*

{What difficulties could you have to carry out a Field Work activity*?} "... The main difficulty is to get permission from both the institution and the parents, either by economic conditions or security. ..."*

With regard to aspects such as the administrative context of the educational institution and the characteristics of the school culture, 14 future teachers (51.8%) believe that only aspects of this style make it difficult to carry out a field practice. Scott et al. (2015) identify, from the point of view of teachers in initial and in-service training, the school culture as a difficulty to develop Field Work as a Biology teaching strategy, due to: administrative issues, the educational priorities, the inspections, the established educational practices, the allocation of time, the bureaucratic burden, the little support of classmates, etc.

For this reason, for Tal and Morag (2013), the school culture focused only on learning and exclusively at school (education school-based), must be reevaluated by a teaching outside of it (outdoor education). The idea of considering the teacher as an element that can facilitate the development of the field activity, as long as he has the knowledge, skills and expertise in it, is considered only by one student (3.7%).

According to the Contribution to teacher training: *Biology Learning*

{What does Field Work provide to your training?} *"... I would bring much knowledge and more than that experience to complete my studies and improve. ..."*

In a majority way, 16 future teachers (59.2%) conceive that the main contribution of field practices in their training as teachers so far, has been that they have learned Biology (they take field trips in the courses of Botany, Systematic, Zoology and Ecology). Only two students (7.4%) value the *Teaching Experience* and 7 of them (26%) *Teaching Biology*. Generally, the teachers in their initial training have participated as apprentices in Field Trips, without having experiences in which they should plan and teach outside the classroom. In addition to this, Lavie Alon and Tal (2016; 2017) affirm that there are quite a few studies on the design of learning environments in the field, however, research on how teachers use the natural environment in teaching remains scarce.

B) Final Conceptions

After carrying out the Training Seminar and the planning and development of field trips with high school students, the conceptions of future teachers in training present the following evolution:

According to Field Work Nature: *Biology Teaching*

{From your point of view, what is a Field Work activity?} "… *A field practice is a teaching strategy in which different activities are carried out depending on the subject to be worked on and in which there are different attitudinal, procedural and conceptual objectives being as integral as possible...."*

For this case, we highlight that 23 future teachers (85.2%), unlike the two at the beginning, make explicit that Field Work is a biology teaching strategy that they can develop with their students in their future work as teachers. They also explain consubstantial aspects of this strategy, for example that Field Work will make their students work in "reality", under "direct contact" and will facilitate studying the living phenomenon as close to their natural conditions. From the statistical point of view, the comparison between the pre and posttest shows a high significance of the data and therefore an important progression in the conceptions of this future teaching staff (p value ≤ 0.001).

Unlike the beginning of the training process, here the approach taken by pre-service teachers is more concrete from the importance of Field Practice as fundamental teaching strategy in learning Biology, with great effectiveness in the acquisition of concepts, procedures and attitudes that help students understand, from a systemic perspective and as a network of relationships, the phenomenon of the living. Unlike other strategies such as museums or zoos, the understanding of wildlife is favored along with a high power in the generation of behaviors in favor of ecosystem conservation (Morag & Tal, 2012).

According to Learning purposes: *Attitudes*

{What do you think the students learn when they do a Field Work activity?} *" … They also have motivation to investigate, curiosity develops, the generation of questions and love for nature ..."*

Unlike the *Conceptual* and *Procedural* contents, in this case we observe the greatest change in the number of students that agree with importance of the *Attitudinal* contents as the learning objective. In this sense, there has been an increase in the number of future teachers -from 12 (44.4%) to 25 (92.6%) who affirm that in outdoor activities, students learn about responsibility, teamwork, respect towards the environment and its conservation, in addition to generating attitudes such as critical viewpoint, reflection and attitudes about scientific work such as the socialization of results, among others. From the statistical point of view, in the *Attitude* subcategory we find a high significance, (p-value ≤ 0.001), unlike the *Concepts* (p-value = 0.327) and *Processes* (p-value = 0.083) contents. For Gavidia (2008), the school has a socializing role and its function is to train critical people with the capacity to make decisions and face the daily problems of today's society, in this case through field practices. The aim is to provide students with the acquisition of basic competences to live with other people and be responsible with the environment. Research such as that of Lavie Alon and Tal (2017) have shown the predominance of conceptual learning of students in the field, however, these emphasize the desire to develop values and reflections on the proper behavior in nature.

According to Planning: *Previous ideas*

{What would you consider in order to carry out a Field Work activity?} *"... I would develop it in my preference beforehand, since it has allowed me, based on previous ideas, to structure more solid knowledge based on experience ..."*

Only six future teachers (22.2%) said at the beginning of the training process, that they would consider the previous ideas of their students to develop a field practice, while 13 (48.2%) consider this concept after our didactic intervention. The comparison between the pre and posttest showed a p-value = 0.056, very close to ≤ 0.05. We can infer that with a larger population, the data could tend towards greater significance. For Behrendt and Franklin (2014), the teacher must take into account the previous ideas of their students and allow a high degree of participation in the field activity, which generates greater motivation in them. On the other hand, for Dourado and Leites (2013), it is ideal that the field activities are planned by the teacher from a constructivist perspective.

According to Difficulties: *Teachers*

{What difficulties could you have to carry out a Field Work activity?} *" … that the students do not want to do it, the permission of the parents or the directors of the school, the space to do it, not knowing how to handle the disabilities of the students ...”*

Unlike the pretest, where the future teachers had contemplated the ideas *School Culture* and *Preparation*, here pre-service teachers identified with greater emphasis these subcategories (63% and 96.2% respectively) and also included in a greater proportion the *Students behavior* (11 students-40.7%) and the *Teacher* (6 students-22.2%). Studies like the one made by Glackin (2016) have shown that one of the main difficulties that new teachers consider to teach in the field is the management of student behavior outside of school. The management of the students both in class and in the field was favored by the fact that each group consisted of around 5 future teachers, so that they could be supported much more in teams and each one focused on small groups of students. For Scott et al. (2015), training, knowledge and trust, are the teacher's own difficulties for the full realization of field activities and therefore recognizing them involves a process of reflection and metacognition, a situation that had been absent in the pretest. From the statistical point of view, the comparison between the pre and posttest yielded a p-value = 0.05 for the *Professor* subcategory.

According to Contribution to teacher training: *Biology Teaching*

{What does Field Work activities provide to your training as a teacher?} *" ... The field practices will allow a better management of the students, strengthen certain knowledge, know the theoretical level that the students have, get ideas to do research within the classroom and finally get a motivation on the part of the students for the subject... "*

Pre-service teachers (21 cases -77.7%) highlight the fundamental role of Field Work as a teaching strategy of great importance that they hope to actively develop in their teaching practice. They highlight the impact and contribution of this activity in the learning of their students from the integration of conceptual, procedural and attitudinal learning, which will also allow them to break the traditional school schemes and to better understand the characteristics of their students, their learning rhythms, their context and their daily life. The comparison between the pre and posttest (p-value = 0.003) shows a high degree of significance. The above corresponds to the approaches of Dourado (2006) and Del Carmen (2011) that conceive Field Work as a fundamental teaching strategy of Biology. Specifically, we emphasize here that future teachers must be aware that Field Work as a teaching strategy contributes explicitly in the construction of the Professional Teacher Knowledge and in the enrichment of the Pedagogical Content Knowledge, their relationships and components (Costillo et al., 2014; Behrendt and Franklin, 2014).

Professional Development

{How does Field Work contribute to your training?} *"… A great satisfaction for having carried out an activity that can end up marking the lives of the students, of having taught them in a different way to the traditional one...."*

15 pre-service teachers (55.5%) explained that the design, implementation and evaluation of a field practice with high school students had contributed to their professional development. These future teachers identified that field work, as a teaching strategy of Biology, could favor the development of affective bonds with their students, professional satisfaction for the proper management in natural environments, project ethics and the image of an integral teacher and how with this activity they contributed to the improvement of the educational processes of the schools where they carried out the experience. The comparison between the pre and posttest showed a p-value = 0.029. The planning, development and evaluation of Field Work in Biology teaching helps generating attitudes of self-efficacy, confidence in their work as teachers (Ateskan & Lane, 2016) and professional development (Tal, 2001).

CONCLUSIONS

The results of this study support the thesis that a training proposal for teachers focused on the design, development and evaluation of Field Work for the teaching of a biological theme addressed to secondary school students, allows the configuration of a specific Pedagogical Content Knowledge. In particular, the teaching experience and the effective preparation of Field Work activities is fundamental for the construction of the Professional Teacher Knowledge, since it allows to consider that in the field students learn by establishing direct contact with biological phenomena, not only through the mere observation but through its investigation, which implies the development of scientific skills and abilities that allow them to generate behaviors in favor of the conservation of biological diversity and sustainability.

From a professional development point of view, it is necessary that the initial training of teachers includes Field Work in the curriculum, considering the need for planning, participating and reflection promotion of students during its implementation, a situation that until the time of our investigation, had not occurred for the first three years of training of these future teachers.

Finally, we have seen that although teachers usually participate in Field Work during their initial training, their conceptions about the didactic characteristics of this teaching strategy, are reductionist. In this sense, they consider that it is enough with the teacher selecting a place and a topic to carry out a field practice, where mainly what students do is corroborate what the teacher has previously transmitted in the classroom. Therefore, training interventions are required in which the teachers design, apply and evaluate Field Work for the teaching of specific biological topics. This will allow the enrichment of their conceptions towards more desirable positions from the framework of research in didactics of the natural sciences.

REFERENCES

Álvarez, J., & Jurgenson, G. (2003). *Cómo hacer investigación cualitativa. Fundamentos y metodología*. México Distrito Federal: Paidos Educador.

Amórtegui, E., & Correa, M. (2012). *Las Prácticas de Campo Planificadas en el Proyecto Curricular de Licenciatura en Biología de la Universidad Pedagógica Nacional. Caracterización desde la perspectiva del Conocimiento Profesional del Profesor de Biología*. Universidad Pedagógica Nacional y Fundación Francisca Radke, Bogotá, Colombia.

Ateşkan, A., & Lane, J. (2016). Promoting field trip confidence: teachers providing insights for pre-service education, *European Journal of Teacher Education*, 39(2), 190-201. https://doi.org/10.1080/02619768.2015.1113252

Behrendt, M., & Franklin, T. (2014). A review of research on school field trips and their value in education. *International Journal of Environmental and Science Education*, 9(3), 235-245. https://doi:10.12973/ijese.2014.213

Cohen, L., Manion, L., & Morrison, K. (2011). *Research methods in education*. New York: Routledge.

Costillo, E., Cañada, F., Conde, M.C., & Cubero, J. (2011). *Conceptions of prospective teachers on nature field trips in relation to own experiences as pupils*. *9th Conference of the European Science Education Research Association.* Lyon, Francia.

Del Carmen, L. (2011). El lugar de los trabajos prácticos en la construcción del conocimiento científico en la enseñanza de la Biología y la Geología. En Cañal, P. (Coord.) *Didáctica de la Biología y la Geología*. (pp 91-108). Barcelona. Graó

Dourado, L. (2006). Concepçoes e práticas dos profesores de Ciencias Naturais Relativas à implementaçao Integrada do Trabalho Laboratorial e do Trabalho de Campo. *Revista Electrónica de Enseñanza de las Ciencias*, 5(1), 192-212.

Dourado, L., & Leite, L. (2013). Field activities, science education and problem-solving. *Procedia Social and Behavioral Sciences*, 106(10), 1232-1241. https://doi.org/10.1016/j.sbspro.2013.12.138

Gavidia, V. (2008). Las actitudes en la educación científica. *Didáctica de las Ciencias Experimentales y Sociales,* 22, 53-66. https://doi.org/10.7203/dces..2420

Gavidia, V., & Cristerna, M. (2000). Dimensión medioambiental de la ecología en los libros de texto de la educación secundaria obligatoria española. *Didáctica de las Ciencias Experimentales y Sociales,* 14, 53-67 http://ojs.uv.es/index.php/dces/article/view/2925 http://dx.doi.org/10.17227/20271034.vol.0num.0bio-grafia1019.1032

Gess-Newsome, J. (2015). A model of teacher professional knowledge and skill including PCK: Results of the thinking from the PCK Summit. En: Berry, A., Friedrichesen, P., Loughran, J. *Re-examining Pedagogical Content Knowledge in Science Education*. (pp 28-42). New York: Routledge.

Glackin, M. (2016). 'Risky Fun' or 'Authentic Science'? How Teachers' Beliefs Influence their Practice during a Professional Development Programme on Outdoor Learning. *International Journal of Science Education,* 38(3), 409-433. https://doi.org/10.1080/09500693.2016.1145368.

Hamilton-Ekeke, J. (2007). Relative effectiveness of expository and field trip methods of teaching on students' achievement in ecology. *International Journal of Science Education,* 29(15), 1869–89. https://doi.org/10.1080/09500690601101664

Lavie Alon, N., & Tal, T. (2016). Teachers as Secondary Players: Involvement in Field Trips to Natural Environments. *Research in Science Education*, 47(4), 869-877. 10.1007/s11165-016-9531-0

Lavie Alon, N., & Tal, T. (2017). Field trips to natural environments: how outdoor educators use the physical environment. *International Journal of Science Education*, part B. 7(3), 237-252. DOI: 10.1080/21548455.2016.1250291

Mellado, V. (2011). Formación del profesorado de ciencias y buenas prácticas: el lugar de la innovación y la investigación didáctica. En Cañal, P. (Coord). *Biología y Geología. Investigación, innovación y buenas prácticas*. (pp 9-26). Barcelona: Graó

Morag, O., & Tal, T. (2012). Assessing Learning in the Outdoors with the Field Trip in Natural Environments (FiNE) Framework, *International Journal of Science Education*, 34(5), 745-777. https://doi.org/10.1080/09500693.2011.599046

Morag, O., Tal, T., & Rotem-Keren, T. (2013). Long-Term Educational Programs in Nature Parks: Characteristics, Outcomes and Challenges. *International Journal of Environmental and Science Education,* 8(3), 427-449. Doi: 10.12973/ijese.2013.213ª

Pedrinaci, E. (2012). Trabajo de campo y aprendizaje de las ciencias. *Alambique Didáctica de las Ciencias Experimentales*, 71, 81-89.

Rennie, L. (2014). Learning science outside of school. En: Lederman, N. & Abell, S. (Eds.). *Handbook of Research on Science Education* (pp 120-144). New York: Routledge.

Scott, W., Boyd, M., Scott, L., Colquhoun, D. (2015). Barriers To Biological Fieldwork: What Really Prevents Teaching Out of Doors? *Journal of Biological Education,* 49(2), 165-178. https://doi.org/10.1080/00219266.2014.914556

Shulman, L. (1986). Those who understand: Knowledge growth in teaching. *Educational Researcher*, 15(2), 4-14.

Tal, T. (2001). Incorporating field trips as science learning environment enrichment, an interpretive study. *Learning Environment Research*, 4(1), 25-49.

Tal, T., & Morag, O. (2009). Reflective Practice as a Means for Preparing to Teach Outdoors in an Ecological Garden. *Journal of Science Teacher Education*, 20(3), 245-262. doi 10.1007/s10972-009-9131-1.

Tal, T., & Morag, O. (2013). A Longitudinal Study of Environmental and Outdoor Education: A Cultural Change. *Journal of Research In Science Teaching,* 50(9), 1019-1046. 10.1002/tea.21111.

DEVELOPMENT OF A SCALE TO TEST ENVIRONMENTAL LITERACY AND TO PREDICT ENVIRONMENTAL RESPONSIBLE BEHAVIOUR OF PRE-SERVICE TEACHERS

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Education for sustainable development (ESD) from early educational stages requires the guarantee of an adequate environmental literacy (EL) of pre-service teachers. Although different attempts have been made to assess the EL of pre-service teachers, few studies have assessed scientific knowledge that fit that of the target educational curriculum. Also, almost no information has been provided on the major predictors of their environmental responsible behaviour, therefore impeding designing educational programs accordingly. In order to meet this need, we have designed and validated an instrument based on the existing literature to properly assess environmental literacy (EL) of pre-service teachers and to provide insights into the potential predictors of environmental behaviour. The instrument tests three components of the EL: environmental attitudes, behaviour and ecological knowledge. The behaviour scale incorporates emerging understudied environmental behaviours. The knowledge scale consists on scientific concepts included in the compulsory education science curriculum considered as core ideas for the understating of the causes and consequences of environmental problems, specifically those dealing with biodiversity loss. The questionnaire has been pretested and validated by 182 university students (pre-service teachers) and showed to be highly reliable considering its good psychometric properties. The three components were significantly correlated. Factor analysis allowed us to identify two bidimensional domains in the attitude and behaviour scales. Specifically, we identified two levels of actual commitment, one referring to integrated habits and a second one corresponding to self-demanding emergent habits, which accounts for the adequacy of the instrument for assessing behaviour's predictors. Preliminary results show that participant pre-service teachers showed good levels of environmental attitude but moderate levels of ecological knowledge and lower levels of responsible environmental behaviour.

Keywords: Environmental Literacy scale, Pre-service teacher's education, Environment Education

INTRODUCTION

Sustainability in the curricula of prospective teachers is key to ensure an effective Education for Sustainable Development (ESD) from early educational stages, including the guarantee of an adequate environmental literacy (EL). As regards the latter, becoming an environmentally literate person involves the acquisition of values, attitudes and skills that allow transforming knowledge into action. Hence, although different components of EL have been proposed (Roth, 1992; Hollweg et al., 2011; McBeth, Hungerford, Marcinkowski, Volk, & Meyers, 2008; McBride, Brewer, Berkowitz, & Borrie, 2013; NAAEE, 2010; Nolet, 2009; Warren et al., 2014) they all can be summarized into three major components: attitudes, behaviour and knowledge. Indeed, the environmental responsible behaviour might be influenced by the affective dimension, including attitudes and values necessary to motivate action, and driven by a comprehensive understanding of environmental problems. In addition, a number of studies have shown that increasing environmental knowledge may improve environmental attitudes (Bradley, Waliczek, & Zajicek, 1999; McMillan, Wright, & Beazley 2004; Pe'er, Goldman, & Yavetz, 2007) and promote environmentally responsible behaviour (Hsu 2004, Liu & Lin, 2015).

Since pre-service teachers will be responsible for the education of future citizenship, assessment of their EL is key in order to select the best educational approaches for their proper training. Although different attempts have been made to assess the EL of pre-service teachers, most studies have focused on their understanding of particular environmental problems (Alvarez-García, Sureda-Negre & Comas-Forgas, 2018 Michail, Stamou, & Stamou, 2007; Pe'er et al., 2007; Teksoz, Sahin & Ertepinar, 2010; Timur, Timur & Yilmaz, 2013; Tuncer et al., 2009) and only a few ones have assessed fundamental understanding of scientific concepts (Muda, Ismail, Suandi, & Rashid, 2011; Yavetz, Goldman, & Pe'er, 2009). Since an environmentally literate individual should be able to make sense of environmental realities by specifically identifying their cause and effect relationships based on scientific knowledge (McBride et al., 2013), instruments assessing EL should incorporate items asking on scientific concepts and processes that enable the interpretation of environmental issues rather than querying on the issues themselves. When it comes to the evaluation of the EL of compulsory school teachers (both prospective and experienced ones), it seems reasonable that the level of scientific knowledge evaluated should fit that of the target educational curriculum. However, this approach has not been commonly undertaken in the design of teachers' EL assessment diagnostic tools (but see Yavetz et al., 2009).

Many studies conducted so far in different countries have revealed that teachers (including pre-service ones) overall display good environmental attitudes but have important gaps and misconceptions regarding environmental knowledge (Teksoz et al., 2010; Tuncer et al., 2009; Yavetz et al., 2009). In this sense, despite the recognized need to prepare effective environmental educators, there is almost no information on the level of EL of teachers in Spain. Interestingly, Alvarez-García et al. (2018) have reported a low knowledge level about environmental realities among Spanish pre-service teachers attending two universities, while simultaneously displaying environmentally responsible attitudes and an ecocentric view of the world.

If the ultimate goal of environmental education is to change pupils' and future citizens' behaviour, in addition to evaluate the level of EL (and its components) of prospective teachers, there is an urgent need to identify the major predictors of their environmental responsible behaviour in order to incorporate those components into educational programs and instructional practices. Yet, there is scarce information on which variables best predict their behaviour (Hsu & Roth, 1999) and no data on how their environmental attitudes and knowledge affect their actual commitment in undertaken environmental responsible actions. Furthermore, there is an additional difficulty nowadays when designing an appropriate environmental behaviour scales since there is increasing information on emergent environmental issues and corresponding responsible behaviours both in the scientific literature and public media. Consequently, traditionally used items should be updated to fulfil current trends on responsible behaviour. For instance, although many environmental behaviour scales systematically include items referring to recycling habits or household energy or water saving (e.g. Kaiser, Wölfing, & Fuhrer, 1999; Leeming Dwyer, & Bracken, 1995; Liu & Lin 2015) items referring to habits oriented to alleviate emergent issues such as microplastic accumulation in oceans or high greenhouse effect gas emissions by intensive farming have not been covered so far.

Account taken of all above, we have developed an instrument to measure pre-service teacher's EL based on the literature concerning EL's indicators, i.e. environmental attitudes and behaviours and ecological knowledge (e.g. AAAS, 2018; Amérigo, Aragonés, & García, 2012;

Leeming et al., 1995; Liu & Lin, 2015; Milfont & Duckitt, 2010) and by incorporating scientific concepts included in the compulsory school science curriculum considered as core ideas for the understanding of the causes and consequences of environmental problems. Since the ultimate goal of ESD is to train for environmental responsible behaviour, our instrument was designed to provide insights into the potential predictors of environmental behavior, including self-demanding understudied behaviours towards emergent little-known environmental issues such as food production's effect on global change, microbeads or endocrine disruptors. We aim at assessing the reliability, validity and psychometric properties of this instrument and to show preliminary results.

METHODS

Instrument development

The designed instrument includes one scale for each of the three components of the EL: environmental attitudes (17 items), behaviours (19 items) and knowledge (28 items). Each scale comprises several domains (Table 1). The environmental attitude scale was adapted from Leeming et al. (1995), Mayer and Frantz (2004), Milfont and Duckitt (2010), Amérigo et al. (2012) and Liu and Lin (2015) and includes three domains: interest in nature, emotional link with nature and anthropocentrism. The environmental behavior scale includes items modified from Leeming et al. (1995), Kaiser et al. (1999) and Liu and Lin (2015) and comprises two sub-dimensions typically found in the bibliography: verbal commitment and actual commitment. The actual commitment dimension was adapted to fit emergent environmental issues (e.g. usage of plastics, meat consumption, etc.).

Attitude and behaviour's scales consist on 5-point Likert-type items ranging from "strongly disagree" to "totally agree". An additional option named "NA" (not applicable) was also added. Based on the premises that ecologically literacy implies the ability of understanding environmental issues by specifically identifying their cause and effect relationships (McBride et al., 2013) and that pre-service teachers should first teach curricular concepts, the following criteria were fulfilled in the designed knowledge scale:

- questions in the knowledge scale were placed in context.
- knowledge scale refers to the understanding of curricular key ecological concepts.
- key ecological concepts included in the scale were considered as indispensable for the comprehension of the causes and consequences of environmental problems, specifically those dealing with biodiversity loss.

The main environmental issues causing biodiversity loss considered here were: greenhouse gas emissions (climate change), toxic gas emissions (acid rain), persistent bioaccumulative and toxic substances (pesticides, microplastics, etc.), nitrate and phosphate contamination (eutrophication), resource overexploitation and habitat destruction (deforestation, agricultural and farming expansion, pollution, etc.) and exotic invasions. The corresponding 6 curricular key ecological concepts considered as necessary to correctly interpret these issues were identified based on the Framework for K-12 education (National Research Council 2012) and the Next Generation Science Standards (NGSS Lead States 2013) and comprise: life functions, biotic and abiotic interactions, environmental fluctuations, dynamics, resistance and resilience, matter cycle and energy fluxes, systems' interconnections and evolution.

Knowledge scale consists on multiple choice questions with a single correct answer (scientific conception) and two answers corresponding to misconceptions of different level of misunderstanding. An additional option was included as "DK/NA" (Do not know/ No answer). Items were adapted from AAAS (2018), Kalinowski, Leonard, and Taper (2016), Leeming et al. (1995), McBeth et al. (2008), Morrone, Mancl, and Carr (2001), and Ozay and Oztas (2003). We also incorporated 11 new items to cover underrepresented concepts such as sexual reproduction or nutrition function and specific fundamental ideas for the correct understanding of the present causes of biodiversity loss such as the understanding of organisms' and ecosystems' response to environmental changes and the origin of biodiversity.

In order to examine factors influencing environmental literacy of pre-service teachers, questionnaires included: (i) demographic characteristics such as gender, age, number of habitants in their hometown, having family farm, (ii) academic data such as having studied Biology during their baccalaureate (16-18 years old) and the mark obtained in that subject, the university entrance mark, the year pursuing in the Bachelor's Degree and the mark obtained in the Biology course during the Degree (if applicable) and (iii) information on their leisure activities such as frequency of going to the nature and traveling to rural areas through the year.

First validation process

The first version of the questionnaire was submitted to evaluation by two experts: one expert in Science Education and professor of pre-service teachers and one Ecologist researcher. Comments by the experts were used to modify pertinent items to elaborate a second version of the questionnaire. The second version of the questionnaire was applied to a sample of 64 students who will not take part in further steps. For each item, the frequency distribution of the response was evaluated. Items showing more than 15% of cases distributed in the extreme values (1 or 5) or showing kurtosis values above 1.5 were reformulated in order to enhance normal distribution in further attempts. As a result a third version of the questionnaire (final version hereafter) was issued.

Participants and data collection

The final version of the questionnaire was administered to 182 pre-service primary education students of the University of the Basque Country. The sex ratio (F:M) of the participants was 2.2 and most represented age range was 18-25 years old. Data was collected during students' free time at the classrooms of the University of the Basque Country. Previously, students were informed about the objectives of the research and they had to sign up a paper stating that they consented their data to be used for research purposes. Students filled in the questionnaire voluntarily. They were sat in separated tables and the test was conducted in absolute silence. Despite the questionnaire was anonymous, each student was provided with an identification number in order to effectively register their data and have the chance to deeply re-analyze their responses (for instance by calling them for a further/more exhaustive study) or to enable a temporary assessment of their ideas. Before starting the task, students were also given some time (approximately 1 minute) to clarify their doubts about the commitment. Afterwards, although there was no time limitation for conducting the task, students were encouraged to finish it in approximately 30′.

Data analysis

Since positive and negative items were used in the attitude and behavior scales, negative items were scored in the reverse order. All scores for a particular participant were added for each scale and dimension. In the case of the knowledge scale the cumulative scores for each core concept were also calculated. In order to account for the DK/NA and NA responses, the total score obtained for a participant was weighed based on the total number of the items responded by this participant according to the maximum possible score that can be obtained in each scale or dimension. Total scores were expressed as a percentage of the maximum scoring that can be obtained for a particular scale or domain.

The consistency of the scales and domains were assessed using the Cronbach alpha reliability index. The validity of each item and core concept was assessed using the corrected

discrimination index (r) which measures the correlation coefficient between a particular item and the total score for corresponding domain after removing that item. The level of discrimination of each item was considered as very good when r ≥ 0.4, good when 0.39 ≥ r ≥ 0.3, deficient when 0.29 ≥ r ≥ 0.20 and inadequate when r ≤ 0.19.
Skewness and kurtosis indices were calculated to assess the normality of the distributions of domains and core concepts. The dimensionality of each domain was assessed through factorial analyses. The dimensionality of each scale and domain was assessed through factorial analyses using the maximum likelihood estimation. The following criteria were used to assess the dimensionality of the scale and domain: percent of accumulated variance must be > 40%, KMO value > 0.6 with level of signification p<0.05 and communalities of items > 0.2 in most cases. Pearson's inter- and intra-correlations between domains and core ideas were also calculated within and among each scale.
General linear models were also performed in order to assess the preliminary results on the influence of demographic and academic and factors on the EL of participants.

RESULTS

After removing items with low discrimination indexes, the instrument showed good psychometric properties (Table 1 & 2). Regarding the attitude scale, two items displayed discrimination indexes < 0.3 and were conflicting within domains too. After removing these items attitude scale's Cronbach alpha was 0.845 and all items' discrimination indexes ≥ 0.3 (Table 1). "Interest for nature" domain was bidimensional (KMO=0.74, chi-sq=1.09, p=0.90) (Table 1). The first factor was interpreted as "support for environmental policies" and the second one as "consciousness of the fragility of nature" as in Milfont and Duckitt (2010). "Emotional connection" and "Anthropocentrism" domains were unidimensional.
Concerning the behaviour scale, two items displayed very low discrimination indexes due to the high number of "NA" responses. These items asked about pre-service teachers' voting intention and about car use respectively. After removing these items, the behaviour scale's Cronbach alpha was 0.806 and most discrimination indexes were ≥ 0.29 except in the case of items referring to the use of energy saving light bulbs and to food shopping criteria, respectively (Table 1). "Actual commitment" domain was bidimensional (KMO=0.73, chi-sq=34.55, p=0.44) (Table 1). Items with lowest and highest scores were associated with factor 1 and 2, respectively. Factor 1 was thus interpreted as "self-demanding emergent habits" and factor 2 as "Integrated ordinary habits". "Verbal commitment" dimension was unidimensional.
Two items were removed from the knowledge scale due to their low discrimination index. The Cronbach's alpha for the new knowledge scale was 0.669 and for the cumulative scores for the 6 core concepts was 0.670.
All inter-correlations within each scale were significant at the 0.05 level except in the case of "Responsiveness to change" vs. "Evolution" correlation (p=0.08). Moreover, the correlation between scales was also significant which supports the validity of the instrument.

Table 1. Attitude and behaviour scales' and domains' statistics.

Scale Domains	Items	Cronbach's alpha	Range	Mean score	Mean score (%)	SD	Skewness	Kurtosis
Attitude	**15**	**0.845**	**0-60**	**40.67**	**67.79**	**1.17**	**-0.39**	**-0.46**
Interest for nature	6	0.734	0-24	17.04	70.99	1.37	-0.49	-0.25
Support environmental policies	3	0.682	0-12	9.22	76.90	1.24	-0.84	2.09
Fragility of nature	3	0.734	0-12	7.81	65.11	2.08	-0.83	-0.12

Emotional connection with nature	5	0.637	0-20	12.78	63.88	1.34	-0.38	-0.56
Anthropocentrism	4	0.583	0-16	10.85	67.79	1.38	-0.34	-0.28
Behaviour	**17**	**0.806**	**0-68**	**34.45**	**50.67**	**0.10**	**-0.6**	**0.12**
Verbal commitment	6	0.728	0-24	12.18	50.74	1.16	-0.29	-0.53
Actual commitment	11	0.629	0-44	20.07	45.61	1.26	0.24	-0.31
Integrated habits	4	0.704	0-16	10.45	65.30	1.99	-0.48	-0.83
Emerging habits	7	0.705	0-28	9.75	34.84	1.39	0.57	0.00

Table 2. Ecological knowledge scale's and core concepts' statistics. Core concepts are arranged from less to high difficulty level.

Scale Core concept	Items	Range	Mean score	Mean score (%)	SD	Skewness	Kurtosis
Knowledge	**26**	**0-26**	**14.39**	**55.35**	**1.11**	**-0.44**	**-0.56**
Large-scale systems interactions	3	0-3	1.83	60.93	0.18	-1.07	2.44
Cycling of matter and energy flux	3	0-3	1.79	59.63	2.44	-0.21	-1.05
Evolution	4	0-4	2.22	55.56	2.09	-0.04	-0.70
Biotic and abiotic interactions	5	0-5	2.76	55.14	1.83	-0.25	-0.40
Responsiveness to change	6	0-6	3.27	54.54	1.41	0.24	0.07
Life functions	5	0-5	2.55	50.94	1.75	-0.00	-0.30

Preliminary results show that participants obtained a better score in the attitude scale (M=67.79, SD=1.17) than in the behaviour (M=50.67 SD=0.10) and the knowledge scale (M=55.35, SD=1.11) (table 2). The "interest for nature" domain in the attitude scale showed the highest mean score (M=70.99 SD=1.37) mostly driven by the mean score obtained in the subdomain "Support for environmental policies" (M=76.90 SD=1.24). In contrast, the lowest mean score was obtained in the "Actual commitment" domain of the behaviour scale (M=76.90 SD=1.24) due to the very low mean score obtained in the "Emerging habits" subdomain (M=34.84 SD=1.39). The effect of the gender on scores was not significant but preliminary results show that going more frequently to the nature may improve the environmental attitude ($p<0.005$).

Concerning the knowledge items, participants' understanding of the idea that large-scale systems are connected, and the existences of cycle and fluxes, was better than that of basic mechanisms of life functions or they responsiveness to environmental changes.

DISCUSSION AND CONCLUSIONS

Our results show that the designed instrument shows good psychometric properties, strong validity and reliable scores. High correlation within scale domains indicates the relevance of the items and concepts. However, it is noteworthy that items of the behaviour scale related to voting intention, car use or household consumption did not prove to be pertinent when assessing the EL of pre-service teachers and, thus, they were removed from the scale. This might be due to the young age of this particular social group who often have limited access to car use and independent housing in Spain. This finding highlights the need to adequate and validate specific diagnosis tools to the actual reality of participant pre-service teachers.

Preliminary results show that participants showed good levels of environmental attitude but moderate levels of ecological knowledge and lower levels of responsible environmental behaviour, which is in line with what has been found by other studies (Alvarez-García et al., 2018; Teksoz et al., 2010; Tuncer et al., 2009; Yavetz et al., 2009). Moreover, our factor analysis allowed us a more accurate interpretation of the results since we were able to identify two sub-domains in the "interest for nature" and "actual commitment" domains within the attitude and behaviour scales respectively. For instance, our instrument allowed us to detect that the highest and lowest relative scores were precisely obtained for the subdomains "support of environmental policies" and "self-demanding emergent behaviours" respectively which enables us to conclude that the demanding attitude towards institutions concerning the environment conservation tends to be more intense that actual personal commitment. Other studies have also pointed out that despite the awareness of prospective teachers of the importance of responsible environmental behaviour, this rarely results in actual behaviour (Goldman, Yavetz & Pe'er, 2006).

In our study we also found that participants showed a high level of commitment concerning integrated ordinary habits such as recycling habits, which contrast with the low commitment with respect to more self-demanding and less known habits such as sustainable consumer behaviours. Since our instrument was designed to provide insights into the potential predictors of environmental behaviour, having detected the "self-demanding emergent behaviours" subdomain in the behaviour scale strengthens the predictive ability of our instrument. This way, when assessing factors affecting the responsible behaviour of pre-service teachers, we could separately consider most integrated habits and self-demanding less known behaviours affecting emergent environmental issues such as food consumption effect on global change, consequences of endocrine disruptors' consumption, etc.

Our results concerning the knowledge scale indicated that, although pre-service teachers taking part in this study seem to have an intuitive idea of the global and interrelated effects of the environmental issues, they may lack the underlying mechanistic explanations of basic biological processes occurring at the organism and ecosystem level. A comprehensive understanding of the ultimate consequences of environmental issues causing biodiversity loss might influence the environmental attitude and the responsive behaviour of pre-service teachers. Therefore, administrating this instrument to a larger sample of pre-service teachers will allow further specific and accurate analysis on the relationships among the EL's dimensions and subdimensions found in this study and the relative influence of the understanding of core scientific concepts that are part of Primary and Secondary School curriculum.

REFERENCES

Alvarez-García, O., Sureda-Negre, J., & Comas-Forgas, R. (2018). Assessing environmental competencies of primary education pre-service teachers in Spain: A comparative study between two universities. *International Journal of Sustainability in Higher Education, 19*, 15-31. doi: 10.1108/IJSHE-12-2016-0227.

American Association for the Advancement of Science. (2018). AAAS Science Assessment Project 2061. Retrieved from http://assessment.aaas.org/topics [20th July 2018].

Amérigo, M., Aragonés, J.I., & García, J.A. (2012). Exploring the dimensions of environmental concern. An integrative proposal. *Psyecology*, *3*, 353-365. doi: 10.1174/217119712802845723.

Bradley, J. C., Waliczek, T. M., & Zajicek, J. M. (1999). Relationship between environmental knowledge and environmental attitude of high school students. *The Journal of Environmental Education*, *30*(3), 17-21. doi: 10.1080/00958969909601873.

Goldman, D., Yavetz, B., & Pe'er, S. (2006) Environmental Literacy in Teacher Training in Israel: Environmental Behavior of New Students. *The Journal of Environmental Educational Researcher, 38*, 3-22. doi: 10.3200/JOEE.38.1.3-22.

Hollweg, K. S., Taylor, J. R., Bybee, R. W., Marcinkowski, T. J., McBeth, W. C., & Zoido, P. (2011). Developing a framework for assessing environmental literacy. Washington, DC: North American Association for Environmental Education.

Hsu, S. J. (2004). The effects of an environmental education program on responsible environmental behavior and associated environmental literacy variables in Taiwanese college students. *The Journal of Environmental Education, 35*(2), 37-48. doi: 10.3200/JOEE.35.2.37-48.

Hsu, S.-J., & Roth, R.E. (1999). Predicting Taiwanese secondary teachers' responsible environmental behavior through environmental literacy variables. *The Journal of Environmental Education, 30*, 11-18. doi: 10.1080/00958969909601879.

Kaiser, F.G., Wölfing, S., & Fuhrer, U. (1999) Environmental attitude and ecological behaviour. *Journal of Environmental Psychology, 19*, 1- 19. doi: 10.1006/jevp.1998.010719.

Kalinowski, S. T., Leonard, M. J., & Taper, M. L. (2016). Development and validation of the conceptual assessment of natural selection (CANS). CBE-Life Sciences Education 15(4).

Leeming, F., C., Dwyer, W., O., & Bracken, B., A. (1995). Children's environmental attitude and knowledge scale: construction and validation. *The Journal of Environmental Education*, *26*, 22-31. doi: 10.1080/00958964.1995.9941442.

Liu, S.-C., & Lin, H.-S. (2015). Exploring undergraduate students' mental models of the environment: Are they related to environmental affect and behavior? *The Journal of Environmental Education*, 46, 23-40. doi: 10.1080/00958964.2014.953021.

Mayer, F.S., & Frantz, C.M. (2004). The connectedness to nature scale: A measure of individuals' feeling in community with nature. *Journal of Environmental Psychology, 24*, 503-515. doi: 10.1016/j.jenvp.2004.10.001.

McBride, B.B., Brewer, C.A., Berkowitz, A.R., & Borrie, W.T. (2013). Environmental literacy, ecological literacy, ecoliteracy: What do we mean and how did we get here? *Ecosphere,* 4, art67.

McBeth, B., Hungerford, H., Marcinkowski, T., Volk, T., & Meyers, R. (2008). National environmental literacy assessment project: year 1, national baseline study of middle grades students –final research report. Environmental Protection Agency, Washington, D.C.

http://www2.epa.gov/sites/production/files/documents/masternela_year1report_081208_.pdf

North American Association for Environmental Education (NAAEE) (2010). Excellence in environmental education: Guidelines for learning (K-12). Washington, D.C., USA: NAAEE.

McMillan, E.E., Wright, T., & Beazley, K. (2004). Impact of a university-level environmental studies class on students' values. *The Journal of Environmental Education, 35*(3), 19-27. doi: 10.3200/JOEE.35.3.19-27.

Michail, S., Stamou, A.G., & Stamou, G.P. (2007). Greek primary school teachers' understanding of current environmental issues: An exploration of their environmental knowledge and images of nature. *Science Education, 91*, 244-259. doi: 10.1002/sce.20185.

Milfont, T.L., & Duckitt, J. (2010). The environmental attitudes inventory: A valid and reliable measure to assess the structure of environmental attitudes. *Journal of Environmental Psychology*, *30*, 80-94. doi: 10.1016/j.jenvp.2009.09.001.

Morrone, M., Mancl, K., & Carr, K. (2001). Development of a metric to test group differences in ecological knowledge as one component of environmental literacy. *The Journal of Environmental Education 32,* 33-42. doi: 10.1080/00958960109598661.

Muda, A., Ismail, N.S., Suandi, T., & Rashid, N.A. (2011). Analysis of cognitive and affective component of environmental literacy of pre-service teachers from institute of teacher education Malaysia. *World Applied Sciences Journal, 14*, 114-118.

National Research Council. (2012). A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas. Committee on a Conceptual Framework for New K-12 Science Education Standards. Board on Science Education, Division of Behavioral and Social Sciences and Education. Washington, DC: The National Academies Press.NGSS Lead States. (2013). Next Generation Science Standards: For States, By States (Dimension 3. Disciplinary core ideas- Life Sciences). Retrieved from http://www.nextgenscience.org/

Nolet, V. (2009). Preparing sustainability-literate teachers. *Teachers College Record*, *111*, 409-442. Retrieved from http://www.tcrecord.org/.

Ozay, E., & Oztas, H. (2003). Secondary students' interpretations of photosynthesis and plant nutrition. *Journal of Biological Education, 37*, 68-70. doi: 10.1080/00219266.2003.9655853.

Pe'er, S., Goldman, D., & Yavetz, B. (2007). Environmental literacy in teacher training: Environmental attitudes, knowledge and behavior of beginning students. *Journal of Environmental Education*, *39*(1), 45-59. doi:10.3200/JOEE.39.1.45-59.

Roth, C. (1992). Environmental literacy: Its roots, evolution and directions in the 1990s. Columbus, OH: ERIC Clearinghouse for Science, Mathematics and Environmental Education.

Teksoz, G., Sahin, E., & Ertepinar, H. (2010). A new vision for chemistry education students: Environmental education. *International Journal of Environmental & Science Education, 5*, 131-149.

Timur, S., Timur, B., & Yilmaz, S. (2013). Determining primary school candidate teachers' levels of environmental literacy. *The Anthropologist, 16*, 57-67. doi: 10.1080/09720073.2013.11891335.

Tuncer, G., Tekkaya, C., Sungur, S., Cakiroglu, J., Ertepinar, H., & Kaplowitz, M. (2009). Assessing pre-service teachers' environmental literacy in Turkey as a mean to develop teacher education programs. *International Journal of Educational Development*, *29*(4), 426-43. doi:10.1016/j.ijedudev.2008.10.003.

Warren, A., Archambault, L., & Foley, R. W. (2014). Sustainability education framework for teachers: Developing sustainability literacy through futures, values, systems, and strategic thinking. *Journal of Sustainability Education*, *6*, 1–10. Retrieved from http://www.journalofsustainabilityeducation.org/

Yavetz, B., Goldman, D., & Pe'er, S. (2009). Environmental literacy of pre-service teachers in Israel: a comparison between students at the onset and end of their studies. *Environmental Education Research*, *15*(4), 393-415. doi:10.1080/13504620902928422.

INTRODUCING PRE-SERVICE EARLY CHILDHOOD TEACHERS TO EDUCATION FOR SUSTAINABLE DEVELOPMENT USING SOCRATES' HOUSE

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Humankind is facing critical situations concerning environmental, societal and financial problems. Through Education for Sustainable Development (ESD) students of all educational levels could gain knowledge and positive attitudes to become democratic and informed citizens, aware of the current problems, and able to take actions. A questionnaire we used to inquire about pre-service early childhood teachers' knowledge, views and attitudes towards ESD showed that most of them had never ESD lessons during formal education. Furthermore, while most students expressed positive attitudes, a clear majority, had very little knowledge what ESD is, with almost all students acknowledging only environmental aspects, half of them also societal issues, and only one third stated in addition economic problems. When asked if they need more education on sustainability, most agreed strongly, while the clear majority stated that including ESD in their curriculum could help them teach about sustainability. To address the above problems, we designed and conducted Teaching Interventions (TIs) using houses as the main theme. Houses constitute a familiar experience to all people throughout time, have environmental impact, are social constructs, and are economic entities. Thus, through houses we can analyze all dimensions of ESD. Highlighting at the same time that a very familiar subject can be complex and multifaceted. In this study we present the outcomes of the TIs we conducted with pre-service Early Childhood teachers. Comparing the findings of the pre- and post- application of the questionnaire we observe the short TIs had a clear increase of the students' knowledge of SD, while students' views and attitudes also improved.

Keywords: Education for Sustainable Development, Initial Teacher Education, Socrates' house, Teaching Interventions

INTRODUCTION

The major problems of our time, as the climate crisis, the migration problems, the extended use of plastic, which ends up in our environment and our food chain, etc. are all issues of Sustainable Development (SD). Therefore, Education for Sustainable Development (ESD) is a complex and multifaceted subject, including environmental, societal and economic aspects and their interrelatedness. Furthermore, ESD is a subject still evolving (McKeown 2002) and it is not just a set of knowledge that can be learned and applied. In addition, successfully applied solutions to local problems seem often unsuitable for other places.

It is imperative to include sustainable development courses at all educational levels if we want to ensure quality life for future generations. However, to achieve changes, not only knowledge, but also positive attitudes and values towards ESD, should be acquired (Dillon & Gayford, 1997). Teachers can influence positive attitudes and values by making pupils aware from youngest ages through formal and informal education. Aspects of ESD can be incorporated in all subjects, while interdisciplinary, interactive and experiential approaches have shown to be appropriate pedagogies. There have been many attempts to incorporate ESD in the higher institutions' curricula worldwide (Cebrián, 2016; Burmeister & Eilks, 2013). Many scholars also suggest including short interventions in all subjects (McKeown, 2014).

Since ESD is such a crucial subject, we wanted to inquire about the knowledge, beliefs and attitudes of pre-service Early Childhood teachers. We used a questionnaire consisting of two parts, of which the first was an inquiry about the knowledge, perceptions and attitudes of students towards ESD issues (Maidou, Plakitsi & Polatoglou, 2019a), while the second part contained questions about heat transfer from everyday life experiences, thermal behavior of building materials, and the form and function of traditional houses and especially traditional houses in Greece. The questionnaire was applied to measure the results of pre-service teachers' knowledge, perceptions and attitudes before and after the Teaching Interventions TIs. We are aware that it is difficult to estimate improvements of attitudes, since a positive expression on something might only show enthusiasm, without necessarily leading to actions or teaching ability. We started the research during the year 2014-15, and since we adapted the teaching approach, tasks, and activities. Here we will report about the outcome of the academic year 2017-18.

Pre-test findings of the questionnaire revealed that 47% of the students consider their knowledge of ESD issues moderate, around 28% little and 11% inadequate. In addition, a large percentage, about 64%, said they never had ESD or Environmental Education (EE) courses. When asked about their stance on sustainability issues, most (about 70%) answered that they believe that it is important for people to be interested about sustainability, but only 12% said they are interested and contribute wherever they can, while nearly 12% stated that they do not know what sustainability is about. Most of the students did not know about the three SD components – 95% acknowledged environmental issues, about 50% mentioned societal problems, and only 34% financial matters. Furthermore, 77% of the pre-service teachers agreed strongly/agreed that ESD should be included in the curricula of future teachers and that the inclusion of ESD would support them in their teachings. When asked if they feel that they need more ESD training, 32% responded 'very much' and 46% 'much'. In conclusion, the findings showed lack of content knowledge about ESD, but positive beliefs and attitudes towards ESD. For all the above reasons, we decided to conduct TIs on ESD using houses. We chose houses to approach ESD, and examined them as cultural phenomena, as social constructs, and as financial entities, and focused on their environmental influences, more specifically on energy consumption in houses.

Furthermore, including history and philosophy in the teaching of sciences, according to Seroglou and Adúriz-Bravo (2012) leads to a more meaningful science education. In the same line, Matthews (2009) supports the inclusion of aspects of history and philosophy of sciences in curricula and classrooms arguing that in this way we can humanize the sciences, connecting students with personal, ethical, cultural, and political concerns, making classrooms more challenging, enhancing critical thinking skills, and contributing to the understanding of the scientific subject. Koliopoulos, Dossis, and Stamoulis (2007) advocate the use of authentic or transformed historical material, mainly text. This approach combines the discovery and explanatory framework and is often connected to the story-line approach.

We conducted TIs using houses and a historical text to elaborate aspects of ESD. Our research questions were:

1. Can short term TIs raise students' knowledge of ESD aspects?
2. Can short term TIs positively affect students' attitudes towards ESD issues?
3. Are houses suitable examples to be used to study several ESD aspects?

METHOD

To enhance the knowledge of the pre-service teachers, we used an inquiry-based approach. We discussed explicitly about the various issues of ESD, allowing them to express their perceptions on why an issue is considered critical for the environment, society and/or economy. We stressed the importance of teachers in the education of critical thinking democratic citizens, willing to take responsibility and face the problems of humankind. In this process, we followed the paradigm of teaching about the Nature of Science (NOS), according to which NOS needs to be explicitly addressed and planned for, through reflective questioning and discussions of the NOS aspects (Abd-El-Khalick & Lederman, 2000; Khishfe, 2012). We furthermore stressed the importance of ESD by presenting the efforts of UNESCO with the Decade of ESD and the following initiative of the 17 SD goals.

ESD can be accessed through the teachings of any key aspect of ESD. We chose houses since they are a very familiar subject to any person of any age, they have profound environmental impact, are social constructs bearing psychological value and are an economic entity.

Buildings consume the highest percentage of the energy consumption in the US (47.6%) and EU (38.1%), higher than industry and transportation. Since at our houses we can control our consumption, the question posed to the students was: 'Can we consume less energy in our homes without compromising our wellbeing?'. When asked where students consume energy at home, they replied mostly for warm water and heating during winter and cooling during summer.

We then presented and discussed traditional architectural solutions to housing from around the world. Igloos and African huts are houses in extreme weather conditions, which offer protection to their inhabitants and are adapted to the local conditions. The same holds for traditional houses in Greece, houses from mountainous areas and from islands. And this adaptation to the local climate conditions and building materials is not new, as can be observed from the excerpt of Xenophon's Memorabilia (1923) of book Γ', 3.8.8-3.8.9, where Socrates mentions how houses should be built:

> '… Is it pleasant to have it [house] cool in summer and warm in winter? Now in houses with a south aspect, the sun's rays penetrate the porticoes in winter, but in summer the path of the sun is right over our heads and above the roof, so that there is shade. … we should build the south side loftier to get the winter sun and the north side lower to keep out the cold winds.'

These building principles were applied until the beginnings of the modern era, to build traditional houses in Greece, both in islands and mountains. Adaptation to local climate conditions, locally available building materials, etc. can be observed in traditional buildings globally. Currently, bioclimatic designers have rediscovered these principles.

After the presentation of the excerpt about the Socrates' house, the students were asked to present drawings of the house, discussing and working in groups of 4-6. They produced correct representations of Socrates' house mostly with the South façade higher than the North façade, while some groups prepared some quite elaborate sketches which were published in Maidou, Plakitsi and Polatoglou (2019b).

Socrates had deep knowledge of the principles of bioclimatic architecture, and the apparent path of the sun in the sky during the year. In the Northern Hemisphere the sun-path reaches the highest noon point at the summer solstice and the lowest one at the winter solstice. In order to comprehend the function of this house we must understand the importance of its orientation, and also grasp the apparent motion of the sun throughout the year. During winter and before the spring equinox the sun rises and sets closer to a southeast and southwest position respectively, reaching the most distant point during the winter solstice. On the other hand, moving from spring to summer and before the autumn equinox, the sun rises northeast and sets northwest, with the most distant point during the summer solstice. A depiction of these phenomena for the Northern Hemisphere is presented in Figure 1. During the TIs we explained with the help of a presentation with picture, simulations and with the help of a house model and a torch the difference of the sun-path during summer and winter.

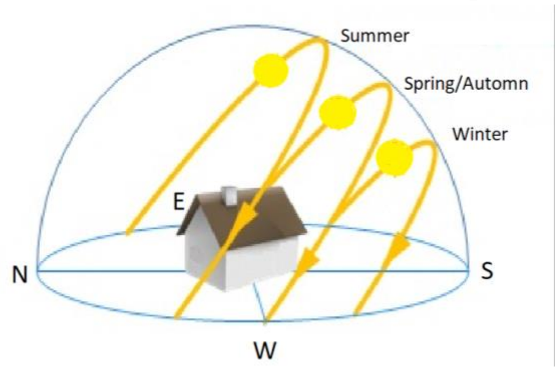
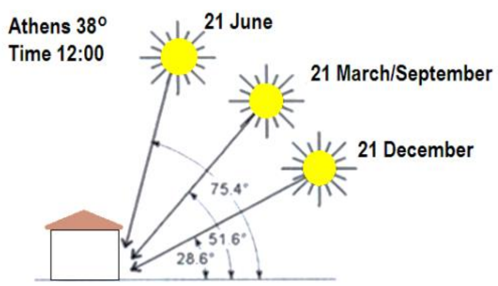


Figure 1. Apparent sun-path during summer, spring and autumn, and winter for the Northern Hemisphere.

In addition, the apparent sun-path reaches during summer a much higher point in the sky in comparison to the much lower highest point it can reach during winter. For example, for Athens at 12:00 on 21st June, the sun rays arrive with an angle 75.4° while on 21st December, the sun rays have an angle of 28.6°, as can be seen in Figure 2. This means that during the winter months the sun-rays reach deeper into the house through the South windows, offering a free heating source, as mentioned by Socrates. This does not cause an overheating problem during summer, since the sun-rays can easily be screened by a small protrusion of the roof – one meter is enough to screen windows and balcony doors of a house in Greece.



Picture 2. Height of the sun at noon during summer and winter solstice and the spring/autumn equinox.

The thermal behavior of buildings is influenced by the buildings materials used. For a bioclimatic building apart from a south aspect with large windows, the building must have materials with high thermal capacity, which are able to store the heat gained by the sun-rays and the building must have good heating insulation in order to keep the heat inside and hinder its escape to the environment, To emphasize the importance of the building materials, the pre-service teachers performed some experiments in groups of 4-6. They were presented with some pieces of building materials: stone, piece of metal, wood, extruded polystyrene, plastic foil. They were asked to list the materials in writing. Afterwards they were asked if they believe that the materials have all the same temperature – the experiment was conducted during the winter semester with relatively low temperatures. All groups answered that the metallic object had the lowest temperature, while all groups agreed that the polystyrene was the warmest material. They had again to prepare a list from the coldest to the warmest material. All groups got a digital thermometer and were asked to measure the materials and write their findings next to each material. The pre-service teachers were highly surprised, finding almost the same temperature for all materials – some thought that the thermometer was malfunctioning. After some discussions among them they reached the result that all materials were in the same room and therefore they all had to have the room temperature. When we insisted how it was possible to feel with their hands such a huge difference, and what kind of materials showed such a discrepancy, after discussing it in each group, they found that metallic materials were good heat conductors, thus allowing heat from their hands to flow to the object and in this way they experienced it as cold, while the polystyrene, an insulator, hindering the heat flow from their hand to the object was experienced as a warm material.

In addition, to show a difference in heat capacity, we used a piece of stone and a piece of metal of approximately the same shape. The instructor (teacher) performed this experiment with the assistance of a student. The student had the digital thermometer and measured both materials, finding initially the same temperature for both. The teacher lit a flame and held one end of the materials in her hand while the other end was in the flame. During short time intervals both materials were removed from the fire and the student measured and reported the temperatures of both materials to the class. The experiment showed that the metallic object gained heat with a much higher rate than the stone. When we stopped the heat flow to the objects the metallic object had reached a higher temperature than the stone. We set both objects down on a wooden board and the student continued the measurements, reporting the temperatures to the class. Again, for the metallic object a quicker drop of its temperature was observed than for the stone, and at the end of the experiment both the metallic object and the stone had the same temperature.

The theoretical background for the design of the TIs was the Cultural-Historical Activity Theory (CHAT). According to Engeström (1999), the socio-cultural frame of Activity theory provides a context of human activity, linking the individual level to the social. The unit of analysis is the activity. This includes the person or group acting towards an object, applying certain rules and the dynamic relationships that develop within the activity system (Engeström, 1999; Barab, Evans & Baek, 2003). Roth and Lee (2004) understand science education as/for participation in the community and state that participation in the collective praxis of a community precedes over individuals and science. Engagement in science activities occurs with tools for dealing with a scientific concept, interacting with each another and with tools, building a community of learners, and working towards knowledge construction with scientifically accurate outcomes (Engeström, 2005). Within the CHAT framework, the individual and its learning experience are correlated with the social environment of the individual. Human interactions with the environment are socially defined. This aspect is linked to the principles of an activity system. The basic principles of CHAT include the hierarchical structure of activity, object-orientedness, internalization/externalization, tool mediation, and development. It is necessary to define object-orientedness to understand the hierarchical structure of an activity and the transformations that take place in the process of development. These transformations are interrelated with the tools of mediation. In addition, the dialectic relation of the principles of internalization/externalization allows individuals to act and transform their sociocultural background (Kaptelinin & Nardi, 2006). CHAT seems to be a coherent theoretical framework which can achieve the scope of real scientific literacy, enhance interdisciplinarity, and develop a new mentality that could reform science education from within. (Plakitsi, 2013).

The participants were Early Childhood Education pre-service teachers, mainly belonging to the age group 20-24 years (94.5%) and mostly female (98%). The same questionnaire was applied prior to the TIs and immediately after it. 192 students completed the pre-test and 184 the post-test questionnaire.

The teaching approaches we applied were student-centered (McNaughton 2012; Tomas, Girgenti & Jackson, 2017) experiential and participatory (Lysgaard & Simovska, 2016), inquiry-based and transformational (Biasutti, 2015; Corney & Reid, 2007; Tomas, Girgenti & Jackson, 2017). These teaching and learning methods promote changes in behaviors and ways of thinking and relate to knowledge and to processes, because these methods teach learners how to think (Biasutti 2015).

RESULTS

We present here the quantitative results of the questionnaire. After the TIs 98.4% of the students acknowledged environmental issues to be aspects of SD, 89.8% societal issues and 85.2% financial, exhibiting a profound improvement of the dimensions of ESD. From Table 1 we can also observe that the total percentages for the answers concerning ‘strongly agree’ or ‘agree’ have improved after the TIs.

Table 1: Students’ views on key elements of SD

Sustainable development implies:	% agree/strongly agree Pre-test (N=192)	% agree/strongly agree Post-test (N=184)
Maintaining biodiversity in the local environment	55.2	89.1
Recycling waste products	64.4	85.1
Helping people to avoid starvation and disease	44.5	80.5
Exploiting natural resources for human benefit while maintaining critical natural capital	55.5	88.3
Significant local production and consumption	43.1	75
Maintaining economic growth	35.1	82.7
Acting now is expensive but may offer quality life for future generations	69.3	81.3
Social progress recognizing the needs of everyone	49.7	82
Gender equality	20.6	82.7

Sustainable urbanization	41.7	87.5

By examining questions on the perceptions pre-service teachers have about ESD we can also observe improvement (table 2).

Table 2: Pre-service teachers' perceptions about ESD

Perceptions about ESD	% Pre-test (N=192)	% Post-test (N=184)
How do you evaluate your knowledge on ESD issues (very good/good)	14.6	46.9
Do you believe you need further training on ESD issues (very much/much)	78.5	81.9
Including ESD in my curricula would influence my ability to teach about it (strongly agree/agree)	72.8	87.4
It is important to include ESD training in future teachers education (strongly agree/agree)	76.8	86.7
Teachers can lead to solutions of environmental problems through their teachings (strongly agree/agree)	70.2	87.5

The same can be observed about the pre-service teachers attitudes towards ESD as illustrated in figure 3 and 2. They state that ESD issues are important for their teachings and their personal stances (pre-test 90% - past-test 98%). They also support that it is important to include sustainability issues in their teachings (80% before and 91% after the TIs).

As to the second part of the questionnaire, students had already a very high understanding of heat transfer and heat capacity phenomena of their everyday life experiences. Concerning the sun-path, before the TIs, when asked if the apparent sun-path is the same during summer and winter, 20% answered yes, 28% no, and 52% I don't know, while after the TI no one answered yes, 98% no and 2% I don't know. As for the building materials, the majority (71%) named polystyrene as an insulator while 64% before. In addition, when asked to identify materials with high heat capacity, 76% named stone and 61% concrete, while before the TIs these materials ranked to 47% for stone and 27% for concrete.

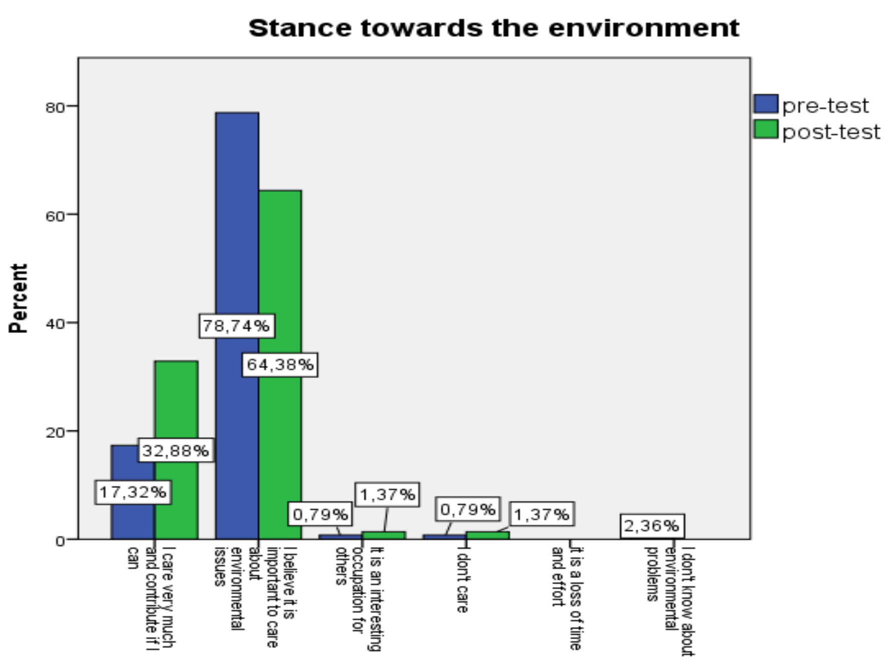


Figure 3. Stance of the pre-service teachers towards the environment.

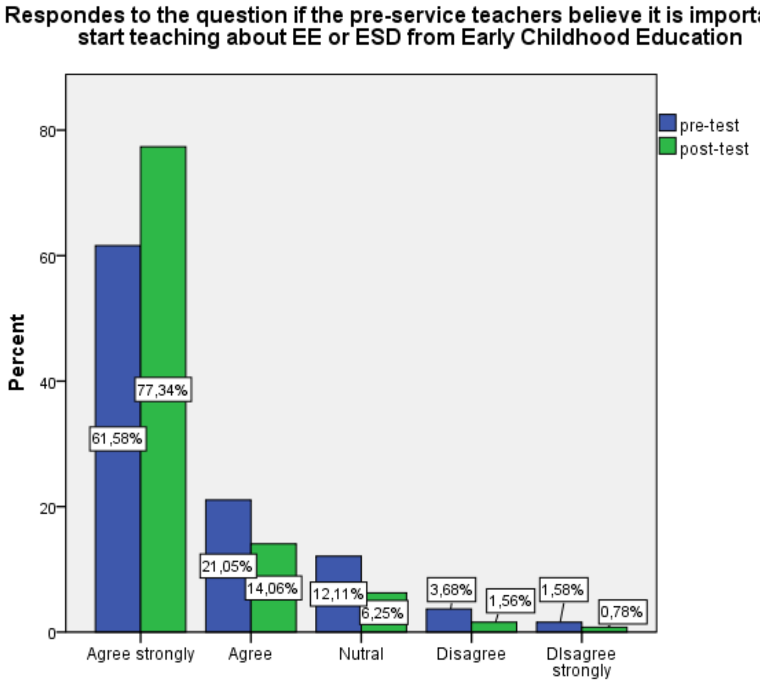


Figure 4. Pre-service teachers' responses to the question if they believe that it is important to start teaching EE or ESD starting from early childhood education.

DISCUSSION AND CONCLUSIONS

ESD is a complex and complicated notion covering environmental, societal and economic aspects and their interrelatedness. To access such a difficult subject, we used houses, a familiar concept to all, of any age and any cultural background.

The inclusion of the excerpt of Xenophon's Memorabilia, where Socrates describes the way a house should be built, to offer comfortable living conditions during winter and summer, proved to be a useful asset in catching the pre-service teachers interest, in order to analyze the sustainability dimensions through the notion house. In this way we connect a familiar subject, the houses, and studied them through the lenses of ESD, focusing on energy consumption in houses. Socrates' house proved to be an excellent starting point, connecting ESD with personal, cultural, ethical, and political concerns. The overall process proved that through aspects of history and philosophy of sciences, classrooms can be more challenging, enhancing critical thinking skills, and contributing to understanding of the scientific subject.

Pre-service teachers showed great interest and participated actively in the whole process, contributing to the discussions and participating in the activities.

We could observe a clear improvement of the knowledge and perception of the pre-service teachers on SD. Furthermore, we found improvement of their attitudes towards ESD. Students stated that they believe that ESD is important for them personally and for their teachings and intent to teach about ESD. They expressed the need for more education on sustainability issues and the importance for introducing ESD into the curriculum of future teachers, as well as that this would improve their teaching ability on this subject. From our findings, it seems that even short-term TIs can have positive outcomes, strengthening the suggestion to include ESD teachings in all subjects.

In addition, also their knowledge of building materials, insulators and heat capacity materials improved, as well as their understanding of the form and function of traditional houses, which apply the principles of the Socrates' house. The later refer to the open-ended questions and will be presented elsewhere.

To assist pre-service teachers in their difficult job of educating critically thinking democratic citizens, universities must help them with proper education and training during their studies and continue with life-long learning during their working life.

REFERENCES

Abd-El-Khalick, F., & Lederman, N. G. (2000). Improving science teachers' conceptions of the nature of science: A critical review of the literature. *International Journal of Science Education*, *22*(7), 665–701.

Barab, S. A., Evans, M., & Baek, E. O. (2003). Activity Theory as a Lens for Characterizing the Participation Unit. In D. Jonassen (Ed.), *International Handbook on Communication Technologies*, (pp. 199-214). Mahwah, NJ: Lawrence Erlbaum Associates.

Biasutti, M. (2015). An intensive programme on education for sustainable development: the participants' experience. *Environmental Education Research*, *21*(5), 734-752.

Burmeister, M., & Eilks, I. (2013). Using Participatory Action Research to Develop a Course Module on Education for Sustainable Development in Pre-Service Chemistry Teacher Education. *CEPS Journal*, *3*(1), 59-78.

Cebrián, G. (2016). A collaborative action research project towards embedding ESD within the higher education curriculum. *International Journal of Sustainability in Higher Education*, *18*(6), 857-876.

Corney, G., & Reid, A. (2007). Student Teachers' Learning about Subject Matter and Pedagogy in Education for Sustainable Development. *Environmental Education Research*, *13*(1), 33–54.

Dillon, P. J. & Gayford, C. G. (1997). A Psychometric Approach to Investigating the Environmental Beliefs, Intentions and Behaviours of Pre-service Teachers. *Environmental Education Research*, *3*(3), 283-297.

Engeström, Y. (1999). Activity theory and individual and social transformation. In Y. Engeström, R. Miettinen & R-L. Punamääki (Eds.), *Perspectives on Activity Theory*. Cambridge: Cambridge University Press.

Engeström, Y. (2005). *Developmental work research: Expanding activity theory in practice*. Berlin: Lehmanns Media.

Kaptelinin, V., & Nardi, B. (2006). *Acting with technology: Activity theory and interaction design*. Cambridge: MIT Press.

Khishfe, R. (2012). Nature of Science and Decision-Making. *International Journal of Science Education*, *34*(1), 67-100. DOI: 10.1080/09500693.2011.559490

Koliopoulos, D., Dossis, S. & Stamoulis, E. (2007). The Use of History of Science Texts in Teaching Science: Two Cases of an Innovative, Constructivist Approach. *The Science Education Review*, 6(2), 44-56.

Lysgaard, J. A., & Simovska, V. (2016). The significance of 'participation' as an educational ideal in education for sustainable development and health education in schools. *Environmental Education Research*, *22*(5), 613-630. DOI:10.1080/13504622.2015.1029875.

Maidou, A., Plakitsi, K., & Polatoglou, H. M. (2019a). Knowledge, Perceptions and Attitudes on Education for Sustainable Development of Pre-Service Early Childhood Teachers in Greece. *World Journal of Education*, *9*(5), 1-15. doi:10.5430/wje.v9n5p1.

Maidou, A., Plakitsi, K. & Polatoglou, H. M. (2019b). Socrates' house: A suitable paradigm to introduce pre-service teachers to Education for Sustainable Development. In F. Seroglou and V. Koulountzos (Eds.), *Conference Proceedings of the 15th International History, Philosophy and*

Science Teaching Conference: Re-introducing science Sculpting the image of science for education and media in its historical and philosophical background, (pp 348-361). Thessaloniki, Greece: Grafima Publications. ISBN: 978-618-5271-79-4.

Matthews, M. R. (2009). History, philosophy, and science teaching: The new engagement. *Asia-Pacific Forum on Science Learning and Teaching*, *10*(1), 1-14.

McKeown, R. (2002). Education for sustainable development toolkit. Retrieved from http://www.esdtoolkit.org/

McKeown, R. (2014). The Leading Edge of Teacher Education and ESD. *Opinion Essay*, *8*, 127–131.

McNaughton, M. J. (2012). Implementing Education for Sustainable Development in Schools: Learning from Teachers' Reflections. *Environmental Education Research*, *18*(6), 765–782.

Plakitsi, K. (2013). Activity theory in formal and informal science education: The ATFISE Project. In K. Plakitsi (ed), *Activity Theory in Formal and Informal Science Education*. (pp 1-16), Rotterdam, The Netherlands: Sense Publishers. http://dx.doi.org/10.1007/978-94-6091-317-4

Roth, W. M., & Lee, S. (2004). Science education as/for participation in the community. *Science Education*, *88*(2), 263-291. http://dx.doi.org/10.1002/sce.10113

Seroglou, F. & Adúriz-Bravo, A. (2012). Introduction: The Application of the History and Philosophy of Science in Science Teaching. *Science & Education*, *21*, 767–770.

Tomas, L., Girgenti, S. & Jackson, C. (2017). Pre-service teachers' attitudes toward education for sustainability and its relevance to their learning: implications for pedagogical practice. *Environmental Education Research*, *23*(3), 324-347. DOI:10.1080/13504622.2015.1109065.

Xenophon (1923) Memorabilia. Translated by E. C. Marchant. Cambridge, MA: Harvard University Press. Retrieved from http://www.perseus.tufts.edu/hopper/text?doc=Perseus%3Atext%3A1999.01.0208%3Abook%3D3%3Achapter%3D8%3Asection%3D8.

WHAT STUDENTS THINK AND DO FOR AN ALTERNATIVE FUTURE: THREE YEARS AFTER A SCIENCE-INFORMED ENERGY COURSE

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Enabling students to act as public-minded citizens is an urgent task if society is to effectively address and resolve critical issues related to environmental sustainability and human well-being. Thus, teaching students the competencies that are critical to making the world a better place should be a vital component and objective of science education today. In this research, a group of 12th graders were interviewed to assess what actions they had taken to make the world a better place three years after taking a science-informed energy course. Content analysis that focused on the actions and rationales related to scientific concepts was conducted on the interview data of 30 students. Four categories of intentional and purposive actions were identified, including personal actions, participatory actions, transformative actions, and preparing for actions. A minority of the students took actions at the highly involved or action-preparing level, while most took actions at the personal or participatory level. A small but significant percentage of the students reported not having taking any action to make the world a better place. Empowering students with the competencies necessary to take positive and meaningful actions that lead to a better future for the environment and humanity should be prioritized in science education.

Keywords: Environment, Science Education, Secondary School

INTRODUCTION

Although the importance of science education in preparing students to be good future citizens has been promoted for several decades, the chronic shortcomings in current science teaching and the lack of consensus regarding the science education curriculum necessary to achieve "good future citizen" goals have frustrated progress on this issue (Choi, Lee, Shin, Kim, & Krajcik, 2011; Roth and Lee, 2004; Deboer, 2000). Efforts in recent years to engage students in discussions and constructing arguments on controversial topics such as socio-scientific issues have been shown to broaden the views and enhance the abilities of students (Dawson & Carson, 2016; Osborne, Donovan, Henderson, MacPherson, & Wild, 2016). In related interventions, students learn to make decisions that reflect their perspectives. However, making informed decisions and expressing positive intent often do not accurately predict subsequent actions or follow-through (Hodson, 2003; 2010). As citizens, students should be encouraged to act to improve social conditions and values in the public sphere (Hodson, 2010; 2017).

In recent science education reforms (National Resource Council, 2012; Next Generation Science Standards Lead States, 2013) have been designed to encourage educators and teachers to involve students in meaningful learning through science-based ideas and practice. However, methodologies to promote problem-solving competencies in students in authentic environments are lacking. Meanwhile, because of the close-ended nature of current school education and the use of predetermined learning content, teachers have been generally hostile to integrating critical approaches into their courses (Barrett & Sutter, 2006; Birshall, 2010; Sinakou, Donche, Boeve-de Pauw, & Van Petegem, 2019; Westheimer, 2015). Therefore, using scientific knowledge to address real-world problems is rare in education today (Birmingham & Calabrese Barton, 2014; Birmingham et al., 2017). However, science is recognized as a discipline that may not only alleviate the effects of a problem but also address and resolve its root causes (UN, 1972). Taking action to resolve societal problems impacts not only how people live in the world today but also the chances for subsequent generations to survive (Hodson, 2003). Empowering students with the competencies necessary to change the world is an urgent task for social and environmental justice (Dittmer et al., 2018; Riemer et al., 2016).

In line with this goal, students' actions are based on the concept of action competence, the objective of which is to "make present and future citizens capable of acting on a societal as well as a personal level" (Jensen & Schnack, 2006, p. 472). Apart from setting this goal in advance, students must be conscious of the existence of the problem and become committed to solving the problems facing this world with the motivation and reason. Moreover, the rationale of the action is important to understanding which scientific concepts are embedded in their actions (Vesterinen, Tolppanen, & Aksela, 2016). Therefore, this study was designed to explore the types of actions and the scientific concepts used by a group of high school students that had taken a science-informed energy course three years earlier with the goal of rethinking the role of science education in developing students as future citizens.

CITIZENSHIP ACTION

Public education has long been designed to promote competencies in students that will better enable them to shape the future as public-minded citizens. However, the efficacy of school education in achieving this goal has fallen far short of policy goals and societal expectations (Reichert & Print, 2018). Scholars have proposed a number of different definitions of citizenship in the context of educating for citizenship. Castro (2013) interviewed pre-service teachers to investigate their views on "ideal citizens", with two views on citizenship emerging. One of these, conservative-value-based citizenship, emphasizes traditional and loyalty-centered citizenship, with citizens in this category equipped with good morals and contributing to the maintenance of their community. The other view, awareness-based citizenship, emphasizes being aware of issues important to the community, with aware and informed citizens participating in local affairs ultimately improving the community. The latter, using negotiation and bargaining, stands in the middle of critical and non-critical forms of citizenship and accepts the need for compromise and give-and-take. Knowles and Castro (2019) analyzed the survey responses of teachers and corresponding actions of students and identified three types of citizens (Westheimer & Kahne, 2004). The conservative perspective on civic education focuses on helping students take personally responsible actions such as obeying laws and recycling. From the liberal perspective, students take participatory action when they learn how the government works and concern themselves with political issues. When they protesting / challenging the status quo, students promote social change with critical perspective.

Citizenship actions have been proposed in the context of education, especially in environmental education, which aims to promote responsible citizenship (Hungerford & Volk, 1990). To minimize the influence of moralistic paradigms on behavior, educating for action should be prioritized in democratic societies to face the problems that are currently threatening our world. Stern (2000) was the first to define environmentally significant behaviors as incorporating both intent-oriented and impact-oriented facets. This category of behaviors reflects a desire to impact positively on the environment. Jensen and Schnack (2006) subsequently criticized the currently accepted definitions of behavior, arguing instead that action should be discerned from behavior, and focusing on decision-making and problem-solving in the real world as a way to redirect the target of EE to educating future citizens on both personal and societal levels. The collective nature of action for citizenship has been highlighted by scholars (Alisat & Riemer, 2015; Chawla & Cushing, 2007; Uzzell, 1999) with regard to solving problems that are embedded at the institutional and systemic levels. Therefore, students learn citizenship through the process of taking sociopolitical action by inspecting root causes and finding solutions. The category of collective action was derived within a democratic context.

Riemer, Lynes, and Hickman (2014) reported that differences exist in student action in terms of the degree and impact of participation. Alisat and Riemer (2015) stated that citizenship action may be categorized according to difficulty, involvement, political pressure, supportiveness, and action competence. In contrast to low-intensity and simple participatory action, leadership action is more committed, organized, and politically oriented. However, self-education for future involvement represents an entry-level participatory action only. Vesterinen et al. (2016) investigated the actions taken by gifted and highly motivated youth at a summer camp, finding that their actions could be divided into three categories. In addition to personal and participatory actions taken in the private and public spheres, actions related to preparing for the future have also been considered in the literature. In this latter category, individuals take actions that are intended to prepare them to act to achieve a better outcome in the future because they currently lack the capabilities necessary to take meaningful action in the present. Therefore, the objective of this study was to identify the types of citizenship action that students take to solve problems and to elucidate their reasons for taking these actions.

RESEARCH CONTEXTS

Participants were recruited from a group of students who had attended a course three years ago as part of their 9th grade chemistry-physics curriculum. This course extended the standard learning unit on batteries to include lessons on energy use and argumentation in the realm of solar energy and on strategies for reducing energy use and carbon emissions in daily life (Chen & Liu, 2018). One of the researchers involved in this study was the chemistry teacher for this group of students, which allowed him to contact this group via social network three years after the course had ended. Thirty students accepted the researchers' invitation to participate in this study. All of the participants were in their twelfth grade in both public and private education systems, with 11 enrolled in senior high school, 18 enrolled in vocational high school, and 1 enrolled in junior college.

DATA COLLECTION AND ANALYSIS

A semi-structured interview was used to collect the data. At the beginning of each interview, participants were asked to describe their impression of the course. The content of the interview focused on two questions: (a) What actions have you taken to improve the environment or society during the past three years and (b) what problems do you desire to solve. Interviews were tape-recorded and each interview session lasted 20-30 minutes. The questions were based on the related literature (Ernst, Blood, & Beery, 2017; Jensen & Schnack, 2006; Vesterinen et al., 2016) and validated by a science-education scholar. The data collected from the interviews were transcribed verbatim by the first author. The unit of analysis was each discrete action that the participants considered as contributing to a better environmental or societal future. After condensing and grouping the units, the data were distilled into several categories using inductive content analysis (Elo & Kyngas, 2008).

Table 1. The category, description, exemplar, and corresponding amount of student actions.

Category	Personal actions	Participatory actions	Transformative actions	Preparing for actions
Description	Acting toward the environment or personally helping people	Participating in school and community projects or sharing issues with others	Organizing actions or influencing government policies	Cultivating oneself for an alternative future
Sample actions	1. Using eco-friendly bags for purchases 2. Reducing the use of air conditioner 3. Helping older adults in need	1. Participating in community cleaning activity 2. Discussing issues on social media 3. Co-tutoring students with learning difficulties	1. Organizing student groups to clean up the community 2. Launching a petition to influence government policy related to the petrochemical industry	1. Learning the technology of brain-computer interface to help people in need. 2. Gaining knowledge on natural resources and ecology to influence people’s actions.
No. of instances	14	10	3	3
References	Jensen (2002)、Kollmuss & Agyeman (2002)、Stern (2000)、Vesterinen et al. (2016)、Westheimer & Kahne (2004)	Alisat & Riemer (2015)、Westheimer & Kahne (2004)、Uzzell (1999)	Alisat & Riemer (2015)、Westheimer & Kahne (2004)、Chawla & Cushing (2007)	Alisat & Riemer (2015)、Reichert & Print (2018)、Vesterinen et al. (2016)

Inductive and deductive analysis of the participants’ responses and the relevant literature (Alisat & Riemer, 2015; Vesterinen et al., 2016; Westheimer & Kahne, 2004) led to the emergence of four categories that, together, described the many actions of the participants and the scientific concepts behind their rationales. The categories, descriptions, sample actions, number of instances, and references for the actions of the participants are listed in Table 1. The inter-rater reliability of data analyses was confirmed after two authors analyzed the data independently. The percentage of agreement was above 85%, and all discrepancies were solved by discussion.

RESULTS AND DISCUSSION

Most of the actions of the participants focused either on environmental problems or on helping others in need. In the following, each subsection demonstrates one kind of action category with two examples providing additional details (S: student; M: Male; F: Female; e.g., SF27: Female student, no. 27).

Personal actions

One-third (33.3%) of the participants remarked during the interview that they had personally taken action to make the world better. Most of these actions were related either to preserving the environment or to helping others in need. In several cases, the participants expressed an intention to save the earth through personal actions. Student SM19 stated that he reduced his use of air conditioning to reduce his contribution to global warming. Student SF13 stated that she took the bus instead of a car whenever possible, noting that emissions from vehicles are a major source of greenhouse gasses.

SM19: *Some time ago, because of energy saving and carbon reduction, that is, the problem that the earth is warming, it was quite a major story at that time. ... Even when the weather was really hot, I just used it for one or two days out of every ten. I mean to say that I reduced using air conditioning. I did it to reduce ... to stop global warming. I wanted to prevent global warming.*
SF13: *The king crab has migrated into the Antarctic due to global warming, and then ... caused an environmental catastrophe. This migration is endangering those creatures in Antarctica because there are too many crabs. It's a disaster for the environment, so it needs to be reduced ... Carbon dioxide causes the greenhouse effect, which makes the earth hotter and hotter, and then the ice will melt.*

Student SM19 was not only aware of the effect of global warming but also had a strategy for alleviating the situation. Student SF13 was aware of the effect as well and described the science behind the effect. This category describes direct action taken within the private sphere, with character and personal responsibility (Kollmuss & Agyeman, 2002), the possible factors affecting these actions. Although the participants have expressed specific reasons for their actions, these reasons reflected aspects of loyalty and duty and were not affected by organizational or policy considerations (Westheimer, 2015). Nonetheless, this category of action actually benefits the world through personal effort.

Participatory actions

One-third (33.3%) of the respondents described having participated in school or community projects such as cleaning up a street or beach or visiting senior citizens in the community. While some students engaged in direct environmental action (see SM11), others promoted greater awareness of issues through indirect action via social networks (see SM01).

SM01: *There is serious air pollution in Taichung because of the thermal power plant. I have tracked the articles posted by Chia-Lung Lin, the mayor of Taichung City. He has been doing some things to improve air pollution ... Yeah, Facebook. I clicked the "like" button and learned more about the types of pollution he is reducing ... Sometimes I would share information (through Facebook and discussions) with my family. It is about the quality of our air in Taichung. Because we were all born in Taichung and are responsible for the health of each other, we must take care of it ... (My classmates) also read these articles and discussed the issue more frequently.*
SM11: *Our fishing club held some coastal cleanup activities near the Zhangbin Industrial Zone ... The garbage is mainly PET bottles and Styrofoam ... mainly Styrofoam. Because these things are lighter and are easier to fall. In fact, they endanger the survival of fish. The crumbs that fish eat include plastic. Fishermen catch fish and sell it to people. This is a vicious cycle.*

Student SM01 was aware of the severity of the air pollution and environmental impacts caused by Taiwan's power-generation plants in the Taichung area, including the photovoltaic haze over the region and a myriad of public health problems. The student wanted others to be conscious of this problem in a way that motivated them to contribute to resolving these problems. Student SM11 engaged in direct action, monitoring the sources of pollution and studying the damage of this pollution to humans. Action is a complex process (Alisat & Riemer, 2015; Birdsall, 2010). Personal action is relatively easy to initiate because of the few social and normative limitations / barriers to this type of action, while participatory action involves a collective decision-making process that allows students to reflect concern on issues that are relatively complicated (Knowles & Castro, 2019). Thus, participatory action enhances not only students' social skills and commitment but also their understanding of environmental science (Birmingham & Calabrese Barton, 2014).

Transformative actions

Ten percent of the participants reported having organized actions or having tried to influence government policies. They had attempted to influence the actions of others through the power of organizations (SF29) or policymakers (SF04).

SF29: *We (the student council) united with other schools into a league. We held a garbage clean-up campaign in Taichung Metropolitan Park ... We initiated a (environmentally) meaningful activity using emotional communication ... Almost 10 schools (joined in this activity). I was vice president of the student council ... I was responsible for counting the number of participants, planning the sites ... and negotiating with park staff.*
SF04: *Once online petitions reach a certain threshold of signatures, it will be proposed and discussed in the Legislature. No one should feel that their power is insignificant, because society can be changed through collective strength ... Everyone just ignores the problem of ecological damage. I don't think we can do so anymore because it will cause more and more serious problems. Therefore, I take the initiative and call on others to work together to change the current situation.*

In taking transformative action, student SF29 learned how to coordinate actions with other student councils and to negotiate with government staff. Student SF04 signed a petition related to industry pollution and encouraged others to follow her example. Unlike participatory action, transformative action has the potential to organize a group to influence a social institution or policy, which has the potential to change the structure of economic, social, and political systems (Birdsall, 2010; Chawla & Cushing, 2007). In taking action, the participants were both conscious of the problem and motivated to assess its root causes in order to engage in problem solving. Thus, social justice is a potential result of this action (Hodson, 2010). Furthermore, students who more frequently engage in indirect actions gain a better familiarity with the different dimensions of action competences (Birdsall, 2010).

Preparing for actions

Ten percent of the participants engaged in actions related to the goal of improving the environment and quality of life. For example, these participants studied innovative technologies (SM24) and worked to improve their communication abilities (SM21) as strategies to achieve their goals.

SM24: *Well, it can solve a lot of problems. For example, if he is in a car accident today, he may break his foot. He may want to install a prosthetic in a few days. But controlling prosthetic limbs is difficult! He may need a brain-computer interface to control his prosthetic limb ... It can help underprivileged groups ... The main thing is to enrich myself and study in this field. By researching this issue more, I can apply my findings in real life, and then I hope to promote it to ... help those who are physically handicapped ... and change the society in the long run*.
SM21: *I will tell them the importance of environmental conservation in terms of the long-term effects of environmental degradation. Therefore, I want to improve my understanding of the natural ecosystem in aspects such as the conservation of marine ecologies and the depletion of natural resources as well as to enrich the content of my dialogue with others. Through communication, some people who may not be aware of the ecological environment and natural resources may become more aware of these damaged environments. Let them understand how we can help the environment, stop environmental degradation, and change those behaviors that may damage the environment in order to protect our environment*.

Scientific and technological innovation has the potential to improve the quality of life of people by applying scientific knowledge to create environmentally beneficial applications. In addition, scientific knowledge may be used as a medium to communicate and convince others of the importance of our shared natural resources, environment, and ecosystem. The participants stated a belief that scientific knowledge has the potential to change the future. Although the participants in this category delayed the timing of their action, they still believed that science could promote change, which echoes the perspective on the role of science taken up in the Stockholm Declaration (UN, 1972). This vision stimulated the participants to prepare to take appropriate actions later in life. Teachers should be facilitators that guide students to deal with problems in order to prevent action paralysis (Jensen, 2004). Gaining relevant knowledge and experience in a critical area of expertise enables individuals to create a better environment and accomplish desired social changes.

CONCLUSION AND IMPLICATIONS

In our analysis, four categories emerged from the responses of the participants. Although they all engaged actively in personal and participatory actions during their three years of high school, only a small number engaged actively in political activism (Alisat & Riemer, 2015). Activist action is considered the realization of democratic citizenship and fundamental to changing the world. As taking action is not a simple process (Birdsall, 2010), some students, especially those concentrating on science-based issues, require more time to prepare themselves for future roles as social influencers. On the other hand, teachers should not be hesitant regarding incorporating the concept of action competence into course material. Teachers should foster a learner-centered, action-oriented, and transformative approach that empowers students to take action in their local and daily lives to attain a sustainable future. In addition, the descriptions of the actions of some scientific concepts provide the reasons or motivations to act. Therefore, science may be an important element and may contribute to actions, as science is the result of human endeavors. Nevertheless, 33.3% of the participants in this study, half of who performed well in their science courses, had not taken any type of action. As action is the ultimate goal of education, further study into how best to motivate students to improve the world is recommended.

REFERENCES

Alisat, S., & Riemer, M. (2015). The environmental action scale: Development and psychometric evaluation. *Journal of Environmental Psychology*, *43*, 13-23. doi: 10.1016/j.jenvp.2015.05.006

Barrett, M. J., & Sutter, G. C. (2006). A youth forum on sustainability meets the human factor: Challenging cultural narratives in schools and museums. *Canadian Journal of Science, Mathematics and Technology Education*, *6*(1), 9-23. doi: 10.1080/14926150609556685

Birdsall, S. (2010). Empowering students to act: Learning about, through and from the nature of action. *Australian Journal of Environmental Education*, *26*, 65-84. doi: 10.1017/S0814062600000835

Birmingham, D., & Calabrese Barton, A. (2014). Putting on a green carnival: Youth taking educated action on socioscientific issues. *Journal of Research in Science Teaching*, *51*(3), 286-314. doi: 10.1002/tea.21127

Birmingham, D., Calabrese Barton, A., McDaniel, A., Jones, J., Turner, C., & Rogers, A. (2017). "But the science we do here matters": Youth-authored cases of consequential learning. *Science Education*, *101*(5), 818-844. doi: 10.1002/sce.21293

Castro, A. J. (2013). What makes a citizen? Critical and multicultural citizenship and preservice teachers' understanding of citizenship skills. *Theory & Research in Social Education*, *41*(2), 219-246. doi: 10.1080/00933104.2013.783522

Chawla, L., & Cushing, D. F. (2007). Education for strategic environmental behavior. *Environmental Education Research, 13*(4), 437-452. doi:10.1080/13504620701581539

Chen, S. Y., & Liu, S. Y. (2018). Reinforcement of scientific literacy through effective argumentation on an energy-related environmental issue. *EURASIA Journal of Mathematics, Science and Technology Education*, *14*(12), em1625. doi: 10.29333/ejmste/95171

Choi, K., Lee, H., Shin, N., Kim, S.-W., & Krajcik, J. (2011). Re-conceptualization of scientific literacy in South Korea for the 21st century. *Journal of Research in Science Teaching, 48*(6), 670-697. doi:10.1002/tea.20424

Dawson, V., & Carson, K. (2016). Using climate change scenarios to assess high school students' argumentation skills. *Research in Science & Technological Education, 35*(1), 1-16. doi:10.1080/02635143.2016.1174932

DeBoer, G. E. (2000). Scientific literacy: Another look at its historical and contemporary meanings and its relationship to science education reform. *Journal of Research in Science Teaching*, *37*(6), 582-601. doi:10.1002/1098-2736(200008)37:6<582::AID-TEA5>3.0.CO;2-L

Dittmer, L., Mugagga, F., Metternich, A., Schweizer-Ries, P., Asiimwe, G., & Riemer, M. (2018). "We can keep the fire burning": Building action competence through environmental justice education in Uganda and Germany. *Local Environment, 23*(2), 144-157. doi:10.1080/13549839.2017.1391188

Elo, S., & Kyngas, H. (2008). The qualitative content analysis process. *Journal of Advanced Nursing, 62*(1), 107-115. doi:10.1111/j.1365-2648.2007.04569.x

Ernst, J., Blood, N., & Beery, T. (2017). Environmental action and student environmental leaders: Exploring the influence of environmental attitudes, locus of control, and sense of personal responsibility. *Environmental Education Research, 23*(2), 149-175. doi:10.1080/13504622.2015.1068278

Hodson, D. (2003). Time for action: Science education for an alternative future. *International Journal of Science Education, 25*(6), 645-670. doi:10.1080/09500690305021

Hodson, D. (2010). Science education as a call to action. *Canadian Journal of Science, Mathematics and Technology Education, 10*(3), 197-206. doi:10.1080/14926156.2010.504478

Hodson, D. (2017). Foreword: The significance of STEPWISE for fostering life-long sociopolitical activism. In L. Bencze (Ed.), *Science and technology education promoting wellbeing for individuals, societies and environments* (pp. 3-18).

Hungerford, H. R., & Volk, T. L. (1990). Changing learner behavior through environmental education. *The Journal of Environmental Education, 21*(3), 8-21. doi:10.1080/00958964.1990.10753743

Jensen, B. B. (2004). Environmental and health education viewed from an action-oriented perspective: A case from Denmark. *Journal of Curriculum Studies, 36*(4), 405-425. doi:10.1080/0022027032000167235

Jensen, B. B., & Schnack, K. (2006). The action competence approach in environmental education. *Environmental Education Research, 12*(3-4), 471-486. doi:10.1080/13504620600943053

Knowles, R. T., & Castro, A. J. (2019). The implications of ideology on teachers' beliefs regarding civic education. *Teaching and Teacher Education*, *77*, 226-239. doi: 10.1016/j.tate.2018.10.009

National Resource Council. (2012). *A framework for K-12 science education practices, crosscutting concepts, and core ideas*. Committee on a conceptual framework for new K-12 science education standards. Board on science education, division of behavioral and social sciences and education. Washington, DC: The National Academies Press.

Next Generation Science Standards Lead States. (2013). *Next Generation Science Standards: For states, by states*. Washington, DC: The National Academies Press.

Osborne, J., Donovan, B. M., Henderson, J. B., MacPherson, A. C., & Wild, A. (2016). *Arguing from evidence in middle school science: 24 activities for productive talk and deeper learning*. CA: Corwin Press.

Reichert, F., & Print, M. (2018). Civic participation of high school students: The effect of civic learning in school. *Educational Review*, *70*(3), 318-341. doi: 10.1080/00131911.2017.1316239

Riemer, M., Lynes, J., & Hickman, G. (2014). A model for developing and assessing youth-based environmental engagement programmes. *Environmental Education Research*, *20*(4), 552-574. doi: 10.1080/13504622.2013.812721

Riemer, M., Voorhees, C., Dittmer, L., Alisat, S., Alam, N., Sayal, R., Bidisha, S. H., De Souza, A., Lynes, J., Metternich, A., Mugagga, F., Schweizer-Ries, P. (2016). The youth leading environmental change project: A mixed-method longitudinal study across six countries. *Ecopsychology, 8*(3), 174-187. doi:10.1089/eco.2016.0025

Roth, W. M., & Lee, S. (2004). Science education as/for participation in the community. *Science Education, 88*(2), 263-291. doi:10.1002/sce.10113

Sinakou, E., Donche, V., Boeve-de Pauw, J., & Van Petegem, P. (2019). Designing powerful learning environments in education for sustainable development: A conceptual framework. *Sustainability*, *11*(21), 5994. doi: 10.3390/su11215994

Stern, P. C. (2000). New environmental theories: Toward a coherent theory of environmentally significant behavior. *Journal of social issues*, *56*(3), 407-424. doi: 10.1111/0022-4537.00175

Vesterinen, V.-M., Tolppanen, S., & Aksela, M. (2016). Toward citizenship science education: What students do to make the world a better place? *International Journal of Science Education, 38*(1), 30-50. doi:10.1080/09500693.2015.1125035

UN. (1972). Report of the United Nations conference on the human environment. Retrieved from http://www.un-documents.net/aconf48-14r1.pdf

Uzzell, D. (1999). Education for environmental action in the community: New roles and relationships. *Cambridge Journal of Education, 29*(3), 397-413. doi:10.1080/0305764990290309

Westheimer, J. (2015). *What kind of citizen?: Educating our children for the common good*. NY: Teachers College Press.

Westheimer, J., & Kahne, J. (2004). What kind of citizen? The politics of educating for democracy. *American Educational Research Journal*, *41*(2), 237-269. doi: 10.3102/00028312041002237

FAMILIARIZING YOUNG CHILDREN WITH THE IDEA OF SUSTAINABILITY

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Humanity's sustainable future is undermined by serious environmental and socio-economic problems all over the world. However, 'Early Childhood Education for Sustainability' (ECEfS) is not yet a high priority and research about it remains rather limited. Our study addresses the question of whether it is feasible to design a learning environment that could effectively combine biology education and EfS to help preschoolers enhance their conceptual understanding about nature along with their socio-environmental awareness. Our focus here is set on identifying whether and how preschoolers' understanding about the idea of 'sustainability' in particular, has changed within the 3rd version of our learning environment (LE3). LE3 was designed in the 3rd research cycle of a design research considering the 'possible futures'-approach, and was tested in a case study with thirty, conveniently selected preschoolers (age 4.5-5.5). Children were divided in six small groups which separately attended fifteen, 20-30-minute sessions, organized in three parts and implemented in an eight-week period. The idea of 'sustainability' was first explored with 'decision-making scenarios' in a 'guided dialogue'-session of the 'Intro- part', but it was actually present in almost every session throughout LE3. Children gave pre/post, individual, semi-structured interviews, which were tape-recorded, transcribed and analyzed in 'NVivo'. The question probing their pre-/post-understanding about 'sustainability' was based on a 'decision-making scenario', similarly structured with those of LE3. According to the results, LE3 worked quite well in familiarizing young children with the idea of 'sustainability', since almost all of them were able to apply it in the post-test scenario.

Keywords: Early childhood education, society and environment education, conceptual understanding

INTRODUCTION

Humanity's sustainable future is undermined by environmental and socio-economic problems all over the world. Therefore, it seems absolutely necessary to systematically provide children with educational experiences that will get them familiar with acute socio-environmental issues and help them develop the strong socio-environmental awareness they need to become action-takers for the well-being of the environment and fellow humans (David, 2007; Davis, 2009; Iliopoulou, 2016; Mackey, 2012; Samuelsson & Kaga, 2008). In other words, it seems that, for everyone's sake, nowadays more than ever, the so-called 'Education for Sustainability' (EfS) should be prioritized and also start as early as preschool (Kahriman-Ozturk et al., 2012; Samuelsson, 2011; Samuelsson & Kaga, 2008; Spiteri, 2018).

Despite the progress that has been made with investigating EfS at higher educational levels, research about 'Early Childhood Education for Sustainability' (ECEfS) is not still as rich as it should be (Ärlemalm-Hagsér, 2013; Cutter-Mackenzie & Edwards, 2013; Duhn, 2012; Elliott & Davis, 2018; Reid & Scott, 2006; Smidt, 2018; Spiteri, 2018). The literature on ECEfS is rather limited and, moreover, mostly theoretical; it does make suggestions about how young children might enhance their socio-environmental awareness and develop responsible attitudes and behaviours towards environment and society, but it does not back them up with rich enough empirical data.

One of the most interesting suggestions found in the ECEfS-literature is to create learning environments in which young children could experience the roles of 'problem seekers', 'problem solvers' and 'action takers' (Davis, 2009; Arlemalm-Hagser, 2013); i.e. learning environments in which they would have the opportunity to (a) get more familiar with socio-environmental problems that may have meaning for them, their families or the place they live, (b) look for possible solutions to these problems, and finally (c) plan the implementation of them or even try perform it. Another interesting suggestion concerning ECEfS is the 'possible futures'-approach (Hicks & Holden, 2007, Rogers & Tough, 1996). The idea is to help young children understand the 'present-future' relationship and their own role in it. More specifically, it is suggested that children should be given the opportunity to (a) examine how their present actions may affect the future of environment and humans, (b) decide if they like the future they are heading for, and, in case that they don't really like it, (c) examine what they should change in their current actions in order to be able to head to a more desirable future instead (Hicks & Holden, 2007).

So, it is clear that although not very rich, previous research on ECEfS could be quite useful. Suggestions like the above could possibly serve as 'design principles' for the development of learning environments that aim to provide young children with the socio-environmental awareness they will need as modern adults. On the other hand, another domain of educational research, Biology Didactics, can actually make suggestions of another kind. It can suggest biological concepts that are important for children's understanding about ecosystems whereas they might fit well in a context where 'nature-humans-economy' inter-connectedness needs to be highlighted for young children (Ergazaki & Andriotou, 2010; Palmer & Suggate, 1996). This actually means that combining biology education and ECEfS seems possible in theory. However, more research is needed in order to ascertain whether and how this combination can really work.

Thus, our study addresses the question of whether it is feasible to design a learning environment that could effectively help preschoolers enhance their conceptual understanding about nature, along with their socio-environmental awareness. Such awareness may actually be facilitated by an essential understanding of ecological ideas (e.g. 'habitat', 'food chain'), but it also requires an essential understanding of key socio-environmental ideas (e.g. the relationships of 'present-future', 'local-global' or 'individual-collective') that contribute in shaping the overarching idea of 'sustainability' which is our focus in this paper. Sustainable development is based on three integrated pillars -environmental, socio-cultural, and economic-, that strongly interact with each other (Kahriman-Ozturk et al. 2012). So, 'sustainability' can be conceptualized as the idea that our present actions should consider the future well-being of the environment, fellow humans and economy at the same time. In this paper we are particularly concerned with identifying whether and how preschoolers' understanding about this idea has changed within the 3rd version of our learning environment that was designed and tested in the 3rd research cycle of our design research.

METHODS

The overview of the study

Our study is concerned with the design of a learning environment for young children, which attempts to combine biology education with education for sustainability. Applying the method of design research (McKenney & Reeves, 2018), we performed three research cycles with one or two case studies each. In the case study of the 1st research cycle, we tested the 1st version of the learning environment (LE1) and we used the findings for coming up with an elaborated, new version of the learning environment (LE2). This had two parts: the 'Forest-part', which was tested in a case study of the 2nd research cycle, and the 'Decomposition/Recycling-part' which was tested in another one. The findings of these case studies were used for coming up with a further elaborated, new version of the learning environment (LE3), which included one more part with some first explorations of the target socio-environmental ideas ('Intro-part'). LE3 was tested in two case studies performed within the 3rd research cycle. Here we are concerned with the second case study, since children's understanding about the idea of 'sustainability' which underlies all three parts of LE3, was tested in its context.

The participants

The participants of the case study we present here were pupils of a public kindergarten, situated in a semi-urban area of Patras with medium/high socio-economic status. Children (N=30, 16 girls/14 boys, age 4.5-5.5) were selected conveniently, due to their teacher's wish to facilitate our study. Their parents were thoroughly informed about the study and didn't raise any objections. Children had the opportunity to meet the interviewer before the starting point of the study, get familiar with her and give their own assent for participating. According to their teacher, children were quite familiar with educational interactions and they had not been engaged in formal activities about our target ideas up to that point. For the implementation of LE3, children were divided in six groups of five. Each group (a) included members of mixed age and mixed level, and (b) took separately part in fifteen, 20-30-minute sessions, led by the 1st author in an eight-week period.

The learning environment

The design of LE3 (as well as the design of the two previous versions) was informed by the 'possible futures'-approach (Hicks & Holden, 2007). The learning objectives concern two types of ideas: (a) ecological ideas ('forest impact on abiotic environment and human life', 'habitat', 'food chain', 'decomposition'), and (b) socio-environmental ideas ('present-future', 'humans-nature equality', 'humans-humans equality', 'local-global', 'individual-collective', 'everyday practices *for* the environment and fellow humans') that all contribute to the construction of the overarching idea of 'sustainability' which concerns us in this paper.

The idea of 'sustainability' was first explored in a 'guided dialogue'-session of the 'Intro-part'. Its exploration was carried out with two 'decision-making scenarios'. Both of them had to do with deciding for or against a business idea ('launching ecotourism in a poor African village' and 'opening a new factory next to a poor city), by equally taking into account the pros and cons for the environment, humans and economy at the same time. This requirement was supposed to encourage children to look for ways to reconcile any conflict of interests and thus practice the idea of 'sustainability' in decision-making. For instance, in the second scenario of the session, they needed to explore whether there could be a way to open the new factory and benefit from the pros for humans and economy, while at the same time avoid -or at least minimize- the cons for environment and humans.

Moreover, the idea of 'sustainability' was actually present in almost every session of LE3, in the sense that all the partial socio-environmental ideas explored throughout LE3 contribute to its construction. For instance, the 'Forest-part' of LE3 was guided by a scenario with a city that was facing a serious unemployment-problem and made the decision to cut its huge forest so that people without jobs could be employed as wood-cutters or wood-sellers (Hadzigeorgiou et al., 2011). This decision took into account only the short-term pros for humans and economy, whereas it left out the long-term cons for environment and humans. So, children had the opportunity to thoroughly explore a possible undesired future, as a consequence of a decision that is *not* guided by the idea of 'sustainability'. This was attempted through the different, preschoolers-friendly activities (e.g. storytelling, guided dialogue, brainstorming, puppet-show, role playing) that were integrated in the different parts of LE3. Similarly, the 'Decomposition/Recycling-part' was guided by a scenario with a city that was facing a waste-management problem and made the decision to continue using a landfill (which was a cheap solution) instead of building a recycling-factory (which was an expensive one). This decision took into account only the short-term pros for economy, whereas it left out the long-term cons for environment, humans and economy as well So, children had, once more, the opportunity to thoroughly explore (through hands-on and minds-on, 'young age'-friendly activities) a possible undesired future, as a consequence of a decision that is *not* guided by the idea of 'sustainability'.

The data collection

Children gave us pre/post, individual, semi-structured interviews, lasting approximately 20 minutes each, at a quiet place of their school. The question about 'sustainability' was based on a 'decision-making scenario' about creating a huge entertainment park in a forest with rare biodiversity, which was supposedly located next to a poor city. At the discussion of the city-council about this idea, there were people who agreed and others who disagreed. Those who were supposed to agree with the park-idea appealed to good things that could possibly derive from creating the park. For instance, they claimed that *'people would find jobs', 'more tourists would visit the city', 'there would be more money', 'people would live better lives'*. On the contrary, those who were supposed to disagree with the park-idea appealed to bad things that could possibly derive from creating the park. For instance, they claimed that *'noise, lights and polluted air would disturb the animals that live in the forest and make them migrate somewhere* *else', 'people would possibly leave garbage in the forest, which would ruin the beauty of the forest and possibly put in danger some of its animals that would try to eat these garbage', 'many people would arrive in big airplanes, buses and cars, all releasing bad gases in the air; so the environment would be polluted and people's health would be in danger'.* So, children were asked to decide for or against the park-idea, in the light of the pros and cons about environment, humans and economy, which supposedly emerged in the city-council. The question was addressed to children like this: *'So, what is your opinion about the park-idea? What do you think about it? Do you think they should create this park or not?'.* Children who supported the park-idea were reminded of the cons that emerged in the city-council; and vice versa: children who rejected the park-idea were reminded of the pros. If they remained consistent to their initial response, then they seemed unable to apply the idea of sustainability and we didn't insist further. On the other hand, if they appeared to abandon their initial 'for or against'-certainty and recognize that people should consider all these things at the same time, then they seemed *potentially* able to apply the idea of sustainability and so they were asked *'what exactly should be done'* according to their opinion and *'why'.*

The data analysis

The pre-/post-interviews were tape-recorded and then transcribed and coded in 'NVivo' (qualitative data analysis software). Children's responses to the 'sustainability'-question were coded as 'naïve', 'transitional' and 'informed', as follows:

- 'Naïve': children did *not* consider the pros and cons for the environment, people and economy at the same time, in order to make a decision. For instance, *'I think they should build the park there, because this way they will have a job and they won't be poor any more. They need the money to buy food, so they should build it.'* (pre-response).
- 'Transitional': children *did* consider all these at the same time, but they were *not* able to make a decision. For instance, *'They should think about the animals. But if they don't have money… I don't know… they should do something. Maybe they should build it after all. But animals and people's health are important too. I don't know. I'm confused.'* (post-response).
- 'Informed': children did consider all these at the same time, and they *were* able to make a decision by reconciling conflicts of interests. For instance, *'I think that in order to have a better future they have to think about the environment and the money and other people before they decide to build the park. I think that the best thing to do is to build the park, but further away, not near the forest. This way they can work and make money and also not ruin the environment. And if they also put in strict rules, people's health will not be damaged. That's how they can take into consideration all three: money and the environment and people.'* (post-response).

The coding was simultaneously performed by the authors and cases of disagreement were discussed until consensus was reached.

RESULTS

Although children did not seem to be aware of the idea of sustainability before taking part in LE3, they actually did quite well afterwards. In the pre-interviews, almost all children (28/30) gave 'naïve' responses, very few (2/30) gave 'transitional' and none (0/30) gave 'informed' ones (Figure 1). In children's own words: '*No. They shouldn't build this 'park' even if they will earn money from it. It doesn't matter if they won't have any money. It is not right for the forest's animals, so they shouldn't do it.'* ('naïve' pre-response); '*They should build the 'park' to make money, because they are poor. But they shouldn't harm the forest or people's health. They should find a way to do both. I don't know how.'* ('transitional' pre-response).
On the contrary, in the post-interviews almost all children (27/30) gave 'informed' responses, very few (3/30) gave 'transitional' and none (0/30) gave 'naive' ones (Figure 1). In children's own words: *'They should think about other people's health and also how to make money and also the forest's animals, before they decide to build the park. But what should they decide? I don't know, but I know they should think about all three of them'* ('transitional' post-response); '*They should build the 'park' elsewhere. Not near the forest. They should do it, because then they'll have money. But they must make strict rules so that the 'park' won't harm environment or people's health. Only if they make rules, they can build it. But not near the forest, elsewhere.*' ('informed' post-response).

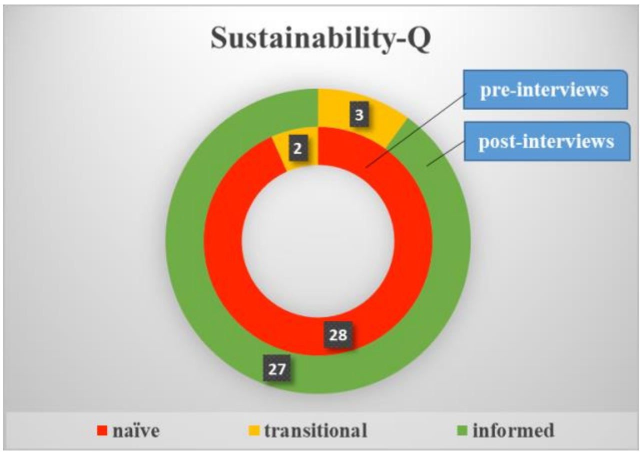

Figure 1. Students' pre/post-responses about the idea of sustainability.

In sum, 'naïve' responses, which were dominant in the pre-interviews (28/30), were absent in the post-interviews (0/30); and reversely, 'informed' responses, which were absent in the pre-interviews (0/30), became dominant in the post- ones (27/30). Finally, it is worth noticing that almost all children (29/30) shifted from lower-level to higher-level response categories (i.e. from 'naïve' to either 'transitional' or 'informed'; and from 'transitional' to 'informed'), whereas just one child (1/30) did not show any progress (both his pre- and post-responses were 'transitional').

DISCUSSION

LE3 seemed to work quite well concerning the idea of 'sustainability'. The shift of children's responses from lower- to higher-level categories indicates that their understanding was enhanced after taking part in LE3. This is further supported by considering that the shift was achieved by almost all children (29/30) *and* in the context of a 'decision-making scenario' that actually requires *applying* the idea of sustainability; i.e. considering all three factors (environment, humans, economy) at the same time and be able to reconcile conflicts of interest between them. Of course, it would be purposeful to carry out a delayed post-test as well, but we did not have such opportunity. However, our findings do show that even very young children can get familiar with demanding socio-environmental ideas such as the overarching idea of 'sustainability'. This is in line with Kahriman-Ozturk et al. (2012), who shed light on young children's potential to understand socio-environmental ideas (e.g. 'recycle', 'respect', 'reuse') that are integrated in the three pillars of sustainability (environmental, sociocultural and economic). These researchers have also stressed the significance of providing young children with educational experiences that promote active learning in ways suitable for their age. In fact, this is probably worth some further discussion, as shown below.

The idea of 'sustainability' or 'sustainable development', which of course is the reference point for EfS and Early Childhood EfS as well, is a complex theoretical construct and so it may very well be considered as developmentally inappropriate for young children, no matter how age-friendly are the types of educational activities through which young children are prompted to explore it. Similarly, this may be claimed (a) for many of the socio-environmental ideas (e.g. 'local-global' or 'individual-collective') that are linked to 'sustainability' and thus are important in the context of ECEfS, as well as (b) for many biological ideas that may have an important place in this context (e.g. decomposition) or not (e.g. genetic inheritance). Fortunately, this is where key-concepts like 'didactic transposition' (Chevallard, 1985) or 'educational reconstruction' (Kattmann et al., 1998; Duit et al., 2012) come into play. Both have to do with simplifying scientific ideas so that they become adapted to children's potential. In other words, they practically have to do with transforming scientific ideas to 'science class ideas' suitable for exploration by young children. And probably more interestingly for our case here, these fundamental concepts that are used to facilitate the early introduction of science can also be used to facilitate the early introduction of 'sustainability' and those socio-environmental ideas that may contribute to shaping it.

So, 'sustainability' can be introduced quite early as the idea that our present actions should consider the future thrives not just of us or other humans, but also of the environment. And since humans' thrive includes money as well, 'sustainability' can be conceptualized as the simultaneous thrive of environment, fellow humans and economy. Helping children get familiar with the idea that all three factors need to be taken into account for 'decision-making' is considered by us as a very significant first step, which will possibly facilitate higher-level explorations of 'sustainability' in the school years to come (Elliott & Davis, 2009).

To sum up, we note the following. Modern adults are expected to have a very strong socio-environmental awareness that will be translated to responsible attitudes towards environment and fellow humans as well as to responsible actions *for* them. Developing such awareness is a life-long process that really calls for an early start. Our study provides evidence that this start is possible and thus contributes to the argument for the feasibility of the highly needed 'Early Childhood Education for Sustainability'.

REFERENCES

Arlemalm-Hagser, E. (2013). Respect-for-nature – A prescription for developing environmental awareness in preschool. *CEPS-Journal*, 3(1), 25.

Chevallard, Y. (1985). *La transposition didactique*. La Pensee Sauvage, Grenoble.

Cutter-Mackenzie, A., & Edwards, S. (2013). Toward a model for early childhood environmental education: Foregrounding, developing, and connecting knowledge through play-based learning. *The Journal of Environmental Education, 44*(3), 195-213

David, M. E. (2007). Changing the educational climate: children, citizenship and learning contexts? *Environmental Education Research*, *13*(4), 425-436.

Davis, J. (2009). Revealing the research- 'hole' of early-childhood-education for sustainability: A preliminary-survey of the literature. *Environmental Education Research, 15*(2), 227-241.

Duhn, I. (2012). Making 'place' for ecological sustainability in early childhood education. *Environmental Education Research, 18*(1), 19-29.

Duit, R., Gropengießer, H., Kattmann, U., Komorek, M., & Parchmann, I. (2012). The model of educational reconstruction – A framework for improving teaching and learning science. In J. Dillon & D. Jorde (Eds.), *The world handbook of science education – Handbook of research in Europe* (pp. 13–37). Taipei: Sense Publishers.

Elliott, S., & Davis, J. (2009). Exploring the resistance: An Australian perspective on educating for sustainability in early childhood. *International Journal of Early Childhood*, *41*(2), 65.

Elliott, S., & Davis, J. (2018). Moving Forward from the Margins: Education for Sustainability in Australian Early Childhood Contexts. In G. Reis & J. Scott (Eds.), International Perspectives on the Theory and Practice of Environmental Education: A Reader (pp. 163-178). Cham: Springer.

Ergazaki, M., & Andriotou, E. (2010). From "forest fires" and "hunting" to disturbing "habitats" and "food chains": Do young children come up with any ecological interpretations of human interventions within a forest?. Research in Science Education, 40(2), 187-201.

Hicks, D., & Holden, C. (2007). Remembering the future: what do children think?. *Environmental Education Research, 13*(4), 501-512.

Hadzigeorgiou et al. (2011). Teaching about the importance of trees: A study with young children. *Environmental Education Research, 17*(4), 519-536.

Kahriman-Ozturk, D., Olgan, R., & Guler, T. (2012). Preschool Children's Ideas on Sustainable Development: How Preschool Children Perceive Three Pillars of Sustainability with Regard to 7R. *Educational Sciences: Theory and Practice*, *12*(4), 2987-2995.

Kattmann, U., Duit, R. and Gropengießer, H. (1998). Educational reconstruction – bringing together issues of scientific clarification and students' conceptions. In H. Bayrhuber and F. Brinkman (Eds.), What – why – how? (Kiel: IPN), 253–262.

Mackey, G. (2012). To know, to decide, to act: the young child's right to participate in action for the environment. *Environmental Education Research*, *18*(4), 473-484.

McKenney, S., & Reeves, T. C. (2018). Conducting educational design research. Routledge.

Palmer, J., Suggate, J., & Matthews, J. (1996). Environmental cognition: early ideas and misconceptions at the ages of four and six. *Environmental Education Research*, *2*(3), 301-329.

Reid, A., & Scott, W. (2006). Researching education and the environment: Retrospect and prospect. Environmental Education Research, 12(3-4), 571-587.

Rogers, M., & Tough, A. (1996). Facing the future is not for wimps. Futures-the Journal of Forecasting Planning and Policy, 28(5), 491-496.

Samuelsson, I. P. (2011). Why we should begin early with ESD: The role of early childhood education. *International Journal of Early Childhood, 43*(2), 103.

Samuelsson, I. P., & Kaga, Y. (Eds.). (2008). *The contribution of early childhood education to a sustainable society* (pp. 1-136). Paris: Unesco.

Smidt, S. (2018). *Early Childhood Education and Care for a Shared Sustainable World: People, Planet and Profits*. NY: Routledge.

Spiteri, J. (2018). Why We Should Start Early with ESD for Lifelong Learning. In W. Filho, M. Mifsud & P. Pace (Eds.), Handbook of Lifelong Learning for Sustainable Development (pp. 109-128). Cham:Springer.

EXPLORING HOW A CARD-TYPE GAME FOR TERMINAL CARE CAN PROMOTE THE HEALTH AND WELL-BEING AWARENESS OF NON-SCIENCE STUDENTS

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In Japan, scientific academic communities are seeking to the reform of the science education curriculum in higher education. They believe that a new curriculum will provide all students, including non-science majors, the opportunity to consider the ethical perspectives of science in their future decision-making. This study aimed to discover what teaching materials would be useful for promoting serious and authentic discussions on ethical perspectives relating to science. The focus was on 'Moshibana', a card game that explores the theme of terminal care, and it was used to investigate how first-year university students reacted to the ethical science issues found in Moshibana. The participants were 47 first-year students (18 years old) in Japan. The students participated in a Moshibana game for 90 minutes at the author's instruction. Out of the 35 Moshibana cards, 27 were chosen by at least one student. This result found that the Japanese first-year university students prioritised the following activities: spending time with their family at home, making independent decisions for medical treatment, and painless treatment for terminal care. The results also revealed that the students tended to find accepting death difficult, and they also lacked religious beliefs. Subsequently, Moshibana can be utilised as an effective teaching material in an ethically focused science education. This game can help students visualise individual ideas and beliefs regarding the ethical aspects of human health and well-being.

Keywords: Higher education, ethics in science, values in science education

INTRODUCTION

Hodoson (2003) argued that in the era of continuous science and technological innovation, the contents and teaching methods of science education needed continuous reform. Specifically, the issues of human health and environment are important in promoting decision-making and discussing moral-dilemmas among people. Hodson advocated for four levels of sophistication in science education (p. 655):

Level 1: Appreciating the societal impact of scientific and technological change, and recognising that science and technology are, to some extent, culturally determined.

Level 2: Recognising that decisions about scientific and technological development are taken in pursuit of particular interests, and that benefits accruing to some may be at the expense of others. Recognising that scientific and technological development are inextricably linked with the distribution of wealth and power.

Level 3: Developing one's own views and establishing one's own underlying value positions.

Level 4: Preparing for and taking action.

The Science Council of Japan (2003) introduced reforms for higher education in science that required all students, regardless of whether they were science majors, to have the opportunity to consider different science-related ethical perspectives. This prepares the students for future decision-making, and to achieve this goal, it was necessary to revise the curriculum of science education in higher education.

Ethical issues in human health and science evolution have been of great concern in medical philosophy (Wear, Bono, Loghe, and McEvoy, 2000). Several academic reports in science education have focused on human health in terms of improving cognition and decision-making for children and young people (e.g., Roth, 2014; Zeyer and Dillon, 2018). The WWF (2018) also noted that education on health and well-being offers significant value for individuals and helps them to live meaningful lives. With this view in mind, promoting youth education is imperative as it helps guide young people into making thoughtful decisions so that they can live more meaningful lives. In particular, it is crucial to identify what kind of materials can spark the interests of young people, as well as their ideas on health and well-being, as this can contribute to the formulation of a contemporary curriculum that incorporates progressive science into meaningful everyday lives.

PURPOSE OF RESEARCH

There are several methods to formulate a concrete educational curriculum. When considering the most appropriate method, understanding how Japanese students participate in complex learning activities that involve ethical issues is essential.

What kinds of teaching materials are useful for non-science students regarding ethical science issues, such as human health and well-being? This research sought to uncover concrete measures that could be used to develop a life-science ethics education tools for non-science students. The study focused on the 'Moshibana' (Institute of Advance Care Planning [iACP], n.d.1), a card game that explores the theme of terminal care, and how first-year university students react when faced with terminal care.

METHOD

Usage of the 'Moshibana (Go Wish)' game

This study used the Moshibana game to examine students' thoughts on the relevance of human health and science, and explore whether this tool encourages the students' discussion abilities and decision-making. The 'Moshibana', originally named 'GoWish' in the United States (Coda Alliance, 2016), consists of 36 cards which are designed to promote discussion on what is important if people were living a shortened life due to serious illness. Moshibana is the Japanese version of GoWish, and was translated, produced, and published by the Institute of Advance Care Planning (iACP) and with permission from the Coda Alliance.

The iACP (n.d.2) reported that Moshibana was effective in encouraging the sharing of ideas about life ethics and the value of life among medical professionals, patients, and their families. However, there have been only a few reports on its educational applicability.

Procedure

The participants were 47 first-year students (18 years old) at Kobe College in Japan. They were taking liberal arts majors in humanities, music, or literature. As part of the author's lecture on human science and environmental life settings, the students participated in a Moshibana game for 90 minutes. The research procedure is llustrated in the Figure 1. Groups of three to four individuals were assigned, and the group members read and talked about the topics founded in Moshibana cards, which contained 35 wishes cards and one free decision card. Then the students discussed their thoughts on each card and why they thought it was important. Next, each student selected the three most important cards and wrote why they chose them. This helped researchers to identify the reasons, as this may reflect their individual values regarding health and well-being.

The students consented to have the results of this study published in an academic form that does not specify their personal information. The use of cards for the research-based purposes and the description for this study were permitted by the iACP.

Quantitative and qualitative assessments were conducted for the commonly selected cards. The qualitative assessment was conducted through a questionnaire that asked why the students chose the particular cards.

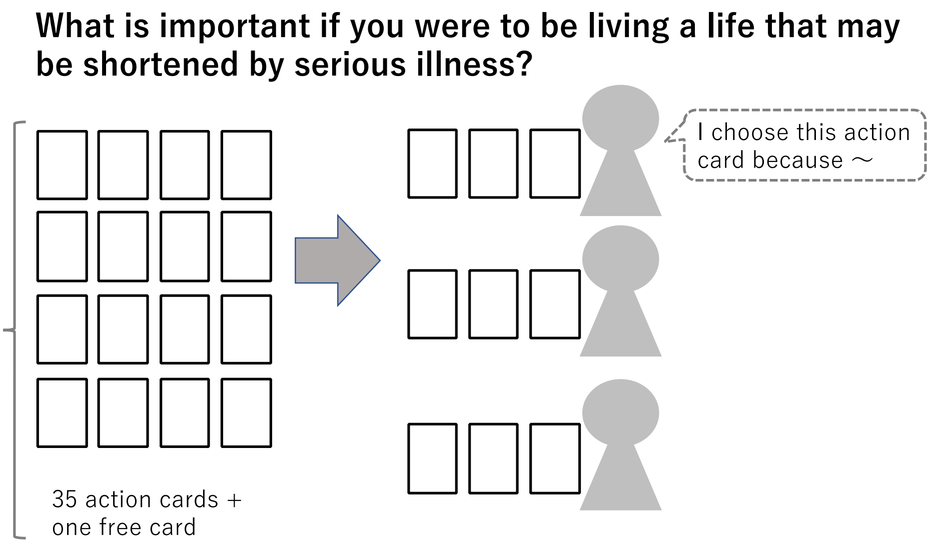

Figure 1. How to play 'Moshibana'

RESULTS AND DISCUSSION

Twenty-seven out of the thirty-five Moshibana cards were chosen by at least one student, while eight cards were not chosen at all.

The Words in the Most Selected Cards

The top ten selected cards are shown in Table 1. The top 10 cards indicate that over 70% of students believed that those ten wishes were important when faced with terminal care. In particular, the top two wishes cards were chosen by more than 10% of the participants. These are: 'To feel that my life is complete' and 'To be free from pain'. Interestingly, the first and second most popular cards involve different senses of time. While 'To feel that my life is complete (#1)' is a long and comprehensive retrospective wishes, 'To be free from pain (#2)' is a temporary event. Other commonly chosen cards demonstrate that the students' desire to spend time with family at home (#3 and #7), and to choose their own medical treatment and care (#4, #9, and #10). In addition, 'not dying alone' (#5) means a strong desire to avoid loneliness among the participants.

Table 1. Top Ten Cards

Wishes	Responses (%)
1. To feel that my life is complete	19 (12.2)
2. To be free from pain	18 (11.5)
3. To have my family with me	14 (9.0)
4. To be treated the way I want to be treated	13 (8.3)
5. Not dying alone	13 (8.3)
6. To take care of unfinished business with family and friends	8 (5.1)
7. To die at home	7 (4.5)
8. Not being a burden to my family	7 (4.5)
9. Not being connected to machines	7 (4.5)
10. Not being short of breath	6 (3.8)
Total	112 (71.8)

The Unchosen Wishes

The unchosen cards relate to four items related to preparation for death, religious issues, and the presence of nurses (Table 2). Since the students were not asked to explain why they did not choose these particular cards, their reasons for avoiding the cards are unknown. However, the unchosen cards imply that the students found it difficult to accept death (#1 and #3) and that they lacked religious beliefs (#2). As the contents in Moshibana were originally created in the United States, some Japanese students might not prioritise some of the wishes because of cultural differences, especially those related to the value of death. Another interesting point is that the presence of a nurse is not important for students if faced with terminal care (#4). This also implies that the students were not aware that nurses could play an important role in terminal care.

Table 2. Cards Items Not Chosen

1. To talk with a family and friends about preparation and fear of death
2. Issues related to religion, praying, and God
3. To know how the body will change
4. The presence of nurses

Qualitative Assessment of the Most Important Wishes

A qualitative assessment was conducted based on the students' written comments for the selected cards. Table 3 provides the representative reasons that students gave for their cards.

Table 3. Reasons behind the Most Selected Cards

Moshibana Card Text	Students' Reasons for their Choices
1. To feel that my life is complete	1-a. I want to believe that my life was happy at my last moment. 1-b. This is my motivation to live my life. 1-c. I want to die with a fresh mind, not negative thinking
2. To be free from pain	2-a. I want to have a peaceful death. 2-b. I saw my grandmother in pain. 2-c. I hate to be in pain.
3. To have my family with me	3-a. I feel calm with my family, as they are always stand by me. 3-b. I want to spend my last moments with my family. 3-c. I want to be with my family, as usual.
4. To be treated the way I want to be treated	4-a. I want to have the care that I want. 4-b. Painful treatment or undesired care means a low quality of life. 4-c. I feel alive if my will is respected.
5. Not dying alone	5-a. It is hard to die alone. 5-b. I want to be with many people to support me, like family, friends, doctors, and nurses. 5-c. Uneasy feeling and suffering will be more severe if I am alone in the end.
6. To take care of unfinished business with family and friends	6-a. I do not want to spend a time alone. 6-b. I want to organise my possessions and save the things I enjoyed. 6-c. If there is something left to do, I will have regrets.
7. To die at home	7-a. I hate to staying in hospitals. 7-b. Dying alone is lonely. 7-c. I want to die in a place of full of memories.
8. Not being a burden to my family	8-a. I would be sorry if my family struggled mentally or physically to solve the issue I left behind. 8-b. I would be sorry if my family had to come to the hospital every day. 8-c. I don't want medical treatment to put a financial burden on my family.

9. Not being connected to machines	9-a. My appearance could be concerning to someone else, and life-prolonging treatment is expensive. 9-b. I want to be able to move freely. 9-c. People who see others in such conditions are worried.
10. Not being short of breath	10-a. I cannot feel calm if my breathing is difficult. 10-b. I had asthma and many breathing difficulties. 10-c. It could make it difficult to talk to people or participate in activities.

One of the most significant elements found in all selected cards was the word ‘family’. For example, the word is appears in 3-a, 3-b, 3-c, 5-b, 8-a, 8-b, and 8-c. It is also interesting that the words ‘happy’, ‘peaceful’, ‘respect’, ‘motivate’, ‘enjoy’, and ‘full of memories’ were selected as dying with dignity. In contrast, the words of ‘alone’, ‘lonely’, and ‘painful’ represent issues to avoid when facing terminal care. Only a few students mentioned the presence of doctors and nurses, whereas most students valued the presence of their families and friends in several responses.

CONCLUSION

This study found that the participating Japanese first-year university students who participated prioritised spending time with their families at home, making their own decisions with regard to medical treatment, and having painless treatment for terminal care.

The participant students in this study were young and generally healthy, so they may not be particularly interested in topics related to death. There were no specific ideas as to their preference regarding medical professionals such as doctors and nurses. Rather, they emphasised that they yearn for family and friends to be present when faced with terminal care. Moshibana proved to be an effective tool that promoted serious contemplation and visualisation of individual ideas and beliefs. However, there is still room for improvement in discussing the ethical aspects of applying science and medical technology to humans.

Scientific and technological innovations in medicine and pharmacology continue to progress on a global scale, and how those advancements are used is left up to the consumers. The author would like to conduct further studies to explore the effective educational use of this material among participants of different ages and different nationalities.

ACKNOWLEDGEMENT

This study was supported by the JSPS KAKENHI Grant Number 17H01982, 15K00998, and 17H04490 from the Ministry of Education, Culture, Sports, and Technology in Japan.

REFERENCES

Coda Alliance. (2016). *The Go-Wish Card Game.* Retrieved from http:// codaalliance.org/ about/

Hodson, D. (2003). Time for action: Science education for an alternative future. *International Journal of Science Education*, 25(6), 645-670. doi: 10.1080/09500690305021

Institute of Advance Care Planning. (n.d.1). *Moshibana game*. Retrieved from www.i-acp.org, (In Japanese)

Institute of Advance Care Planning. (n.d.2). [Activity Report]. Retrieved from https://www.i-acp.org/activity/, (In Japanese)

Roth, W. (2014). Personal Health—Personalized Science: A new driver for science education?. *International Journal of Science Education*, *36*(9), 1434–1456. doi: 10.1080/09500693.2013.807447

Wear, S., Bono, J.J., Logue, G., & McEvoy, A. (Eds.) (2000). *Ethical issues in health care on the frontiers of the twenty-first century*. Dorcent, NL: Kluwer academic publishers.

WWF. (2018). *Living planet report – 2018: Aiming higher.* Grooten, M. and Almond, R.E.A. (Eds). WWF, Gland: Switzerland.

Zeyer, A. & Dillon, J. (2018). The role of empathy for learning in complex science | environment | health contexts. *International Journal of Science Education*, *41*(3), 297–315. doi: 10.1080/09500693.2018.1549371

ANIMALPOCKY: AN OBSERVATION LEARNING SUPPORT APPLICATION FOR ZOOS USING AUGMENTED REALITY

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This study proposes the use of a three-dimensional computer graphics (3DCG) application in zoos to support children's observation of animal skeletons and their movements to facilitate their learning about zoo animals. This 3DCG application uses augmented reality (AR) to represent the skeletal structures and movements of three animals: lions, penguins, and pandas. It is characterised by its use of 3DCG to seamlessly display information about the animal under observation, including its skeletal form and structure, so that (1) the skeleton of the animal can be observed from all angles, 360 degrees; (2) details can be observed by selecting a part of the skeleton and enlarging it; and (3) movements of the animal can be observed by moving the skeleton (however, the movements of lions were limited to walking, penguins to swimming, and pandas to feeding).

Zoos are optimal places for learning about animals, and are likely ideal for informal science education. However, children primarily visit zoos for leisure and play, and learning based on scientific observations does not tend to occur in zoos. Moreover, a certain level of expert knowledge needs to be acquired before making scientific observations in zoos; the provision of this knowledge to children is insufficient. For example, they are not generally provided with the morphological knowledge related to animal skeletons which would allow them to make informed observations.

Researchers in the present study developed an AR-based 3DCG application to support the observation of animal skeletons. User assessment was held to consider the effectiveness of learning support for the 3DCG application. At Kobe Oji Zoo, in Kobe, Japan, twenty lower primary school students were provided with iPads with the 3DCG application installed. Students participated in pre and post-usage questionnaires about their interests in animals and their skeletons, and in post-survey questionnaires about the usability of the application.

The results indicate that the children's curiosity towards animal skeletons was aroused by the 3DCG AR application. Their interest towards the application, its simple operational method, and realistic rendering of 3DCG-created images were also assessed positively. This indicates that this 3DCG application provides effective support for children to learn about animals.

Keywords: Augmented Reality, Zoos, Science Education

INTRODUCTION AND BACKGROUND: BACKGROUND OF THE STUDY AND PROBLEM IDENTIFICATION

Zoos are considered arenas that facilitate informal science education (Rennie & McClafferty, 1995; Patrick & Tunnicliffe, 2013). However, it is not necessarily easy for learners to make scientific observations in zoos. One reason for the difficulty is because the original motive for

the visit; children generally visit zoos for leisure and play, not for learning. Another reason is that even if children did visit a zoo with learning in mind, they may lack the level of expert knowledge required for making scientific observations (Eberbach & Crowley, 2009).
Most children were found to have insufficient knowledge about the animal skeletons that are the subject of this study (Prokop et al., 2007). However, zoos do not necessarily implement sufficient and effective learning support for children to acquire expert knowledge. Zoos tend to stop at the creation of commentary panels regarding the animals. Some recent attempt were made to provide learning support in zoos using Internet technology situation (e.g., Webber, 2016). However, no attempts were made to effectively provide children with the prerequisite information on the skeletons and movements of the animals that are the subject of observation.
In an attempt to provide a solution, this study developed a three-dimensional computer graphics (3DCG) application which offers visualisations of animal skeletons using augmented reality (AR). This application can represent the skeletons and movements of three types of animals: lions, penguins, and pandas. This AR functions seamlessly to display information on the animal subject to observation, and its skeletal form and structure, so that (1) the skeleton of the animal can be observed from any angle, (2) the details can be observed by selecting a part of the skeleton and enlarging it, and (3) movements of the animal can be observed by moving the skeleton (however, lions' movements were limited to walking, penguins to swimming, and pandas to feeding). The skeletal content reflect advice from animal experts, and detailed observations of real skeletal specimens. A preliminary evaluation experiment was performed at Kobe Oji Zoo to assess the effectiveness of the 3DCG application for learning, and lower primary students were the subjects for this experiment. The following summarises the 3DCG application and reports the results of a preliminary user assessment.

SYSTEM OVERVIEW

The development of the 3DCG application can be divided into two parts.

1. System

The following software was used for this application so that images could be displayed using AR on iPads. Unity was used for the AR platform, and Vuforia was used for the AR library. The methods for using the application and its subsequent process of information are as follows (Fig. 1). (1) Users hold out their iPads in front of the marker of the animal they wish to observe. (2) When the iPad camera acquires the marker's information, the software (Unity + Vuforia) creates an object image, a 3DCG image of the animal's skeleton, based on this information. (3) The object image is displayed on the iPad screen. The designers of the operating system considered the young age of the users and avoided using words as much as possible so that children could operate the system smoothly. The size and positioning of the buttons, and the sizes of the screen icons, were decided after considering the size of children's hands (Fig. 2).

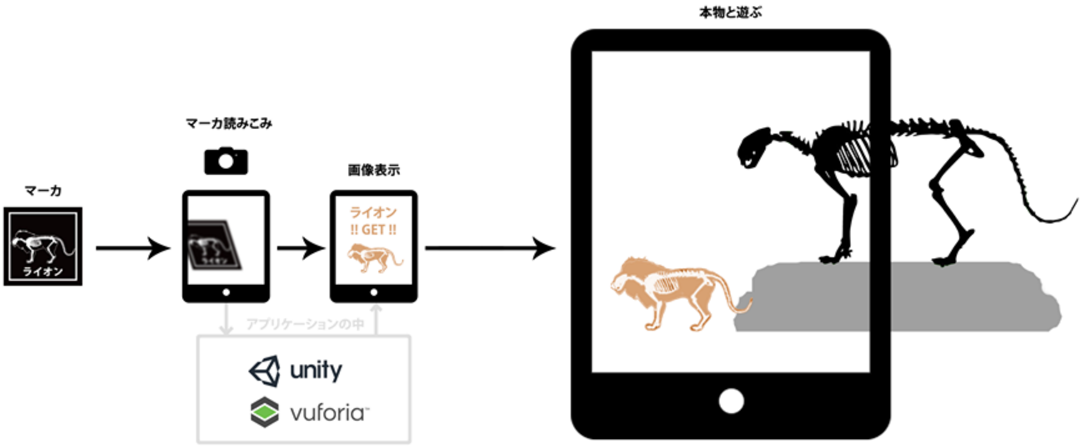

Fig. 1: Summary of the flow of information for the 3DCG application

Fig. 2: The interface of the 3DCG application: For lions. If you select a part of the lion's skeleton, as seen on the bottom right, the selected part will be displayed so that you can observe its detailed form and structure. If you tap the bottom centre, the skeleton will start walking.

2. Skeletal Images Using 3DCG

Graphic representations can be made for three types of animals, penguins, pandas, and lions. Figures 3, 4, and 5 are examples of 3DCG-created skeletal images for each animal. All skeletal images were designed using Maya. Users can observe the images from all angles, at 360 degrees, as they are created using 3DCG technology. In addition, each part of the skeleton can be selected and enlarged so that its detailed form and structure can be observed. Moving images were created so the skeletons moved, demonstrating each animal's strength and flexibility. The moving images were designed so viewers could understand the movements unique to each animal, and how each skeleton moved. For example, leg movements were stressed when representing the movements of the lion, while the moving images of penguins stressed swimming. Because limited data existed on penguins' foot bone movements during swimming, other animals with similar movements were referred to when designing the moving images. The moving images of pandas in the act of feeding focused on the panda's hand usage. For maximum accuracy, the 3DCG created skeletal images based on observations of actual skeletal specimens.

Fig. 3: An example of a 3DCG-created skeletal image of a panda

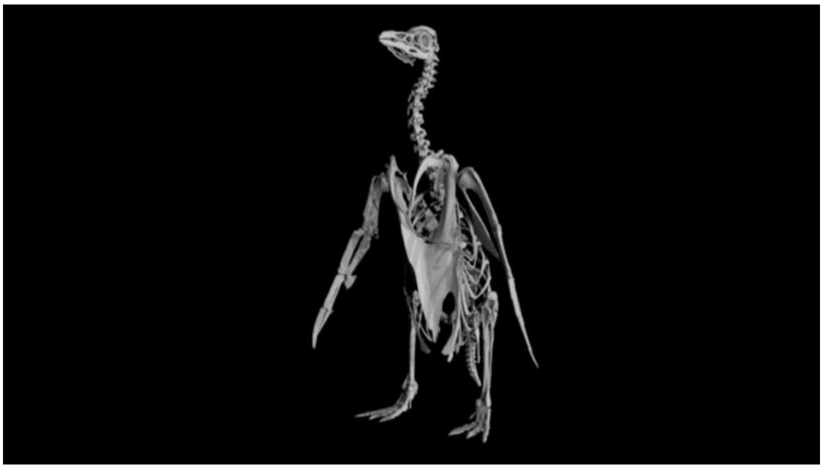

Fig. 4: An example of a 3DCG created skeletal image of a penguin

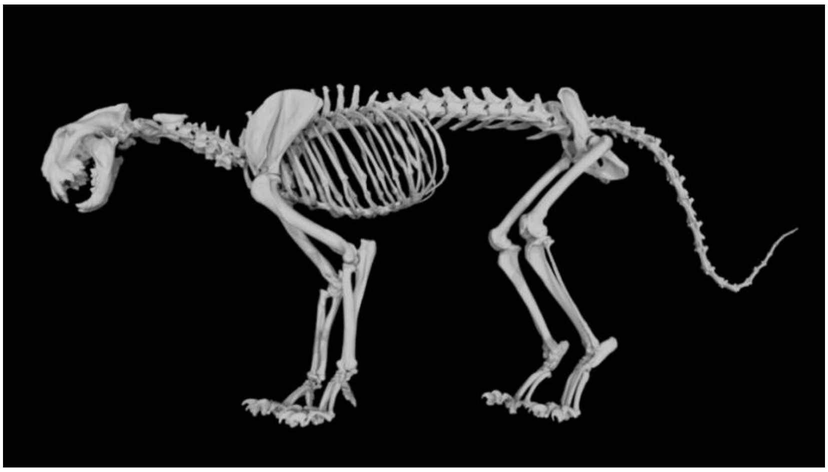

Fig. 5: An example of a 3DCG-created skeletal image of a lion

EVALUATION EXPERIMENT

Research questions: The two research questions for evaluation were as follows:

- Does the 3DCG application, which provides skeletal information on animals, arouse interest in animal skeletons among lower primary students?
- Is the 3DCG application, which provides skeletal information on animals, usable for lower primary students?

Participants: 20 lower primary students (12 students in first grade, eight in second grade)
Assignment: Two assessments were conducted using questionnaires; one was held before the students' usage of the 3DCG application, and the other, after. The pre-usage assessment comprised six items related to children's interest in animals and their skeletons. The post-usage assessment asked questions similar to those in the prior assessment, as well as seven additional question related to the usability of the 3DCG application. All items in the questionnaire were answered on a five-point rating scale (strongly agree, agree, neutral, disagree, strongly disagree). The post usage assessment also sought freely written answers from students on their opinions about the 3DCG application.
Procedure: Lions, penguins, and pandas were the subject animals of this observation. First, students answered survey questions about their interest in each animal and its skeleton. Second, students toured the zoo and observed the animals represented in the application for 30 minutes. Finally, students answered the post-usage survey (Fig. 6). The preliminary survey required three minutes to complete, and the post-usage survey required 15 minutes. The date of the evaluation experiment was October 18, 2018.

Fig. 5: a user at the Kobe Oji Zoo

RESULTS

Table 1 represents the interest of the students toward the subject animals and their skeletons in the pre and post-usage surveys. While students showed interest in the animals in the preliminary survey, relatively few students had a similar degree of interest in the skeletons. However, when compared with the preliminary survey, the post-survey showed a significant increase in the number of participants who had a positive interest in all featured animal skeletons ($p<.05$). Therefore, the students were found to have the same degree of interest towards animals and their skeletons by using the 3DCG application.

Table 2 demonstrates the results of the post-usage survey related to the usability of the 3DCG application. The answers for each item were divided into positive answers (strongly agree, agree) and other answers (neutral, disagree, strongly disagree). The bias of these results was considered using the direct probability calculation, which led to the finding of the significant increase in positive answers compared to other answers for all items. Participants were found to have positively assessed their interest towards the 3DCG application, its simple operational method, and realness of the 3DCG-created images. Lastly, for the freely written answers in the post-usage study, 12 students wrote answers including words related to bones and six students wrote answers regarding how fun it was to use the application.

Table 1: The change in children's interest towards animals and skeletons in the preliminary and post surveys (n=20)

	Strongly agree	agree	neutral	disagree	strongly disagree
I am interested in pandas	14/17	4/3	2/0	0/0	0/0
I am interested in pandas' bones*	5/13	4/6	7/1	2/0	2/0
I am interested in lions	10/15	6/3	2/2	2/0	0/0
I am interested in lions' bones*	5/12	4/7	6/1	4/0	1/0
I am interested in penguins	17/15	0/5	2/0	0/0	1/0
I am interested in penguins' bones*	10/13	3/5	4/2	0/0	3/0

The table shows the number of respondents in the preliminary/post-surveys. The first number shown for each item represents the number of respondents for the preliminary study and the second the number of respondents for the post-usage study.

* ; $p<.05$ (Sign test, two-sided test)

Table 2: A post-usage assessment related to the usability of the 3DCG application (n=20)

	strongly agree	agree	neutral	disagree	strongly disagree
Animal Pocky was fun＊	17	2	1	0	0
I became interested in bones after seeing Animal Pocky＊	14	4	2	0	0
it is interesting that the bones of Animal Pocky move＊	15	4	0	1	0
the bones of Animal Pocky seemed real＊	16	3	1	0	0
I want to see other animal bones with Animal Pocky＊	17	3	0	0	0
using Animal Pocky was easy＊	16	2	2	0	0
I could see bones from wherever I wanted using Animal Pocky＊	13	5	2	0	0

＊The 3DCG application was called *Animal Pocky.*

CONCLUSION AND FUTURE WORKS

The present study proposed using a 3DCG application to support observation of animal skeletons for children to learn about animals in zoos. To this aim, lower primary students were requested to participate in a preliminary user assessment for the application. As a result, children's interest in the featured animals and their skeletons was aroused, and the 3DCG application received positive reviews. This feedback suggests that the use of AR in zoos to provide information could prove to be effective. The following functions were used by the participating students and were designed to enhance their motivation towards learning about animals: (i) the animal skeletons represented through the 3DCG application, (ii) being able to observe the skeletons from all angles, (iii) being able to observe individual parts of the skeleton by selecting and focusing on them, and (iv) being able to observe skeletons which simulate the movements of the real animals.

Zoos are considered arenas for science education, able to facilitate important learning opportunities. Methods to encourage and support scientific learning in zoos must be considered in the near future so that zoos can function as places where visitors acquire scientific knowledge, rather than simply acquiring leisure or entertainment. The distribution of skeletal information using the 3DCG AR application can be considered an effective means to potentially achieve this objective. Future challenges may include increasing the types of subject animals and additional variations of animal movements.

REFERENCES

Eberbach, C., & Crowley, K. (2009). From every day to scientific observation: how children learn to observe the biologist's world. *Review of Educational Research, 79*(1), 39-68.

Patrick, P. G., & Tunnicliffe, S. D. (2013). *Zoo talk*. Dordrecht, Netherlands: Springer.

Prokop, P. G., Prokop, M., Tunnicliffe, S. D., & Diran, C. (2007). Children's ideas of animals' internal structures. *Journal of Biological Education, 41*, 62-67.

Rennie, L. J., & McClafferty, T. P. (1996). Science centres and science learning. *Studies in Science Education*, *27*, 53-98.

Webber, S., Carter, M., Smith, W., & Vetere, F. (2017). Interactive technology and human-animal encounters at the zoo. *International Journal of Human-Computer Studies, 98,* 150-168

EVALUATION OF LEARNING SUPPORT FUNCTION OF SIMULATION GAME FOR FOREST MANAGEMENT

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Sustainable Development Goal 15 'Life on Land', addresses deforestation and desertification caused by over development, resulting in a biodiversity crisis in most countries. Japan has a unique problem that forests herein have no longer been managed. Forests in Japan that are traditionally and manually managed are known as Satoyama (woodlands adjacent to a village). Its biodiversity is much better protected when they are managed instead of being left unmanaged. Therefore, it is important to learn the methods in managing Satoyama in terms of biodiversity conservation. However, it is difficult because of the large time scale of vegetation succession. In order to solve this problem, a simulation game called the 'Satoyama Management Game' was developed. This game aids the player to be interested in Satoyama management and to effectively learn about it. Earlier studies reveal that primary school students have the ability to learn methods of Satoyama management to some extent. There is an area for learning support found on top of the game screen. This study analysed the eye movements of university students who hardly knew of Satoyama, and experts, in managing Satoyama during the game to demonstrate the effectiveness of the said area. The results showed that all of the students scored higher in the sixth game than in the first game, and that the university students watched the area for learning support more frequently than the experts did. These results suggested that an inexperienced person needs the area for learning support and that the said area enables even an inexperienced person to learn the methods in managing Satoyama effectively.

Keywords: Vegetation succession, environmental education, simulation game

INTRODUCTION AND BACKGROUND

The United Nations (UN) set the Sustainable Development Goals, universally known as the SDGs. Amongst the 17 SDGs, 'Life on Land' aims to address biodiversity risks by preventing deforestation and desertification (United Nations, 2019). The UN has identified that the populace is in danger of losing biodiversity due to the over development of the human race. Japan, on the other hand, believes that its biodiversity has been lost in a different way. In the past several decades, biodiversity loss has been aggravated by the fact that people who lived in areas adjoining the forest have failed to manage the same. In fact, this is leading cause of biodiversity loss because there is a plethora of species found within Satoyama and rely on a well-managed environment.

Approximately two thirds of Japan's land area are composed of forests. Two thirds of the forests are traditionally and manually managed by the people who live near them (Ministry of the Environment Government of Japan, 2017), which are called Satoyama where both wild and second-growth species live. Records show that more than the half of the forests are Satoyama managed by inhabitants living nearby, which have kept biodiversity high. Biodiversity in Satoyama can be maintained at a high level when they are appropriately managed manually instead of being left unmanaged. According to Ichikawa et al. (2006), Satoyama management has been abandoned because the inhabitants living nearby are ageing and industrial structures are changing. Based on the foregoing, in Japan, less interference with forests will cause biodiversity loss.

Based on the context above, Kawaguchi et al. (2017) developed a simulation game called 'Satoyama Management Game', which enables the player to learn how to manage Satoyama from the perspective of vegetation succession. Ideally, it would be more desirable to learn vegetation succession in an actual Satoyama, but such is unattainable since succession takes over tens or even hundreds of years. To understand the phenomenon that occurs during this large period of time, Clark, Tanner-Smith, & Killingsworth (2015) analysed numerous researches on digital game and suggested the effectiveness of simulation games. Therefore, using a simulation game to learn the methods in managing Satoyama would be an appropriate way. In fact, an earlier study revealed that students who played the Satoyama Management Game learned, to some extent, the process in managing Satoyama (Kawaguchi et al., 2018).

PURPOSE OF THE STUDY

The effectiveness of simulation games and the Satoyama Management Game have been confirmed by prior research. On top of the game screen of the Satoyama Management Game is an area that helps a player learn the methods in managing Satoyama. By measuring the players' line of sight, this report attempted to reveal whether the player learned the methods from the said area or whether they learned through other areas of the game. Additionally, this report aimed to discuss how the game enabled the understanding of biodiversity from the viewpoint of vegetation succession.

SATOYAMA MANAGEMENT GAME

The 'Satoyama Management Game' is a simulation game that models a Satoyama in Hyogo, Japan. By playing the game, a player is expected to be interested in Satoyama and to learn the methods of managing them. The game also expects the player to understand complex vegetation succession after the playing the game. The factors such as the relationship between trees, the impact of harmful insects and animals, and the player's management approaches influence the succession.

The game covers 10 species, which can be sorted into three types: two early-stage species, five middle-stage species and three late-stage species. There are plenty of complicated rules in the game that are also found in real forests. For instance, evergreen trees block the sunlight which prevents early- or middle-stage species from growing.

The game screen composed of three areas, the area for learning support, the area of visualised Satoyama, and the area of management option buttons, as shown in Figure 2. Figure 1 is an example of the game screen. On top of it is the area made for learning support, which this report focused on. The following can be found in the said area in Figure 1: the stage, the name of each tree, its population and its picture. The metre representing the population of each tree is also displayed therein. The centre of the game screens is where the player looks to comprehend the Satoyama that he or she is managing. The player also finds pictures of harmful insects (pine weevils) and animals (deer), and the current turn in this area. The player chooses one of the six methods, which are marked as buttons found at the bottom of the game screen: clear-cutting, evergreen tree-cutting, planting trees, pest control, deer culling and doing nothing. The player has to choose one of six buttons for every turn within the allotted time (twenty seconds). Failure to choose a button will result to 'doing nothing' as automatically selected.

After twenty turns, the player finds out his or her score on the game screen. Each tree has an ideal number for its population, and the score therein is calculated based on the difference between the ideal number and the number of trees in the Satoyama in the game. One turn corresponds to approximately fifteen years. In the game, the player is tasked to keep a high biodiversity for about three hundred years.

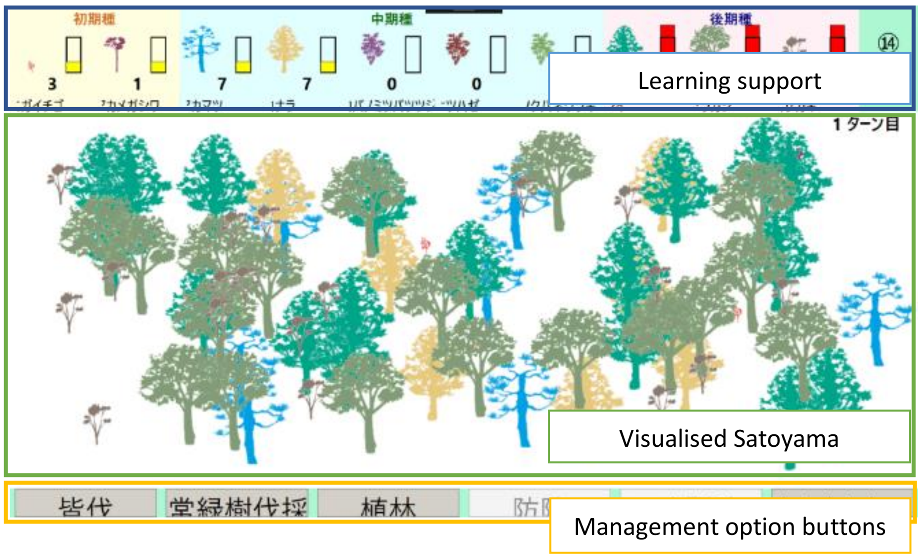

Figure 2. Example of the game screen

EXPERIMENTAL METHOD

Participants

Eighteen people participated in the experiment. Amongst them, nine are students at Tokyo University of Science and three are students at Kobe University. They hardly knew Satoyama

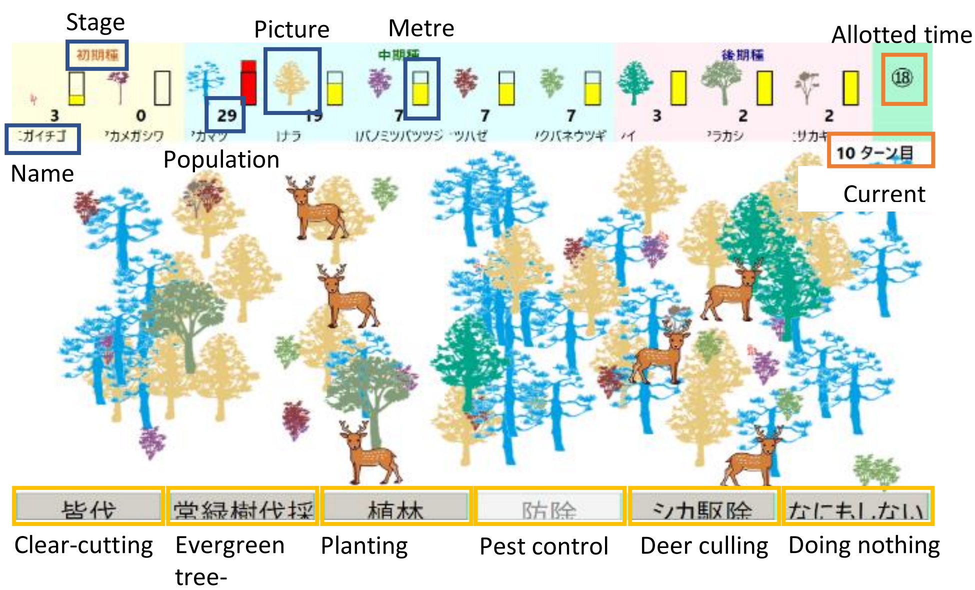

Figure 1. Example of the game screen

and did not specialise in biology or any other field related to vegetation succession. Meanwhile, the six other participants were experts in the management of Satoyama. Amongst the six experts, four of them had been managing Satoyama for more than five years, while two of them were researchers of the fields relating to Satoyama.

In spite of the fact that eighteen people participated in the experiment, no more than six of the students and three of the experts could be analysed. This is because the eye-tracking device EMR-9 (nac Image Technology Inc.) sometimes caused errors, and the line of sight was not correctly measured for the other participants.

Procedure

The experiment began by explaining to the participants how the game operated, the purpose of the experiment was, and that they would play the game six times. The participants were not informed of the rules before the game, for if they had known, they may not have tried to discover other rules and may have watched limited areas. One of the rules is that it is difficult for small species, such as early- or middle-stage species, to grow when there are evergreen trees in Satoyama. The explanation was followed by the fitting of the EMR-9 on the participants. This was preceded by calibration. After calibration, each player would play the game six times.

Analysis

The participants' scores and stationary points were analysed. The latter were analysed using a software called EMR-dFactory (nac Image Technology Inc.). The stationary points are ones where the line of sight stops for more than 0.1 seconds. The stationary points were compared between the students and the experts.

RESULTS

Scores

Table 1 indicates the participants' scores. Because of the small number of the participants, the tendencies of their scores were not clear. The fact is, however, that eight of the nine participants scored higher in the sixth game than in the first one.

Stationary points

Figure 3 shows the proportion of the stationary points which were on the top of the game screen (the area for learning support). In this figure, the lines of the experts were thickened for comparison. This graph reveals that the students relied on the area for learning support more frequently than the experts. Moreover, this implied that students sought more information by referring to the said area. Figure 4 and Figure 5, respectively, indicate student 6's and expert 1's stationary points. Figure 4 shows that there are large circles on the area for learning support. The larger the circle is, the longer the participant saw one point. Figure 5 shows that most of the stationary points of the expert were limited to the area of visualised Satoyama.

The results of the student 1 is interesting because his stationary points were shifted from the area of late-stage species to the area of the middle-stage species, as shown in Table 2. It suggested that he realised that he should have kept the middle-stage species while playing the game. Additionally, the students perhaps found out that cutting evergreen trees regularly was important to keep biodiversity in Satoyama, thus he did not feel that he had to see the area of late-stage species.

Table 1. Scores of the participants

Participants		Play					
		1st	2nd	3rd	4th	5th	6th
Students	1	67	69	69	69	57	69
	2	58	34	30	70	58	81

Table 2. Proportion of the stationary points on the area of early-, middle-, and late-stage species out of all the stationary points on the area for learning support (%)

		Play					
Participant	Stage of species	1st	2nd	3rd	4th	5th	6th
Student 1	Early	4	2	4	12	6	9
	Middle	26	30	50	59	63	64
	Late	70	68	47	29	31	27

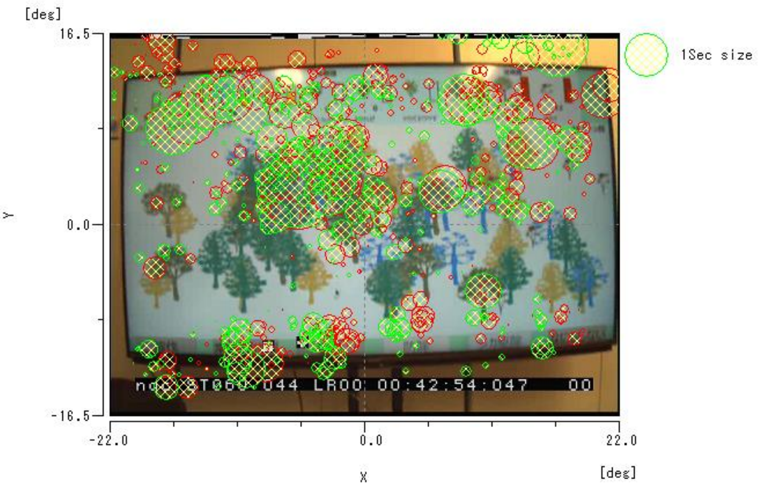

Figure 4. Student 6's stationary points

DISCUSSION AND CONCLUSION

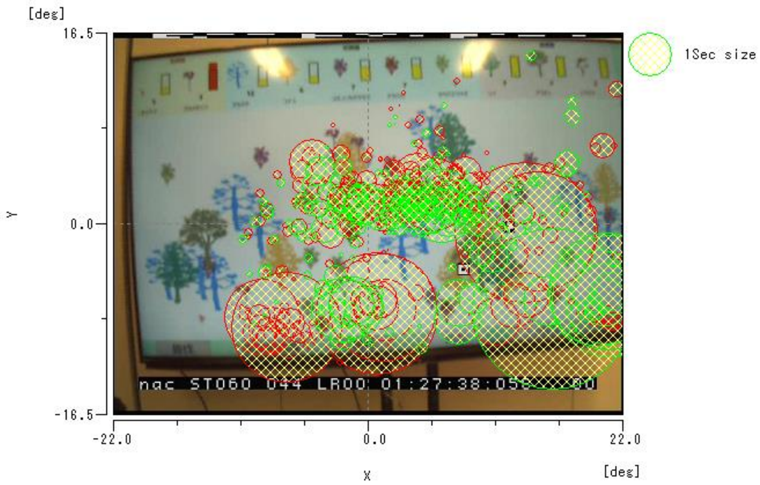

Figure 5. Expert 1's stationary points

This study aimed to reveal the effectiveness of the area for learning support found on top of the game screen. The results showed that all of the students and two of the three experts scored higher in the sixth game than in the first one, and that the students incessantly looked at the area for learning support found on top of the game screen, while the experts merely relied at the visualised Satoyama. These two results suggest that the students needed the area for learning support to get higher scores in the game. Moreover, the results indicated that the stationary points of one student shifted from the area of the late-stage species to that of the middle-stage species. This result meant that he realised the importance of keeping the middle-stage species for biodiversity in Satoyama.

This study perhaps confirmed that the area for learning support in the Satoyama Management Game is effective for an inexperienced player who has no particular knowledge on Satoyama, and that it successfully enabled them to learn how to manage Satoyama, its biodiversity, and vegetation succession.

This study only involved eighteen participants. Due to the small number of participants, the correlation between their scores in the game and where they watched are not conclusive. More data must be collected and analysed in detail to make the suggestions herein more conclusive. Also, the kind of information the participants pay attention to in responding to the appearance of pine weevils and deer should be analysed. This will let us know what the player learned when a specific event takes place in the game. In sum, understanding what types of user interface attracts a player's attention will be useful to improve the Satoyama Management Game. It will help the player learn the methods in managing Satoyama more effectively.

ACKNOWLEDGEMENT

This study was supported by JSPS KAKENHI Grant Number JP19H01734.

REFERENCES

Clark, D. B., Tanner-Smith, E. E., & Killingsworth, S. S. (2016). Digital games, design, and learning: A systematic review and meta-analysis. *Review of Educational Research, 86(1),* 79-122.

Ichikawa, K., Okubo, N., Okubo, S., & Takeuchi, K. (2006). Transition of the satoyama landscape in the urban fringe of the Tokyo metropolitan area from 1880 to 2001. *Landscape and Urban planning, 78(4),* 398-410.

Kawaguchi, S., Mizoguchi, H., Egusa, R., Inagaki, S., Kusunoki, F., Funaoi, H., & Sugimoto, M. (2018). Augmentation of environmental education using a forest management game to stimulate learners' self-discovery. In A. Jobér, M. Andrée, & M. Ideland (Eds). *Future Educational Challenges from Science and Technology Perspectives. Proceedings of XVIII IOSTE Symposium: Future educational challenges from science and technology perspective,* 122-127.

Kawaguchi, S., Sakai, T., Tamaki, H., Mizoguchi, H., Egusa, R., Takeda, Y., … Sugimoto, M. (2017). Satoyama: Time-limited decision game for students to learn hundreds years forestry management. *Proceedings of the 9th International Conference on Computer Supported Education, 1,* 481-486.

Ministry of the Environment Government of Japan. (2017). Chapter 3 Natural Environment. *Annual report on environmental statics 2017.* 77-132. Retrieved from http://www.env.go.jp/en/statistics/e2017.html.

United Nations. (2018). Forests, desertification and biodiversity. Retrieved from https://www.un.org/sustainabledevelopment/wp-content/uploads/2018/09/Goal-15.pdf

INTERDISCIPLINARY SCIENCE OUTDOORS': EXPLORING OPPORTUNITIES FROM RESEARCH–PRACTICE PARTNERSHIPS

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This proposal presents an outdoor science activity based on Interdisciplinary Teaching and Learning of Science (ITLS) undertaken with a collaborative research methodology as a Research-Practice Partnership (RPP). The ITLS activity was carry out in the Río Clarillo National Reserve in Chile as part of a continuing professional development unit. It was co-designed by in-service science teachers on a Chilean Master's degree programme and researchers. The study aimed at answering the following research questions: 1) How do in-service teachers, working in a RPP, connect and articulate different science topics through methodological and theoretical interdisciplinary perspectives? 2) Can a RPP be a pedagogical resource to generate positive changes in professional development within the practice of managing outdoor science activities? This analysis was qualitative and based on content analysis of data collected from (a) questionnaires about the teachers' perceptions and (b) scientific posters designed by the teachers as part of the final assessment of their course. The main findings revealed that teachers were able to connect interdisciplinary topics – using theoretical and methodological interdisciplinarity – to solve real problems that arise from the environment within a field trip. In addition, findings reveal benefits of RPP and ITLS, as a tool for the management of outdoors activities, supporting the importance and relevance of learning of science outside the classroom. However, the boundaries between researchers and science teachers should consider the cultural worlds of participants in the partnerships.
Keywords: Outdoor Education, Interdisciplinarity, Collaborative learning

INTRODUCTION

In recent years, growing attention has been paid to out-of-school science teaching settings and its impact on students' learning. Outdoor science activities positively influence attitudinal, physical/behavioural and inter-social constructs among students (Rickinson et al., 2004). In particular, researchers, teachers and policy-makers have highlighted the crucial role of the learning of science outside the classroom regarding the promotion of more connections with complex and real-life (Braund & Reiss, 2005). In this context, where science education lacks authenticity – because many concepts are taught in an abstract way – it has been claimed that more connection with real life contexts should be established to counterbalance this situation (Bencze & Hodson, 1999). Nevertheless, some studies highlight a significant challenge related to outdoor science learning, namely that most science teachers have limited pedagogical expertise in terms of planning and preparing activities outside the classroom (Ayotte-Beaudet, Potvin, Lapierre, & Glackin, 2017). Relatedly, K-12 science teachers infrequently incorporate outdoor learning into their practices (Power, Taylor, Rees, & Jones, 2009). For that reason, teachers need to be supported in their initial and continuing professional development, to cultivate dispositions to feel confident to work with activities outside the classroom .

Within this scenario, interdisciplinarity and interdisciplinary teaching and learning of science (ITLS) has appeared as a pedagogical resource to promote the learning of science outside the classroom (Klein, 2005), particularly as a way to: i) encourage K-12 science teachers in their development and planning of outdoor activities, integrating propositions and concepts across disciplines (theoretical interdisciplinarity) and borrowing methods from other disciplines (methodological interdisciplinarity) ; and, ii) as a resource to lead students to the understanding of their own environment and/or, at the same time, of the global environment (Boix Mansilla, 2017). Thus, students might become aware of their 'glocal' (global and local) environment, to develop the ability to relate local problems to global scenarios. This study proposes a methodology based on Research-Practice Partnerships (RPPs) (Penuel, Allen, Coburn, & Farrell, 2015) as a potential pedagogical and collaborative tool to support and generate positive changes in the process of management of outdoor science teaching, and, at the same time, to fulfil the potential of interdisciplinarity as a resource to strengthen learning and teaching outside the classroom. Furthermore, this research therefore examines an ITLS activity outside the classroom conducted in the Río Clarillo National Reserve, in the central zone of Chile.

Teaching and learning of science outside the classroom

Science outside the classroom is usually envisaged as trips or pedagogical itineraries that are designed for an educational purpose in which students interact with the environment or exhibitions (e.g. local nature reserves, zoos, botanic gardens, museums, farms, streetscapes, and so on). These activities provide pedagogical opportunities to develop experiential connections and knowledge of an object, idea, concept, theme or operation (Nabors, Edwards, & Murray, 2009; Scarce, 1997). In terms of students' learning, science education in contexts other than the classroom can show significant benefits (Amos & Reiss, 2012). In particular, activities carried out outside the classroom complement pedagogical resources to help students in multiples domains of learning – cognitive, affective, physical and behavioural (Mohamed, Perez, & Montero, 2017). It is through contact with reality that students can be helped to relate theory to the practical value of the learning they are building, which can generate meaning and a positive attitude towards the topics addressed in the outdoor activities (Behrendt & Franklin, 2014). Such learning motivates students to develop connections between theoretical concepts seen in classes and what they experience empirically (Hudak, 2003). Moreover, learning beyond the classroom has been shown to have the capacity to link knowledge to most areas of curriculum and can be a positive influence on students' understanding, interest and motivation (Braund & Reiss, 2006). With regards to the nature of outdoor science activities, some studies indicate that in order to reach optimal levels of learning, outdoor science activities must be carefully planned (Dillon et al., 2005). These findings imply that outdoor science activities must be related to activities developed in the classroom in order to favour inquisitive behaviour involving conceptual and attitudinal learning and development of skills in science. Nevertheless, although several studies indicate that students increase their knowledge as a result of outdoor activities, teachers typically have difficulties developing outdoor initiatives related to its implementation in the classroom (Ayotte-Beaudet et al., 2017). Furthermore, most science teachers have limited pedagogic knowledge and teacher training regarding the process of planning and preparing such activities (Michie, 1998; Tal & Morag, 2009).

Theoretical and methodological approach to interdisciplinarity

The synthesis, integration or blending of knowledge has been understood as the defining characteristic of interdisciplinarity. However, the definition of interdisciplinarity and a set of terms to delineate interactions of disciplines into classifications of multi-, pluri-, inter-, and trans-disciplinarity is complex. The initial use of interdisciplinarity emerged during the 1970s, created for an international conference co-sponsored by the Organization for Economic Cooperation and Development (OECD) (Klein, 2017). The OECD's definition of interdisciplinarity was broad, including any kinds of interaction defined as "simple communication of ideas to the mutual integration of organizing concepts, methodology, procedures, epistemology, terminology, data, and organization of research and education" According to this definition, interdisciplinarity tends to be conceptualized epistemologically, in terms of using a simple 'blend', 'integration' or 'combination' of different types of disciplinary knowledge (Frodeman, 2014). Nevertheless, 'simple communication' does not involve key attributes of interdisciplinarity . For that reason, we favour the definition of interdisciplinarity provided by (Boix Mansilla, Gardner, & Miller, 2000, p. 219):

> The capacity to integrate knowledge and modes of thinking in two or more disciplines or established areas of expertise to produce a cognitive advancement – such as explaining a phenomenon, solving a problem, or creating a product – in ways that would have been impossible or unlikely through single disciplinary means.

This definition builds on a performance-based view of understanding, meaning that individuals understand a concept when they are able to apply it – or think with it – accurately and flexibly in novel situations . Differences are further evident in the distinction between methodological and theoretical interdisciplinarity, and there are both narrow and broad definitions of interdisciplinarity, depending on the number of disciplines involved and the compatibility of their epistemological paradigms and methodologies (Klein, 2017). Theoretical interdisciplinarity "implies an epistemological form embodied in creating conceptual frameworks for analysing particular problems, integrating propositions and concepts, connecting topics across disciplines, and synthesizing continuities between models and analogies" (Klein, 2017, p. 7). On the other hand, methodological interdisciplinarity "promote[s] the improvement of the quality of results, typically by borrowing a method from another discipline to test a hypothesis, to answer a research question, or to help develop a theory" (Bruun, Hukkinen, Huutoniemi, & Klein, 2005). In the area of science education, previous studies have reported an explosion in the number of educational programmes which intend to promote and integrate theoretical and methodological interdisciplinarity across a wide variety of curriculum proposals (Tobi & Kampen, 2017), and there is a growing recognition of the importance of teaching and learning science through an interdisciplinary approach (You, 2017). For instance, the Next Generation Science Standards (NGSS) highlight that students need to integrate modes of thinking and knowledge informed by a variety of science and engineering disciplines – e.g. STEM (Science, Technology, Engineering and Mathematics), STEAM (Science, Technology, Engineering, Arts and Mathematics) and others . Moreover, various international standards have already proposed the need for interdisciplinary learning for the development of scientific knowledge (OECD, 2018). There is today a greater enthusiasm for ITLS due to a growing recognition that many of today's global scientific challenges – such as climate change, pollution, use of energy, among many others – involve interactions between humans and their environment. A monodisciplinary approach is unable to capture the complexity of these challenges (Gehlert et al., 2010). Moreover, studying the complexity of a natural system it is not easy, and to succeed necessitates interdisciplinary understanding informed by the integration of different disciplinary backgrounds (You, 2017). Therefore, ITLS can provide an integration of knowledge, theories and methods from the different subjects that influence the construction of learning among students in outdoor science activities (Guerrero, Joglar, & Carrasco, 2019).

METHODS

This research adopted a qualitative approach while investigating interdisciplinary science projects that were undertaken outside the classroom and involved a total of nine in-service science teachers and three science education researchers working in three Research-Practice Partnership (RPPs). The study was implemented in the Río Clarillo National Reserve, which preserves native species and their natural environment, being the closest national park to Santiago, the capital of Chile. Nine teachers were enrolled on a Science Master's degree programme for which developing an outdoor science activity in one of physics, earth sciences, chemistry or biology was the final assignment. Qualitative data from interviews with the teachers, field observations of teachers' management and organisation during the outdoor science activity, and materials generated as a result of the interdisciplinary projects were analysed using the Software NVIVO 12. To analyse the data from the scientific posters we applied thematic and directed analysis of content . In the first stage, we started by creating a code bank with predetermined categories and codes of analysis from the literature. This was done both for: (1) Theoretical interdisciplinary codes: (i) integrating propositions and concepts, (ii) connecting topics across disciplines, and (iii) synthesizing continuities between models or analogies from other disciplines (Klein, 2017); (2) Methodological interdisciplinary codes: (i) borrowing a method from another discipline to collect data, (ii) analysing data connecting different methods across disciplines, (iii) testing a hypothesis from different approaches, and (iv) answering the research question or developing a theory. For ethical reasons, the study did not use the real names of the participants. Instead, an encoding process was employed with code names in the transcripts. Informed consent was obtained according to the research ethics committee requirements of the university in Chile.

Research-Practice Partnerships (RPPs) and interdisciplinary projects

In this study, we propose a methodology based on the conceptual framework of Research-Practice Partnerships (RPPs) (Penuel et al., 2015) as a pedagogical resource for bringing about positive outcomes in the process of managing outdoor science teaching and achieving the potential of interdisciplinarity as a resource to strengthen learning outside the classroom. RPPs are collaborative partnerships between researchers and practitioners contributing to more robust educational theory and practice (Penuel et al., 2015). A RPP can enhance the role of teacher as researcher on in-service teachers' professional development. In this case, we developed RPPs as a resource to manage and support interdisciplinary science learning outside the classroom. The activity carried out through RPPs resulted in three different interdisciplinary projects where in-service teachers identified problems and proposed common work objectives, addressing conceptual, procedural and attitudinal aspects.

Data collection

As part of the data collected, at the end of the activity and as part of the final assessment of the courses (physics, chemistry and biology), teachers had the task of making scientific posters. The posters aimed at teachers developing tools for research and planning an interdisciplinary activity outside the classroom. The posters addressed the research problems, objectives, a theoretical framework, methodology, results and conclusions of the activity. Based on the information from the three scientific posters, a content analysis was conducted to answer the first research question of this paper: ‘How do in-service teachers, working in an RPP, connect and articulate different science topics through methodological and theoretical interdisciplinary perspectives?’. In addition, the teachers completed questionnaires which were designed to reveal the teachers’ perceptions of ITLS through outdoors science activities set in a RPP and to establish their views about RPP and ITLS as tools towards improving the management of outdoor science activities.

Findings

Theoretical and methodological interdisciplinarity within the learning of science outside the classroom

From the content analysis of the scientific posters designed by the teachers, it was evident that there was a clear interdisciplinary approach. Teachers connected and articulated different disciplines, topics, content and methods to improve the quality of each project according to codes presented above. Most of the projects integrated disciplinary content, methodologies and topics from chemistry, physics and biology (with a special focus on ecology, plant physiology and botany). Furthermore, two of the groups also connected geography, geology, biochemistry, agrochemistry and agrophysics. In this paper for reasons of the rules for submission and space only one example based on project 1 will be presented. In the case of this project, the research question and the study objective draw on theoretical interdisciplinary concepts as is indicated by the title of the project: ‘Analysing the incidence and effects of temperature and humidity on the development of the *Cestrum parqui* species in the Clarillo River National Reserve’. Teachers began by connecting different topics and concepts across disciplines to investigate how temperature and weather affect *Cestrum parqui*, also known as willow-leaved jessamine – a fast-growing shrub. For instance, a Physics’ in-service teacher attributed some connections of the problem to the effect of temperature in the phenomena of capillarity in the plant, linking with Physics and the dynamics of fluids. Also, he connected the effect of the temperature, frosts or frozen dews and relative humidity on changes in the frequency of light to change the green colour and produce a ‘new’ colour in the damaged leaf. The Biology teacher explained the problem, talking about photosynthesis and leaves’ stomata, evapotranspiration and its impact on the absorption of water and nutrients, which may consequently result in the rupture of cell membranes. At the same time, together they were able to connect these topics with an absence of chlorophyll, connecting with Physics again, talking about solar exposure, and length of waves and a phenomenon called ‘chlorosis’ (insufficient production of chlorophyll by leaves). This information is highlighted in the poster of project 1. On the other hand, the Chemistry teacher connected the deficit of minerals and the lack of nutrients with the deceleration of chemical reactions, for instance, the production and exchange of CO_2 which impacts, again, the weakening of structures such as the cell membrane. This was summarised in his contribution to the initial working hypothesis 'low temperatures and high humidity would directly affect the photosynthetic activity and the chemical composition of *Cestrum parqui*, preventing its normal development'. In order to answer the research question, teachers used elements of botany and plant physiology regarding the transpiration of plants (see figure 1). At the same time, the teachers used elements of geography and climatology to investigate what occurs to the leaves when there is a frost. Also, they were measuring the temperature of the soil and the external environment using methods from physics and chemistry.

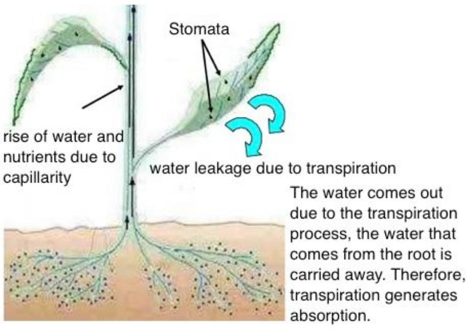

Figure 1. Part of the poster produced by the teachers undertaking project 1. Effects of transpiration on water absorption in plants. (Source: Diagram from scientific poster made by in-service teachers in project 1.)

The results of project 1 show that teachers were able to use theoretical and methodological interdisciplinarity to answer their initial research question. This approach of the teachers is indicated in Figure 2, which is taken from the results section of their scientific poster.

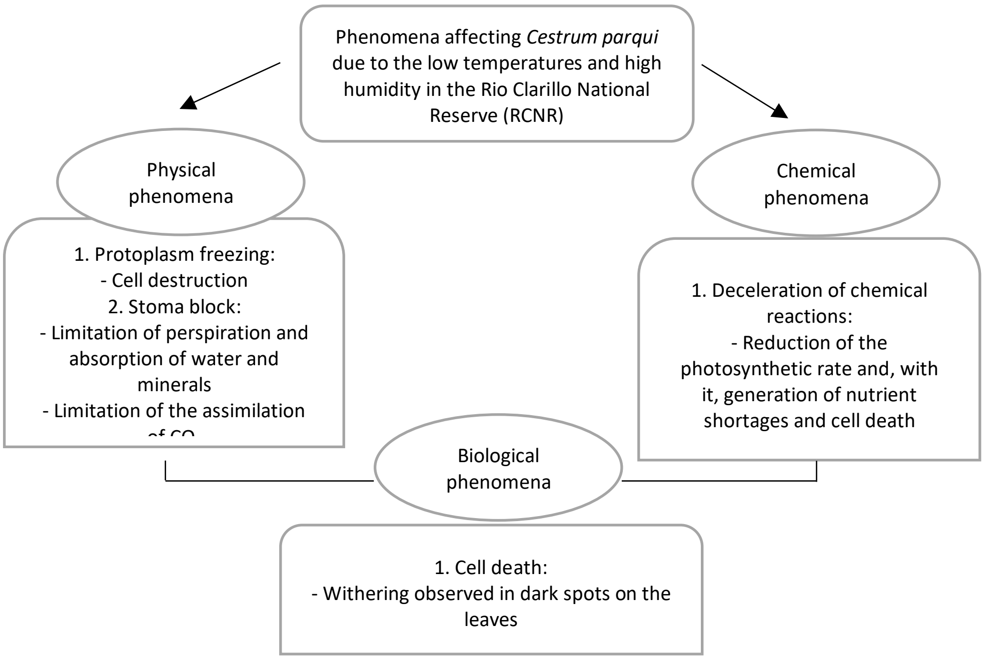

Figure 2. Example of theoretical interdisciplinarity: Effects of low temperatures and high humidity on Cestrum parqui in the Río Clarillo National Reserve. (Source: Diagram from scientific poster made by in-service teachers in project 1.)

From Figure 2, we can appreciate that teachers were able to connect different concepts and disciplines, finding an answer to the problem. In this case, the temperature and humidity affect the species Cestrum parqui in the River Clarillo National Reserve:

> "These phenomena are producing black spots on the leaves of Cestrum parqui, which is attributed to the cell death which is generated by the alteration of various biological, chemical and physical process that occur in the plant." (Findings from scientific poster in project 1).

Teaching and learning of science through RPPs in outdoor science activities

Regarding the perceptions about teaching and learning outside the classroom, teachers suggested that these types of activities are essential for science education. Teachers mentioned that the importance of working in this way is based on developing a broader understanding of complex issues and real-life problems, saving time and simplifying their work in the classroom,

> The differences are related to saving time and simplifying our work. Normally, you tend to fall into unnecessary repetitions of the subjects, and as a teacher of the subjects of biology and chemistry at the same time, I visualize that students lose interest when one teaches something they already know or repeats. (Biochemistry teacher)

In addition, teachers suggested that a pedagogical fieldtrip would help consolidate the content covered in classes, also benefiting the development of learning, the appropriation of concepts, thinking, reasoning and research skills from a real-life problem:

> I think that addressing a problem in real life, was key to consolidating the contents worked, to 'download' and apply them and to be able to relate the different specialties, I think it would not have been possible to have seen it only in the class sessions (...) I feel that benefited learning, thinking reasoning and research skills. (Biology teacher)

Teachers working through RPPs were able to connect different topics seen during their Master's modules with their visit to the Río Clarillo National Reserve through the ITLS approach. According to the perceptions of teachers about ITLS and science outdoors, activities developed through the ITLS approach facilitated teachers' thinking about natural phenomena by familiarising them with real-world problems, as highlighted by one science teacher:

> Contributions of interdisciplinary teaching through science outdoors activities for the teaching-learning process are evident (…) it allows us to solve issues that through distinct subjects would not have been possible, such as the case of environmental issues (…) I think they allow us to develop critical thinking, scientific reasoning, drawing conclusions from different perspectives and encouraging meaningful learning. (Biochemistry teacher)

Perceptions about RPP and collaborative work are clear. Teachers consider a key aspect of the outdoor science activity to be the work developed through collaborative partnerships. This appears as a contribution to the management of science activities outside the classroom. Indeed, teachers highlight the experience as a contribution to their teaching practice and also to the development and an impact on the researcher-teacher role:

> The topics were born from conversations with my colleagues, where we could share experiences about some activities that we have wanted to be developed in our subjects and with our students but had never been translated. That is why I think that this pedagogical outdoor activity is a great contribution to our teaching practice and future activities that can be developed outside of our schools (…) The researchers were very

> helpful, because important questions about the methodology were solved. (Physics teacher)

However, some obstacles are related to the time required and for the need to make a previous visit to the National Reserve. The majority of the teachers complained about the time needed for the implementation, and there were also complaints about the guidelines given by researchers at each stage. On the other hand, one teacher wanted more time to have been spent on the implementation:

> I think it would have been favourable, to have made more than one visit to the place, in the first instance to identify the problem and then to be able to measure the variables, since we could have carried more appropriate instruments. (Biology teacher)

In addition, another obstacle was related to the guidelines provided by the researchers during the process and to limitations between the roles of the teachers and of the researchers. In this case, some teachers maintained that the decisions about what to do emerged from the teachers without help from the researchers:

> I feel that the professors / researchers were willing to contribute in our work, however we as students proposed what and how to do it, I think that, if we had been very disoriented, they would have helped us more, but it was not the case. (Biology teacher).

However, and conversely, teachers felt supported during the development and production of the scientific posters:

> Especially in the preparation of the scientific poster, they helped us to limit the problem, find information about the variables, relate everything and translate it in an understandable and summarised way, that was the challenge. (Chemistry teacher)

Overall, the findings from teachers' perceptions reveal benefits of RPP and ITLS, as tools for the management of outdoor activities, supporting the importance, relevance and feasibility of learning science outside the classroom.

DISCUSSION AND CONCLUSION

As a result of outdoor science activities using an interdisciplinary approach, teachers may find their disciplinary knowledge and skills improved, with the result that they are more able to answer research questions in real environments. Moreover, through theoretical and methodological interdisciplinarity, teachers may foster the creation of new conceptual categories and methodological tools, using concepts or procedures from other disciplines in an auxiliary relationship (Klein, 2017). From this perspective, interdisciplinary outdoor science activities have the potential to organise scientific topics and ideas and answer questions across different disciplines (DeZure, 2017). Furthermore, these kinds of activities provide an opportunity to develop problem-solving abilities, generally considered as an instance of higher order thinking within science courses. Thus, interdisciplinary teaching outside the classroom leads learners to have more meaningful learning experiences. Interdisciplinary outdoor science activities carried out through RPPs appear to generate common work objectives, addressing conceptual, procedural and attitudinal aspects across science subjects. Nevertheless, the teachers in this study found it difficult to specify quality teaching itineraries for implementation in the classroom. Therefore, collaboration with researchers can play a key role in facilitating interdisciplinary teaching. This research revealed some benefits of RPPs and ITLS as pedagogical approaches to supporting learning outside the classroom. In the research presented in this article, the experience provided a rationale for more collaborative-action work projects to foster curricular planning of outdoor science activities and in-service teacher education. RPPs benefit from collaborative learning in all the phases of an outdoor science activity. However, the cultural, professional, and disciplinary boundaries between practitioners and researchers must be considered (Penuel et al., 2015). Collaboration between researchers and in-service teachers allows the science education community to respond to some of the dissuasive elements faced by teachers when considering research work. Although it would become a key requirement within RPPs that teachers develop skills and knowledge in research as part of their professional development, there are some difficulties to position and articulate research with the daily practice of teachers in terms of implications and the relationships between teaching practice, formative research and self-reflection activities for the transformation of practice.

REFERENCES

Amos, R., & Reiss, M. (2012). The Benefits of Residential Fieldwork for School Science: Insights from a five-year initiative for inner-city students in the UK. *International Journal of Science Education, 34*(4), 485-511. doi:10.1080/09500693.2011.585476

Ayotte-Beaudet, J. P., Potvin, P., Lapierre, H. G., & Glackin, M. (2017). Teaching and Learning Science Outdoors in Schools' Immediate Surroundings at K-12 Levels: A Meta-Synthesis. *EURASIA Journal of Mathematics, Science and Technology Education, 13*(8), 5343-5363. doi:10.12973/eurasia.2017.00833a

Behrendt, M., & Franklin, T. (2014). A Review of Research on School Field Trips and Their Value in Education. *International Journal of Environmental & Science Education, 3*(3), 235-245. doi:10.12973/ijese.2014.213a

Bencze, L., & Hodson, D. (1999). Changing practice by changing practice: Toward more authentic science and science curriculum development. *Journal of Research in Science Teaching, 36*(5), 521-539. doi:10.1002/(sici)1098-2736(199905)36:5<521::Aid-tea2>3.0.Co;2-6

Boix Mansilla, V. (2017). Interdisciplinary Learning: A Cognitive-Epistemological Foundation In R. Frodeman (Ed.), *The Oxford Handbook of Interdisciplinarity (2 ed.)* (pp. 261-275). New York: Oxford University Press.

Boix Mansilla, V., Gardner, H., & Miller, W. (2000). On disciplinary lenses and interdisciplinary work. In S. S. Wineburg & P. Grossman (Eds.), *Interdisciplinary curriculum: challenges to implementation* (pp. 17-38). New York: Teachers College Press.

Braund, M., & Reiss, M. (2005). *Learning Science Outside the Classroom*. London: Routledge.

Braund, M., & Reiss, M. (2006). Towards a More Authentic Science Curriculum: The contribution of out-of-school learning. *International Journal of Science Education, 28*(12), 1373-1388. doi:10.1080/09500690500498419

Bruun, H., Hukkinen, J., Huutoniemi, K., & Klein, J. T. (2005). *Promoting interdisciplinary research: The case of the Academy of Finland.* (Vol. 2005). Helsinki: Publications of the Academy of Finland. Academy of Finland.

DeZure, D. (2017). Interdisciplinary Pedagogies in Higher Education. In F. Frodeman (Ed.), *The Oxford Handbook of Interdisciplinarity (2 ed.)* (pp. 558-572). New York: Oxford University Press.

Dillon, J., Morris, M., O'Donnell, L., Reid, A., Rickinson, M., & Scott, W. (2005). *Engaging andlearning with the outdoors—the final report of the outdoor classroom in a rural context action research project.* Slough: National Foundation for Education Research.

Frodeman, R. (2014). *Sustainable knowledge: A theory of interdisciplinarity*. London: Palgrave Pivot.

Gehlert, S., Murray, A., Sohmer, D., McClintock, M., Conzen, S., & Olopade, O. (2010). The Importance of Transdisciplinary Collaborations for Understanding and Resolving Health Disparities. *Social Work in Public Health, 25*(3-4), 408-422. doi:10.1080/19371910903241124

Guerrero, G., Joglar, C., & Carrasco, V. (2019). Salidas pedagógicas interdisciplinares: rutas didácticas hacia el aprendizaje en el marco de una investigación asociativa Universidad-Escuela. In G. Guerrero, R. Fernández, & G. Watson (Eds.), *Investigando Juntos: Experiencias Asociativas entre Escuelas y la Universidad de Santiago de Chile* (pp. 70-92). Santiago: Editorial Usach.

Hudak, P. E. (2003). Campus Field Exercises for Introductory Geoscience Courses. *Journal of Geography, 102*(5), 220-225. doi:10.1080/00221340308978550

Klein, J. T. (2005). Integrative Learning and Interdisciplinary Studies. *Peer Review, 7* (4), 8–10.

Klein, J. T. (2017). Typologies of Interdisciplinarity: The Boundary Work of Definition. In F. Frodeman (Ed.), *The Oxford Handbook of Interdisciplinarity (2 ed.)* (pp. 21-34). New York: Oxford University Press.

Michie, M. (1998). Factors influencing secondary science teachers to organise and conduct field trips. *Australian Science Teachers Journal, 44*(4), 43-50. Retrieved from http://search.proquest.com.ezproxy.lib.monash.edu.au/docview/194498429/13E584736A15CA039FF/11?accountid=12528

Mohamed, M., Perez, M., & Montero, M. (2017). Salidas pedagógicas como metodología de refuerzo en la Enseñanza Secundaria. *ReiDoCrea, 6*, 194-210.

Nabors, M. L., Edwards, L. C., & Murray, R. K. (2009). Making the case for field trips:What research tells us and what site coordinators have to say. *Education, 129*(4), 661-667.

OECD. (2018). *The future of education and skills, Education 2030.* Paris: OECD Publishing.

Penuel, W. R., Allen, A.-R., Coburn, C. E., & Farrell, C. (2015). Conceptualizing Research–Practice Partnerships as Joint Work at Boundaries. *Journal of Education for Students Placed at Risk (JESPAR), 20*(1-2), 182-197. doi:10.1080/10824669.2014.988334

Power, S., Taylor, C., Rees, G., & Jones, K. (2009). Out-of-school learning: Variations in provision and participation in secondary schools. *Research Papers in Education, 24*, 439-460. doi:10.1080/02671520802584095

Rickinson, M., Dillon, J., Teamey, K., Morris, M., Choi, M. Y., Sanders, D., & Benefield, P. (2004). *A Review of Research on Outdoor Learning*. Shrewsbury: Field Studies Council.

Scarce, R. (1997). Field Trips as Short-Term Experiential Education. *Teaching Sociology, 25*(3), 219-226. doi:10.2307/1319398

Tal, T., & Morag, O. (2009). Reflective Practice as a Means for Preparing to Teach Outdoors in an Ecological Garden. *Journal of Science Teacher Education, 20*(3), 245-262. doi:10.1007/s10972-009-9131-1

Tobi, H., & Kampen, J. K. (2017). Research design: the methodology for interdisciplinary research framework. *Quality & Quantity*, 1209-1225. doi:10.1007/s11135-017-0513-8

You, H. S. (2017). Why Teach Science with an Interdisciplinary Approach: History, Trends, and Conceptual Frameworks. *Journal of Education and Learning, 6*(4), 66-77. doi:10.5539/jel.v6n4p66

Yuan, R., & Lee, I. (2015). Action research facilitated by university-school collaboration. *69*(1), 1-10. doi:10.1093/elt/ccu031

COMPLEMENTARY NETWORKING OF OUT-OF-SCHOOL LEARNING ENVIRONMENTS

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During the past two decades, extracurricular educational institutions like museums, science centres, student labs, environmental education centres and others have received increasing attention in their educational function throughout Europe (Tal, 2012). The study presented here uses the educational development research approach. Based on empirical data about learning processes in out-of-school learning environments existing educational offers are developed. At the same time, generalisable findings on learning at extracurricular educational institutions are gained. The study examines how the offerings of different out-of-school educational institutions can be systematically related so that they complement each other. Subject-related clarifications and empirical investigations form the basis for combining the offers of individual learning locations into a new, complex educational offer. The research framework is the Model of Educational Reconstruction (Duit, Gropengießer, Kattmann, Komorek & Parchmann, 2012).

Keywords: Cognitive Skills, Design Based Research, Non-formal Learning Environments

INTRODUCTION: THE CONCEPT OF COMPLEMENTARY NETWORKING

The development of educational regions is a declared objective of the UNESCO (2008). This mainly refers to an organisational link between schools and extracurricular educational institutions. The extracurricular learning environments among themselves are also often organisationally linked, above all similar out-of-school training facilities through their interest groups, such as Student laboratories or museums. Complementary networking goes beyond organisational contacts (Richter, Sajons, Gorr, Michelsen & Komorek, 2018). Here different types of learning venues such as museums, student laboratories, science centres, environmental education centres connect their offers to each other in terms of their content, methodological approaches or even their social perspectives.

A possible complementary connection between different out-of-school education offers can be a similar topic of all as for example the topic “coastal protection”. For this, e.g. a National Park House, a museum and a student laboratory offer very different, but complementary approaches. In the student laboratory, students can build and try out various dike variants by themselves, while in the museum they learn about storm surges and historical aspects of dike construction and the changes in the coastal area. The National Park House visualises the conflicts of interest between coastal protection, nature conservation and tourism.

Common educational goals such as education for sustainable development (ESD) or the education of interested laypersons in the sense of a public understanding of science can also be achieved through complementary networking. Scientific, cultural, historical, economic, ecological, ethical, technical, political and other perspectives are introduced by the complementary networked extracurricular educational institutions according to their orientations and strengths. The development of certain competences of the visitors or the sharing of objects and products can also be starting points for the complementary cooperation. There are several "paths" of complementary networking that can be supported by instruments such as flyers, signposts with connecting questions at the respective extracurricular educational institutions or apps for smartphones.

Advantages for all sides involved. Complementary networking is currently rarely implemented, although the added value for all participants can be very high:

- Visitors to extracurricular educational institutions, tourists, laypeople, and especially students, can gain better understanding of complex issues such as coastline, climate, environmental protection, energy supply, or regional development through complementary approaches, increasing their sensitivity to the complexity of topics that often lead to social conflicts and dilemmas. Interdisciplinary subject related understanding can also be better achieved by networking out-of-school educational institutions.
- Complementary networking helps teachers to reach their subject related and interdisciplinary goals; they have access to new extracurricular education environments and can be advised by the network on the complementary use of learning venues.
- The learning venues are more effective when focussing on their strengths, which can also help to profile and enhance the offerings. Because a place can be focussed on certain offers additions, if it is known that other places offer additions. It also opens possibilities for often required innovation.
- The participation in education increases throughout the educational region regarding those who are particularly interested but also those who are otherwise disadvantaged in education. In addition, the flexibility with regard to social challenges and key problems is also increased if these are addressed in a networked way.

METHOD

In this study, six extracurricular educational institutions have worked in a network. All together these extracurricular learning sites attract around 8,000 visitors per year. The learning venues are a national park house, a historical museum, a botanical garden, a naval museum, a student laboratory and an environmental education centre. This study is based on the model of Educational Reconstruction (Duit, Gropengießer, Kattmann, Komorek & Parchmann, 2012), in which subject-related clarifications of the offers of the extracurricular learning environments, empirical studies on learning, and the design of complementary offers at different types of learning venues are closely related. The model was applied to the situation of out-of-school learning (see Laherto, 2013) in order to systematically redesign the educational offers at the cooperating learning venues and design a complementary offer by combining them

Clarification of the subject matter structure and elaboration of basic ideas. The educational offerings of the participating extracurricular educational institutions were analysed in terms of specific characteristics, which can be related to one another according to a shared educational objective. For this purpose, the subject-related structure of educational offers was examined using methods of content analysis (see Mayring, 2014) in order to develop specific networking paths (Pollmann, 2018).

Empirical Studies. The empirical research focuses on the teacher`s needs for complementary networked offerings and on how they would embed these offerings in their lessons. For this purpose, a questionnaire study and an interview study with a structured guideline interview are taking place. In order to know the perspectives of teachers, the participating learning venues have offered a teacher training day that introduces teachers to the networked offerings of the six learning venues explaining the concept of complementary networking. The aim is to investigate to what extent teachers expect that networked offers support their pupils' subject-specific learning and their motivation in terms of perceiving the relevance of connected offers and the perception of self-efficacy (Deci & Ryan, 2008). Visitors to the learning locations were also asked (Schetzberg, 2018) how they perceived the added value of the networked offers.

Design of complementary networked offerings. The results of the analysis of the offerings of the learning sites and the empirical results on the needs of the teachers and the first attempts at networking were the basis for the design of networked educational offers. For this a number of didactic means have been developed (Pollmann, 2018). Core of the educational design of the offer was that a main topic was defined and that key questions were asked, that could only be answered if the visitors compare the information from two learning environments with each other.

RESULTS

Two complementary networked educational programs have been designed and tested. One of the offers is titled "The Challenge of Life at the Coast". It discusses from different perspectives the difficulties people have faced on the coast for centuries. This includes the perspective of nature, which is altered by forces of nature, and the cultural activity of humans, including the military use of the coast. Also, the dyke construction and the importance of plants for coastal protection is discussed. The visitors experience in each place, how it contributes to the main topic. The operators of the learning venues embed their special offer in the main topic and refer it to the offers of the other learning venues. Flyers and hand-on turntables support networking. The visitors themselves carry out scientific experiments at the learning locations. Empirical data show (Schetzberg, 2018) that the visitors establish the relation of the learning places to the respective main topic, that they work out the differences in the perspective of the places of learning and that they can also name conflicts that exist between environmental protection, industrial use and tourism at the coast.

Another designed offer is the format of a project week for school classes about the topic "The challenge of life in climate change". With the project week, five of the out-of-school learning places wanted to raise the pupils' awareness of the topic of climate change and convey important basics. The central goal of the project week was to develop a complex picture of the challenges of life in climate change. 130 sixth graders from five school classes (comprehensive school, high school) took part in the project week. On the first four days of the week, they visited one of the learning locations each day. Each learning location aligned one of its existing offers with the main topic and made explicit references to the other learning locations at the beginning and at the end of the visit days (fig. 1). On the fifth day they reflected and brought together the experiences and impressions in their schools. For this purpose, accompanying material and a handout were developed for the teachers and the leaders of the learning locations (Zinn, 2019).

In the student laboratory "Lernort Technik und Natur" the pupils produced a solar boat, which stands for the use of clean energy to reduce the CO_2 entry into the atmosphere. At the "climate breakfast" of the environmental education centre, the pupils worked out their behaviour when buying food and the consequences of their consumption. The offerings from these two learning venues complemented each other by highlighting various measures that can be used to slow down climate change. From a historical perspective, the coastal museum illustrated protective measures taken by coastal residents against storm surges and against the natural and man-made rise in sea levels. The coastal museum and the environmental education centre complemented each other in that they combined a look into the past with one's own behaviour in the future. The offer of the coastal museum and that of the botanical garden complemented each other in that both learning places deal with the meaning of dikes. In addition, there was the perspective of the Wadden Sea Visitor Centre, which focused on the global consequences of climate

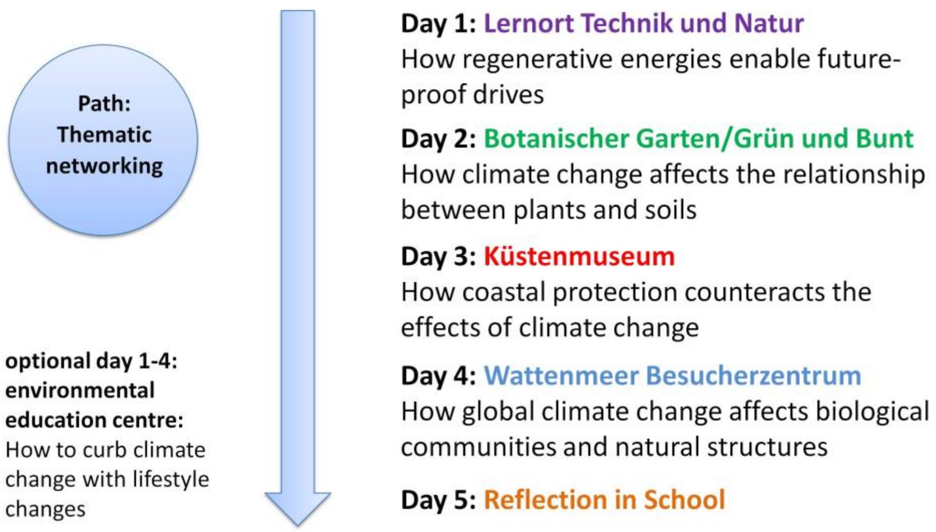

Figure 1: project week for school classes about the topic "The challenge of life in climate change"

change.
In the accompanying research for the project week (master thesis by Jonas Tischer, in progress) pupils, their teachers and the leaders of the learning places were interviewed in order to relate the perceptions and insights of these three groups of actors. Regarding the pupils, the following research questions were concerned:

- To what extent can pupils reflect on and justify their actions at the different learning locations?
- To what extent can pupils abstract the different perspectives of the learning locations from the offers visited and relate them to the motto of the project week?
- How can the pupils relate the perspectives of the learning locations to each other and work out similarities, but also differences? To what extent can they understand possible conflicts and dilemmas that arise from the sometimes opposing perspectives?
- And to what extent can the pupils work out and formulate the complex challenges that the coastal population faces due to climate change?

The pupils were interviewed during and after the offers as part of a semi-open structured guideline interview. Field notes during the project week and interviews in schools complemented the data acquisition. The evaluation took place within the framework of qualitative content analysis (Mayring, 2014) of the interview and observation data. First analysis of the data show, that the majority of the pupils were not only able to reproduce the offers of the individual learning locations, but could also name the (abstract) perspectives of the offers (historical, scientific, technical, political, ...) and relate them to each other. This is an astonishingly high level of abstraction by the young pupils. In addition, many of them were able to put the very different offers and perspectives in connection with the overall topic "The challenge of life in climate change" of the project week in the follow-up at school and use them to derive specific dispositions for action.

DISCUSSION AND CONCLUSIONS

The complementary networking of learning offers from different extracurricular educational institutions seems to have great value in understanding open, complex problem situations. This fits in with modern educational discussions, where it is an important goal to prepare young people for a world of ill-defined open problems. The preliminary study in the context of the project week showed that the concept of complementarily networked offers can support pupils in the lower grades to understand the complex challenges that climate change brings. However, project weeks are singular events, which have a high intensity but are not linked to regular lessons, although the school preparation and follow-up of such visits is important. In general, singular formats such as individual visits to non-school learning venues are not of lasting cognitive and motivational impact (Pawek, 2009).
Therefore there is a need for development and research, firstly as regard to the embedding of extra-curricular visits in regular lessons and secondly how several visits can be related to one another over a longer period of time. Encouraged by the positive results of the project week,

two of the participating schools (Neues Gymnasium Wilhelmshaven and Wilhelmshaven Comprehensive School) are interested in trying out the integration of the complementarily networked offers over two school years. Several school subjects should also be involved in this, beyond the STEM area. School climate education should be closely interlinked with extracurricular educational offers; also a digital networking application for smartphones will be designed to help connecting the different learning environments. In addition this offer allows particularly interested pupils to get to know the learning environments and to to take advantage of other offers, even in the afternoon.

These participating schools want to achieve a climate education of their students, which includes climate knowledge, understanding of the climate system, taking different disciplinary perspectives on climate change as well as dispositions of individual and social action. The planned project is based on the Sustainable Development Goals of high-quality education and immediate and urgent action with regard to climate change (UN General Assembly, 2015).

REFERENCES

Deci, E. L., & Ryan, R. M. (2008). Self-determination theory: A macrotheory of human motivation, development, and health. *Canadian Psychology/Psychologie canadienne, 49*(3), 182-185.

Duit, R., Gropengießer, H., Kattmann, U., Komorek, M. & Parchmann, I. (2012). The Model of Educational Reconstruction – a framework for improving teaching and learning science. In: D. Jorde & J. Dillon (Hrsg.), *Science Education Research and Practice in Europe* (S. 13-37). Rotterdam: Sense Publishers.

Laherto, A. (2013). Informing the development of science exhibitions through educational research. International Journal of Science Education, Part B: Communication and Public Engagement, 3:2, 121-143, DOI: 10.1080/21548455.2012.694490

Mayring, P. (2014). Qualitative Content Analysis: Theoretical Background and Procedures. In: A. Bikner-Ahsbahs, C. Knipping & N. Presmeg (Hrsg.*), Approaches to Qualitative Research in Mathematics Education* (S. 365-380). Berlin, Heidelberg: Springer.

Pawek, C. (2009). *Schülerlabore als interessefördernde außerschulische Lernumgebungen für Schülerinnen und Schüler aus der Mittel- und Oberstufe*. Kiel: Universität Kiel.

Pollmann, S. (2018). Entwicklung und Umsetzung eines Konzepts zur komplementären Vernetzung außerschulischer Lernorte in der Region Wilhelmshaven [Development and implementation of a concept of complementary networking of extracurricular learning environments in the region of Wilhelmshaven]. University of Oldenburg.

Richter, C., Sajons, C., Gorr, C., Michelsen, C. & Komorek, M. (2018). Vernetzung außerschulischer GINT-Lernorte. In: C. Maurer (Hrsg.), Qualitätsvoller Chemie- und Physikunterricht - normative und empirische Dimensionen. 660-663; Universität Regensburg.

Schetzberg, C. (2018). Empirische Begleitung eines Aktionstages zur komplementären Vernetzung außerschulischer Lernorte – Thematische Vernetzung zur „*Herausforderung Leben an der Küste*" [Empirical accompaniment of an action day on the complementary networking of extracurricular learning places - Thematic networking on the "Life on the Coast Challenge"]. Oldenburg: University of Oldenburg.

Tal, T. (2012). Out-of-School: Learning Experiences, Teaching and Students' Learning. In: B. J. Fraser, K. Tobin & C. J. McRobbie (Eds.) Second International Handbook of Science Education. Heidelberg: Springer, 1109-1122

UNESCO (2008): Inclusive Education: *The Way of the Future, International Conference on Education*, 48th session. Final Report. Geneva: UNESCO.

United Nations General Assembly (2015). *Resolution adopted by the General Assembly on 1 September 2015. Draft outcome document of the United Nations summit for the adoption of the post-2015 development agenda* (http://www.undocs.org/A/RES/69/315)

Zinn, I. (2019). *Konzeption und empirische Begleitung einer komplementären Projektwoche "Herausforderung Leben im Klimawandel".* Master Thesis: Universität Oldenburg.

PART 10: STRAND 10

Science Curriculum and Educational Policy

Co-editors: *Andreas Redfors & Jim Ryder*

CONTENTS

STRAND 10: INTRODUCTION

SCIENCE CURRICULUM AND EDUCATIONAL POLICY

Policy is relevant, and often deeply influential, across all educational contexts. Education policy frames priorities and targets resources on themes such as curriculum content, assessment, pedagogy, school governance, teacher education and development. Underpinning such policies are educational aims and values that extend well beyond education contexts to broader societal and cultural settings. The contributions in this section provide diverse analyses of the significance of education policy. They are diverse in terms of geographical context (Asia, Europe, South America), exploring three national projects, with one comparison between two countries – one in Asia and one in Europe. In addition, they demonstrate varied methodologies and conceptual frameworks. Taken together they demonstrate the powerful, yet often hidden, influence of education policy on society, schools, teachers and young people. We hope that the compelling messages of these studies inspire other researchers within the ESERA community and beyond to make policy itself, its development, enactment and outcomes, the focus of sustained and high-quality research internationally.

Michel Pisa Carnio and Marcos Cesar Danhoni Neves examine national policies in Brazil and the nature of authoritarian thinking and its implications for the educational field. They present an analysis of the national project Escola Sem Partido, echoing calls for 'politically neutral schools' seen in many countries. Analysis considers different 'registers of influence' including public policy texts and the experiences of individual stakeholders. They argue that there are misconceptions about science education inherent in the Escola Sem Partido project that are communicated by project advocates. Such misleading projections of education can be damaging for the authority and autonomy of teachers and schools.

Susumu Nozoe and Tetsuo Isozaki presents an analysis of how science teachers' viewpoints and attitudes influence the implementation of curricula in Japan. They report on a survey of lower secondary science teachers in Japan and England. They discuss science teachers' pedagogical perspectives in the two countries and conclude presuppositions about the nature of the world are more contested in Japan where western science is introduced in a differing culture. They report that sociocultural contexts in Japanese society are often accepted implicitly by Japan's science teachers and hence influence implementation of curricula fundamentally.

Teresa Lupión-Cobos, José Hierrezuelo-Osorio, Isabel Cruz-Lorite and Ángel Blanco-López analyse how secondary school science teachers in Spain experience the different stages of a training programme designed to meet the challenges of educational reform. The analysis of two individual interviews and a focus group uses a framework representing personal (individual), internal (school) and external factors of influence. They report on data from four teachers following the training programme. They found that personal (individual) factors were initially important, but influence from program and peers increased as the program continued. They conclude that the analysis framework of personal/internal/external factors can be beneficial for education researchers, designers of training programmes and the development of education policy

Damienne Letmon, Eilish McLoughlin and Odilla E. Finlayson explore 50 years of policy influences on upper secondary physical sciences curricula in Ireland. They examine and compare the cognitive demands of upper secondary level physics and chemistry examination questions from 1966-2016. A sample of ten physics and ten chemistry Leaving Certificate higher-level examinations papers were selected. They found that despite changes in syllabi and question styles there was no significant change in cognitive demand levels. They conclude that the findings of their analysis are relevant for the development of assessment practices that recognise and assess higher order thinking skills.

These contributions demonstrate the commitment within ESERA to researching curriculum and policy using a range of methodologies and including international and comparative studies. We hope that you will enjoy reading the papers and that they provide models for related studies in other policy areas across Europe and beyond.

Andreas Redfors & Jim Ryder

THE IMPACT OF AUTHORITARIAN THINKING ON PUBLIC POLICIES AND SCIENTIFIC EDUCATION: A BRAZILIAN CASE[1]

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Considered unconstitutional by the opinion of a Minister of the Federal Supreme Court, the bill "Escola Sem Partido"[2] continues to be referred, discussed and voted in municipal and state chambers throughout Brazil. Through the appropriation of the ideas of thinkers of the Frankfurt School, in the interface between philosophy of education and psychoanalysis, this paper aims to reflect the nature of authoritarian thinking and its implications for the educational field. We performed a qualitative analysis of three records related to the Escola Sem Partido, resulting in five misconceptions that are constantly disseminated by the supporters of the movement. We argue that the fragility of the ego, added to the instrumental rationality of society, results in misleading projections about education and its formative orientation. We highlight the project Escola Sem Partido as a false projection of the educational field, with the presence of many signs of authoritarian thinking directed to education.

Keywords: Educational Reform, Science Education Policy, Culture and Education.

INTRODUCTION

The "Escola Sem Partido" project in the context of recent Brazilian public policies

In a global context of education perspectives in the neoliberal system, in Brazil there is a deepening of the implementation of unpopular public policies after the dismissal of the Dilma government. At first, the National Common Curricular Base (BNCC) underwent major changes in the post-impeachment period (2016), both in the conduct of its process and in its content. Subsequently, the Secondary School Reform (Law 13,415 of 2017), breaking with the democratic rites that followed the Brazilian Constitution of 1988, appears as the imposition of the executive government of an anachronistic proposal, with hasty ballots in the Chamber of Deputies. Finally, the project "Escola Sem Partido" comes on the scene. Although considered unconstitutional by the opinion of the Minister of the Supreme Court Luis Roberto Barroso, continues to process in several municipal and state legislative chambers of Brazil.

In its website, the project is justified as "a reaction to the phenomenon of instrumentalisation of education for political-ideological, partisan and electoral purposes"[3], but its movement has caused disturbing reactions from the point of view of a democratic education. Recent literature has reiterated that the Escola Sem Partido uses a "language close to common sense, resorting to simplistic dichotomies that reduce complex issues to false alternatives" (Penna, 2017), in the

[1] Work presented at the VI National Symposium on Science and Technology Education (SINECT), held in the city of Ponta Grossa, Paraná, Brazil, from 27 to 30 November 2018.
[2] A literal translation could be "Unpolitical School".
[3] Available in: <http://escolasempartido.org/midia/395-entrevista-de-miguel-nagib-a-revista-profissao-mestre>.

case of "proposing supposedly neutral ideas, but which conceal, in fact, a strongly persecutory, repressive and violent content "(Ramos, 2017).

Populist and sensationalist, the movement manages to channel the frustrations of a population weary of daily maladjustments and the sensation of a world in permanent disenchantment - a feeling often reinforced and nourished by the banalization of (in)formation in virtual media. In their supporters, there are tendencies of aggressive and intolerant positioning that, instead of encouraging the debate and the collective construction of the best ways to guide the national education, close to the dialogue and always try to impose their point of view to whom thinks differently. These Brazilian movements are in line with similar international mobilizations that advocate the need for a "neutral school" (as in the case of the United States) or the German "Neutrale Schule Berlin" website of the far right AfD party, which serves as a platform of teacher denunciation.

Contributions of Critical Theory to reflect on authoritarian thinking in education

We turn to the studies of the thinkers of the Frankfurt School to reflect the education and the tendencies of thought that permeate society.

As observed in the capitalist world, the fragmentation of the school, which is subject to the logic of the market, corresponds to an experience with profound implications for the non-realization of a democracy whose foundation is the realization of autonomous and emancipated individuals. For this reason, “the relationship of loss of autonomy for thought, which has been standardized by the administration of the logic of the common denominator and the utility function, implies, according to Adorno, in the process of barbarizing culture” (Carnio, 2012, p. 62).

To this barbarization of culture, Adorno refers mainly to the experience of apology and totalitarianism of German Nazism experienced by him and other members of the Frankfurt School. Recalling that emblematic episode in the history of mankind, he argued that the most basic objective for which education should strive was “that Auschwitz should not be repeated” (Adorno, 1995, p. 1). When emphasizing that “the attempt to overcome barbarism is decisive for the survival of humanity” (Adorno, 1950, p. 156), we list the central point of the author's thought in education, highlighting the need and importance of reviewing the educational and the formative objectives that we want in our schools.

Horkheimer (2002) analyzes the influence of the culture of each epoch on the familiar and psychic constitution of the subjects, in which "each new impression of the world is already preformatted by it" (219). Already Adorno and Horkheimer (1972) understand rationality (or enlightenment) as an escape from the fear of the unknown, where Homer's Odyssey would represent the prototype of the bourgeois individual.

For these thinkers, all perception about the world is the fruit of a projection of the subject to the world. Thus, the outside world would have a similar amplitude to the inner world, where the semiformation (or malformation) of the subjects would result in false projections of reality. In these cases, instead of the internalization of the social imperative (culture) in the subject's psychic structure, there is an immediate identification with stereotyped values scales fed by the subject himself. This lack of a genuine relation to things (Adorno, 1975) is due in large part to the ego's fragility in dealing with its own frustrations and limitations.

In addressing the study of Authoritarian Personality, Adorno (1950) reflects why people are acting against their own interests. In analogous reflection, we aim to analyze how the ideas and educational conceptions propagated by the No-Party School go against the contemporary educational tendencies that cherish the construction of autonomous and critical consciences of the students.

METHOD

It is a research based on historical dialectical materialism that values a historical and contextual treatment of the object. Without disregarding the fact that the social subject is part of the social phenomenon he studies, we value a historical and contextual treatment of the object, in “a supplementary effort to understand the current situation” (Bogdan & Biklen, 1994, p. 91).

In order to provide a broader picture of the foundations of the Escola Sem Partido, the composition of analysis records considered the different spheres of life in which authoritarian thinking is revealed and reproduced (Adorno, 1998; Horkheimer, 2002). Three registers of great influence in the public debate are analyzed: i) the contextual level of public policy, through the Bill in its entirety[4]; ii) the family level, based on a speech by the lawyer Miguel Nagib - who proposed the Law from a case in the school of his son - in a special commission of the project[5] and iii) the individual level, through the story of Ana Caroline Campagnolo, a history teacher who claims to have suffered ideological persecution by her mentor at the graduate school[6]. From these materials we identified five misconceptions that are related to the presence of signs of authoritarian thinking in Brazilian scientific education.

RESULTS

In its Article 1, Bill 867/2015 intends to be inserted in the Laws of Directives and Bases of Brazilian national education, based on VII principles that are exposed in Art. 2 (which it says are based on the Constitution, however with relevant subtractions). The ideological and repressive tone of the proposal takes shape in the following article, when it

> 3rd. In the classroom, the practice of political and ideological indoctrination as well as the transmission of content or activities that may be in conflict with the religious or moral beliefs of parents or guardians of students (PROJETO, 2015, p. 2).

Subsequently, he exposes six "duties of the teacher" which, at first glance, may converge opinions that the teacher should not even take advantage of the "captive audience" of the students to "co-opt" or "harm" them because of their convictions political, ideological, moral or religious, or lack of them "(Project, 2015, p. 4), under a critical eye it is clear that it is an argumentative technique that builds a hypothetical educational scenario where such practices would already be the rule, and not the exception.

The project's justification reveals the concern with the “sexual morality” taught in the textbooks. When this does not coincide with the values preached by the family, they are considered "practice of political and ideological indoctrination in schools, and the usurpation of parents' right to their children to receive moral education that is in accordance with their own convictions" (Project, 2015, p. 4). Finally, 17 topics represent “illicit practices that violate fundamental rights and freedoms of students and their parents or guardians” (Project, 2015, p. 4).

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[4] Available in: < http://www.epsjv.fiocruz.br/sites/default/files/files/PL.pdf >. Accessed in August 2018.
[5] Available in: < https://www.youtube.com/watch?v=5aKkQ8RN2dc>. Accessed in July 2018.
[6] Available in: < https://www.youtube.com/watch?v=4GW9abYxlOA&t=1003s>. Accessed in July 2018.

Lawyer Miguel Nagib has gained notoriety as a result of his participation in the preparation and dissemination of the Escola Sem Partido project. In that presentation at a public hearing, the lawyer begins his speech by presenting some examples to justify the need for the project. Among them, i) the audio of a person denouncing the legal excesses in the persecution of former President Lula at the expense of the release of other political figures (0min1sec), ii) the video of a teacher in the schoolyard, criticizing the recent reforms educational and suggesting that students demonstrate (2min30sec); iii) a video of a hall full of students repeatedly shouting “Fora Temer” (6min30sec); and iv) posters and dissemination of a project of the Gender Center of UFSC where the deconstruction of gender prejudices is developed with students of basic education, inviting them to express themselves through drawings (8min30sec).

According to Nagib, “[...] this is what many teachers understand by critical vision, by critical thinking: attacking your enemies, attacking your political, ideological opponents” (2min13sec), “[...] using students as mass of maneuver of their own political and partisan interests ”(6min09sec). In his view, "[...] there are parents who are forced to send their children to school, who disagree with this point of view" (10min30sec), and this would be "[...] the result of this political and party indoctrination , of this systematic propaganda that has been made in the education systems, in the classrooms of public and private schools ”, transmitting“ to the children of others their own moral values ”(10min53sec). Then, the lawyer presents the Bill saying that it was inspired by the consumer protection code, where “the consumer, in this case the consumer of educational services provided by schools, by the State or by the private school, he has the right to know the your rights - this is citizenship ”(15min30sec).

Also in a public audience report, history professor Ana Caroline Campagnolo was invited by the Chamber “[...] exactly to prove that there is indeed indoctrination” (0min27sec). She says she suffered indoctrination and religious persecution from the professor who was her master's advisor from 2013 to 2015. Ana reports that she graduated in history at a private university and passed a master's selection at a public university. In the first e-mails exchanged with the teacher, she was very polite and said that both would do a good job. However, after some colleagues sent e-mails to the advisor teacher denouncing Ana's publications on facebook - containing Bible verses - the teacher suggested that “[...] you have every right to be anti-feminist or conservative, but not it matches this research or the practices we have about achievements ... ”(2min17sec).

Ana claims to have suffered political and partisan persecution in the course, mainly by the teacher, who "[...] has a certain power conferred on her by the State" (7min57sec). When delimiting the extent to which religious thought would be able to dialogue with the line of research in question, she considers that the teacher, who is a civil servant, “[...] a civil servant, who receives money from mine and from your tax, which go to her salary, but in her discipline can only be those who agree with the premises of feminism and other theories ”(16min30sec).

From this first contextualization of the records, we can identify five thematic axes that, still showing traces of authoritarian personality along the lines of the thinkers of the Frankfurt School, also demand new systematizations and resignifications of these references in analyzes of the educational field. Are they:

Teaching authority and parental authority: conflict between public and private interest in the school field

The project is based on a false dichotomy between the teacher's freedom to teach and the students' freedom to learn. As the main pedagogical currents consider that the process of teaching and learning is two-way (teachers and students as beings in permanent formation), the premise that should guide educational practices is that of dialogue, not that of vigilance, punishment, of coercion.

Historically, the family sphere is recognized as the sphere of individual rights and freedoms where the authority of parents over the values, norms, customs, traditions and cultural affinities produced and reproduced in this environment prevails, even reaching, in bourgeois society, little by little. little to transform authority into introjected coercion (Horkheimer, 1990). In contrast, the public and social sphere is characterized by the appropriation of that broader culture that permeates the whole of society, with the school being one of the main institutional means where this enculturation occurs, that is, the learning of values and precepts that enable tolerance, respect, coexistence and learning with perceptions of the world and ways of life naturally different from those of the family.

Therefore, in the school environment, the prevalence of difference would not be an obstacle, but a fundamental aspect for social life and for the formation of citizens. However, it is common in the records analyzed that the school should not “overlap” its teaching with family values. The concern with the students' moral formation is constant throughout the project, which can be mentioned in item 15:

> Now, if it is up to parents to decide what their children should learn in terms of morals, neither the government, nor the school, nor teachers have the right to use the classroom to deal with moral content that has not been previously approved by students' parents (Project, 2015, p. 8).

By not recognizing school and teachers the competent authority to organize and develop pedagogical projects, the project seeks to override the particular interest above the public interest.

False dichotomization between disciplinary content and values

In the words of project proponents, the idea that disciplinary content is "pure" and separate from ethical, moral, and cultural appropriations of society is permanently present. Such a view disregards the fact that scientific knowledge not only represents changes in our ways of understanding the world, but also influences our own constitution as subjects of this world.

> Instead of internalizing the social imperative - which not only gives it a more mandatory and at the same time more open character, but also emancipates from society and even turns it against society - there is a ready and immediate identification with stereotyped value scales (Adorno; Horkheimer, 1985, p. 163).

Coupled with this projection of educational ideas based solely on life experience, there is little evidence of the support of Escola Sem Partido supporters to dialogue with literature or even with education professionals - especially teachers, who are effectively in the classroom. Such a positioning proves to be authoritarian, of those who want to impose their way of seeing others. From a psychoanalytic point of view, this aversion to different thinking is due to the constitution of a weakened ego that, because it is unable to discern its false projection of concrete reality, becomes unable to open up to the different and recognize its own limitations. In this sense, it is imperative that scientific education makes it possible to reflect on the values, beliefs, premises, foundations and attitudes of the subjects.

Between freedom of opinion and arbitrary relativization of scientific knowledge

In Ana Maria Campagnolo's account a conceptual confusion is evident: the claim that, because she is attending an institution of public education - which is supported by taxpayer money - every opinion or view of the world must be accepted, regardless of its validity before the current lines of scientific research historically consolidated.

Upon hearing from the professor “If we are here in this course, it is because we enrolled in a perspective of thought” (5min02sec), Ana interpreted that her teacher would be abusing her power in graduate school, taking the position of banning the student from course. However, it is noted that the teacher aimed to explain that Ana's ideas, although legitimate in the private sphere or in the course as a whole, did not maintain coherence with the historically constructed knowledge related to that discipline.

The characteristics of conventionalism and cynicism are typical of authoritarian thinking (Adorno et al., 1950), in which, through fallacies and false comparisons, the oppressor victimizes himself, revealing difficulties in dealing with his own frustrations. When the prevailing intersubjective discourse is one of hatred and annulment of the other, consciousness, instead of understanding explicit contradictions, is attached to fixed ideas, denying reality. “Individual autonomy disappears with the subjects' psychological impoverishment in the face of objective irrationality (Gomide, 2011, p. 130).

In favor of her freedom of opinion, the teacher makes an arbitrary relativization of scientific knowledge. That is, although they are legitimate in the private sphere, to be recognized as potential scientific research, personal opinions should seek certain coherence with the historically constructed knowledge related to some discipline or line of research.

Another element present in the analyzes was the concept of citizenship supported by the pedagogical common sense. In a reductionist allusion to the concept of citizenship, the bill argues that "the best way to combat abuse of the freedom to teach is to inform students of their right not to be indoctrinated by their teachers" (Project, 2015, p. 8). This passage overlooks the potential of education to provide individuals with critical thinking beyond the sociocultural structures of which they are a part, and thus seems to point to the reproduction rather than the confrontation of the contradictions of social life.

The concept of citizenship based on pedagogical common sense: a defense against critical thinking

In a world totally permeated by science and technology, training for citizenship necessarily requires strong scientific training that includes both elements of science (content, concepts, procedures and methods) and elements about science (the functioning of science, its relationship with society, its relation to ethical, moral, cultural, value, power and economic interests).

Between the true object and the undoubted data of the senses, between the interior and the exterior, an abyss opens up that the subject has to overcome at his own risk. To reflect the thing as it is, the subject must give back more than he receives from it. The subject recreates the world outside him from the vestiges that the world leaves in his senses (Adorno; Horkheimer, 1985, p. 155).

In this case, the subject has already objectified the phenomenon in question (citizenship), and, without realizing the gap of “vestiges that the world leaves in his senses”, he returns to the world only the petrified image of a concept that limits all potential emancipatory that the term citizenship should include. Self-sabotage of the struggle for rights.

The teacher as the origin of all evil: the construction and demonization of the enemy

Finally, the bill and its supporters consider the teacher as the origin of all evil in education, and so build the image of this professional as if it were an enemy to be fought. The use of terms extraneous to contemporary education reinforces the persecutory character of the present proposal, which refers to students as a "captive audience" on which teachers would seize and co-opt "because of their political, ideological, moral or religious convictions, or of their lack ".

Proponents are unaware of the complexities and demands to which teachers are subjected, and, consciously or not, they create a ghostly image (scarecrow) of a teacher and generalize characteristics considered bad - a characteristic process of a group that seeks to unite and legitimize itself by building stereotyped images of outsiders, those who think differently.

Such constructs are part of the subjects' own life repertoire. By disregarding all the theoretical and methodological foundations focused on the pedagogical aspects of teacher training and the effective reality of the school context, it remains to charge that teachers work on political, socio-cultural and economic issues in a “fair way” (item IV), not favoring or harming students. students because of these convictions (item 2). All that remains is the “inability of the subject to discern in the projected material between what comes from him and what is alien” (Adorno; Horkheimer, 1985, p. 154). Phantom images of teachers are created, generalizing characteristics considered bad.

DISCUSSION

We find that the pillars of the argumentation of the Escola Sem Partido Project stem from false projections about the formative sense of education and about the role of the teacher in the teaching process. This is exacerbated by the lack of openness to dialogue and the stereotyped way in which people think differently.

Insofar as, on the whole, there is a growing trend towards the dissolution of the guarantees of the rule of law, the encouragement of meritocracy and the blame of the individual for his ills, studies and research in scientific education must begin to consider the aspects of the subjects' psychic formation, in a dialectical relation. The loss of teaching authority, the overlapping of private interests to the public interest and the relativization of scientific knowledge are elements that can be analyzed in the light of this relation between philosophy, sociology and psychoanalysis.

We believe that the research contributed with theoretical references that propose elements of resistance and emancipation to the authoritarian invested with conservatism in education and scientific education.

ACKNOWLEDGEMENT

Thanks to CAPES for funding and to the Postgraduate Program for Science and Mathematics at the State University of Maringá (UEM).

REFERENCES

Adorno, T. W. (1975). Opinión, demencia y sociedad. In: *Filosofía y superstición* – Madrid, Alianza/Taurus.

Adorno, T. W. (1995). ***Educação e emancipação***. São Paulo: Paz e Terra.

Adorno, T. W. (1998). Education after Auschwitz. In: *Critical Models: Interventions and Cathwords. New York: Columbia University Press*.
Adorno, T. W.; Frenkel-Brunswik, E., & Levinson, D. J.,& Sandford, R. N. *The Authoritarian Personality*. New York: The Norton Library, 1950.
Bogdan, R., & Biklen, S. K. (2003). *Qualitative research for education*: An introduction to theory and methods. Boston: Allyn and Bacon.
Carnio, M. P. ***O significado atribuído por licenciandos ao currículo de Biologia numa perspectiva CTSA.*** 2012, 192f. Dissertação (Mestrado em Educação para a Ciência). Faculdade de Ciências, Universidade Estadual Paulista, Bauru, 2012.
Horkheimer, M. (2002). Culture, family and authority. In: *Critical Theory*: selected essays. New York: Continuum.
Horkheimer, M., & Adorno, T. W. (1972). *Dialectic of enlightenment*. [New York], Herder and Herder.
Penna, F. (2017). O Escola sem Partido como chave de leitura do fenômeno educacional. In: Frigotto, G. *Escola "sem" partido*: esfinge que ameaça a educação e a sociedade brasileira. Rio de Janeiro: UERJ, LPP.
Project. *Projeto de Lei nº 867/2015*: Escola Sem Partido, 2015.
Ramos, M. N. (2017). Escola sem Partido: a criminalização do trabalho pedagógico. In: Frigotto, G. *Escola "sem" partido*: esfinge que ameaça a educação e a sociedade brasileira. Rio de Janeiro: UERJ, LPP.

ANALYSIS OF IMPLEMENTED SCIENCE CURRICULA: AN APPROACH FROM TEACHERS' PEDAGOGICAL PERSPECTIVES

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The science curriculum is delivered to students through a controlled process at different levels and in various contexts. Although it has been said that science teachers' viewpoints and attitudes influence the interpretation of curricula, we were interested in factors affecting their pedagogical perspectives, such as their beliefs and teaching practices. Therefore, the objective of this research was to assess implemented curricula from the pedagogical perspectives of science teachers in Japan. To achieve this objective, we conducted a survey of lower secondary science teachers in Japan and England. We then examined their pedagogical perspectives both quantitatively and comparatively. Based on the empirical research data, we discussed science teachers' pedagogical perspectives in the context of proximal fields of study, and with references to research literature more closely related to the present investigation. Through empirical and theoretical analyses, we concluded that sociocultural contexts imbued in Japanese society serve as universal elements, and are accepted implicitly by Japan's science teachers. These customs serve to regulate implemented science curricula in Japan.

Keywords: Science Curriculum, Pedagogical perspectives, Sociocultural contexts

BACKGROUND AND THEORETICAL FRAMEWORK

Learning contents such as science curricula are delivered to students through a controlled process at different levels and according to various contexts (Goodson & Dowbiggin, 1994; Jenkins, 2000; Lloyd-Staples, 2012). Logically, science curricula, such as the Course of Study in Japan and the National Curriculum in England, affect classroom practices of science teachers. Ryder and Banner (2013) analysed the effect of secondary science teachers by reforming the National Curriculum, and Hanley, Ratcliffe, and Osborne (2007) also examined science teachers' experiences of teaching 'ideas-about-science' in Twenty First Century Science (GCSE Science courses) developed by the University of York Science Education Group (UYSEG) beginning in the early 2000s. All these studies found that changes in science educators' teaching practices were neither uniform nor dramatic; rather, they were various and gradual. However paradoxical it may be, science teachers also shape the science curriculum based upon their own beliefs and knowledge about science lessons. Fensham (2009) referred to many countries' traditions of teaching/learning pedagogy as teachers' authoritative domain, indicating that '[t]he "how" of teaching is seen as the teachers' province' (p. 1086). The research focusing on teachers as important figures who connect policies and classrooms is arguably playing its exact role and significance. It is inevitable that the 'Implemented Curriculum' defined by the International Association for the Evaluation of Educational

Achievement (IEA) has gaps between 'Intended Curriculum' and 'Attained Curriculum' due to diversity in teachers' knowledge and beliefs, as well as other factors that affect science lessons.

Many studies on teachers' knowledge and beliefs have been conducted thus far (e.g. Barnett & Hodson, 2001; Lumpe, Haney, & Czerniak, 2000; Lunn & Solomon, 2000; Magnusson, Krajcik, & Borko, 1999; Nespor, 1987; Pajares, 1992; Shulman, 1986, 1987; Simmons et al., 1999; Van Driel, Beijaard, & Verloop, 2001). Shulman (1986, 1987) advocates pedagogical content knowledge (PCK)—the special amalgam of content and pedagogy that identifies the distinctive bodies of knowledge for teaching—and also discusses the phases of pedagogical reasoning and action (i.e. comprehension, transformation, instruction, evaluation, reflection, and new comprehensions). Magnusson et al. (1999) conceptualise PCK for science teaching as consisting of five components: orientation toward science teaching, knowledge of science curriculum, knowledge of students' understanding of science, knowledge of assessment in science, and knowledge of instructional strategies. The authors indicated that these components function as parts of science teaching by interacting in highly complex ways. These studies assume that science teachers can teach only within the knowledge structure they possess. However, science teachers' beliefs are also involved. It is difficult to make a clear distinction between knowledge and beliefs, and we cannot specify the boundary where knowledge ends, and belief begins. Nespor (1987) and Pajares (1992) attempt to distinguish beliefs from knowledge theoretically, and to identify the structure and features of teachers' educational beliefs. Such studies argue that teachers' beliefs—rather than their knowledge—strongly affects their behaviours in the classroom (Nespor, 1987; Pajares, 1992). In sum, while beliefs and knowledge are closely intertwined, beliefs are acquired through the process of cultural transmission and these beliefs act as a filter when teachers faced something new phenomena. Barnett and Hodson (2001) suggest that good teachers have the ability to respond to shifting contexts in appropriate ways and coined the term pedagogical *context* knowledge. This is an extension of knowledge than PCK, and also considers societal knowledge landscape. Pedagogical *context* knowledge consists of four elements that overlap and interact with each other: academic and research knowledge, PCK, professional knowledge, and classroom knowledge.

Dillon and Manning (2010) note that pedagogy implies the whole philosophy and value system that leads teachers to make choices about what they do and how they teach. In this study, we focus on science teachers' beliefs and teaching practices, defining them as 'science teachers' pedagogical perspectives'.

AIMS AND RESEARCH QUESTIONS

The objective of this study is to assess the implemented curricula from science teachers' pedagogical perspectives using a comparative approach. Hence, the following research questions were formulated:

(1) Is there a difference between Japanese science teachers' perspectives and those of science teachers in England?

(2) If so, how does the sociocultural situation regulate Japanese science teachers' pedagogical perspectives?

SAMPLE AND METHODS

To answer these research questions, we designed a survey for lower secondary science teachers so that we could analyse their pedagogical perspectives. We arranged the direction of this survey at Hiroshima University in Japan and the University of Leeds in England; then, we selected the following three dimensions of science teaching: *science teachers' beliefs*, *the approach used in designing lessons*, and *the method used in teaching science*. The survey instrument used in this research was a questionnaire conducted in Japan (Hiroshima) and England (Leeds) that consisted of carefully selected items, and each question was based on the selection form to analyse the findings objectively and statistically.

First, we conducted a pilot survey of science teachers in a training course for students at Hiroshima University (Japan) and the University of Leeds (England). We collected 24 Japanese data in May 2013, and 11 English data in June 2013, respectively. The questionnaire was modified to make the nuances of Japanese and English equal based on the pilot survey results.

Next, we conducted a final survey of 84 science teachers at lower secondary schools in Hiroshima (Japan) in July 2013, and 24 science teachers at comprehensive schools in Leeds (England) in December 2013. Valid responses were obtained from 79 teachers (Japan) and 24 teachers (England), respectively. In order to exclude special cases, the target schools in both countries were narrowed down to comprehensive schools, and the science teachers working there were randomly selected. By doing this, we tried to approach the derivation of the general characteristics of both countries, although this was a local survey. The quantitative data from the questionnaires were summarised in tabular form and statistical tests were applied.

Finally, we examined the factors involved in forming science teachers' pedagogical perspectives based on the survey results from quantitative and comparative viewpoints. Additionally, we discussed the science teachers' pedagogical perspectives in relation to the proximity field of research and with references to the relevant research literature. Through these research methods, we attempted to clarify the phases of an implemented science curricula in Japan both empirically and theoretically.

DATA COLLECTION AND ANALYSIS

To investigate whether Japanese science teachers' pedagogical perspectives differed from those of science teachers in England, we conducted a survey using a comparative approach. The quantitative data from the questionnaires were summarized in tabular form, and statistical tests were applied. We performed cross-tabulations with regard to science teachers' pedagogical perspectives in Japan and England, respectively. The data collected were qualitative data of nominal scale (categorical data) with small sample sizes, and the frequencies were unevenly distributed. Therefore, we statistically analysed the significant difference between the two groups using Fishers' exact test of nonparametric method. In analysing the significant difference, the numerical value of 'Blank (Unidentified)' has no meaning, and there was a fear that an erroneous result could be obtained in the analysis. Consequently, the numerical value of 'Blank (Unidentified)' was excluded in each statistical test. In addition, some responses regarding personal information were incomplete, so the totals did not coincide with the number of valid responses.

First, we investigated to what extent the differences in terms of country affect science teachers' beliefs. We performed a cross-tabulation with regard to beliefs of science teachers in Japan and England (see Table 1).

Table 1. A Cross-tabulation regarding science teachers' beliefs in Japan and England

	The most important learning objective in school science								
Country (Region)	1. Skills of laboratory work and observation	2. Knowledge and understanding about science	3. "Decision-making" ability based on scientific evidence	4. Scientific thinking	5. Interest in science	6. Ability to explain scientifically	7. Investigation and inquiry	8. The relation between science and daily life	9. The others
Japan (Hiroshima) (n = 74)	3 (4.1)	9 (12.2)	11 (14.9)	10 (13.5)	16 (21.6)	1 (1.4)	4 (5.4)	19 (25.7)	1 (1.4)
England (Leeds) (n = 17)	0	7 (41.2)	0	1 (5.9)	2 (11.8)	2 (11.8)	0	5 (29.4)	0
Total (N = 91)	3 (3.3)	16 (17.6)	11 (12.1)	11 (12.1)	18 (19.8)	3 (3.3)	4 (4.4)	24 (26.4)	1 (1.1)

Figures in parentheses are percentages of n or N values relating to each row.

The percentage of science teachers who considered 'the relation between science and daily life' the most important was high in both countries. But, on the other hand, the percentage of science teachers who considered 'interest in science' the most important was high in Japan, whereas that of science teachers who considered 'knowledge and understanding about science' the most important was high in England. A finding from Fisher's exact test indicated that a significant difference appeared at the 0.05 level ($p < .05$).

Next, we investigated to what extent differences based on country affect the approach used in designing science lessons. We performed a cross-tabulation with regard to the approach used in designing lessons in Japan and England (see Table 2). In Japan, the percentage of science teachers who considered 'textbooks' to be the most useful resource for designing lessons was high, whereas the tendency was different in England. The percentage of science teachers who considered 'national curriculum' and 'the others (e.g. schemes of work, specification, etc.)' as the most useful information for designing lessons was high in England. A finding from Fisher's exact test indicated that a significant difference appeared at the 0.01 level ($p < .01$).

Table 2. A Cross-tabulation regarding the approach used in designing lessons in Japan and England

The most useful information for designing science lessons

Country (Region)	1. Textbooks	2. National curriculum	3. Textbook publishing company's instruction books for teachers	4. Notebooks of your own composition (Your own experience)	5. Pupils' current knowledge	6 The policy of your school	7. Materials of outside seminars and workshops	8. The others
Japan (Hiroshima) (*n* = 72)	30 (41.7)	5 (6.9)	7 (9.7)	12 (16.7)	12 (16.7)	0	4 (5.6)	2 (2.8)
England (Leeds) (*n* = 17)	0	5 (29.4)	0	2 (11.8)	2 (11.8)	2 (11.8)	0	6 (35.3)
Total (*N* = 89)	30 (33.7)	10 (11.2)	7 (7.9)	14 (15.7)	14 (15.7)	2 (2.2)	4 (4.5)	8 (9.0)

Figures in parentheses are percentages of n or N values relating to each row.

Finally, we investigated to what extent differences based on country affect the method used in teaching science. We performed a cross-tabulation regarding this topic for science teachers in Japan and England (see Table 3).

Table 3. A Cross-tabulation regarding the method used in teaching science in Japan and England

The most useful teaching material(s) for science lessons

Country (Region)	1. Textbooks	2. Exercise books	3. Explanatory diagrams	4. Worksheets of your own making	5. Worksheets of textbook publishing company making	6. Teaching materials for experiment and observation	7. ICT resources	8. The others
Japan (Hiroshima) (*n* = 70)	24 (34.3)	0	4 (5.7)	18 (25.7)	1 (1.4)	12 (17.1)	8 (11.4)	3 (4.3)
England (Leeds) (*n* = 16)	0	3 (18.8)	1 (6.3)	4 (25.0)	0	2 (12.5)	4 (25.0)	2 (12.5)
Total (*N* = 86)	24 (27.9)	3 (3.5)	5 (5.8)	22 (25.6)	1 (1.2)	14 (16.3)	12 (14.0)	5 (5.8)

Figures in parentheses are percentages of n or N values relating to each row.

The percentage of science teachers who considered 'Worksheets of your own making' to be the most useful teaching material was high in both countries. But, on the other hand, the percentage of science teachers who considered 'textbooks' the most useful teaching material was high in Japan, whereas that of science teachers who considered 'ICT resources' the most useful teaching material was high in England. A finding from Fisher's exact test indicated that a significant difference appeared at the 0.01 level ($p < .01$).

Results of Fisher's exact test indicated that significant differences appeared in all dimensions, though they differed in degree. Among the three dimensions of science teaching, *the approach used in designing lessons* and *the method used in teaching science* showed a marked difference compared to *science teachers' beliefs*. These results show that the country in which a teacher worked influenced differences involving science teachers' pedagogical perspectives. From analysis of empirical research data (Nozoe & Isozaki, 2016, 2018), we interpreted that a science teacher's pedagogical perspective was informed by the respective country in which he or she taught.

DISCUSSION AND CONCLUSION

Dillon and Manning (2010) argued that science teachers' pedagogical development relates to their perceived need to challenge the orthodox 'teaching values and intentions' (p. 14), which manifest themselves in what many would describe as 'traditional science teaching' (p. 14). 'Traditional science teaching in Japan' should be questioned. Generally, Japanese science teachers are trained at domestic universities; then, they belong to the teacher group at the school and acquire the paradigm, which includes their roles and positions. Kind (2009) indicated that part of the process involved in becoming a science teacher is a re-shaping of subject matter knowledge (SMK), adapting prior personal SMK to an extent that is replaced by a modified version for school use. That is to say, after being science teachers, their professional development has been conducted within their professional societies and in the context of their professional culture (e.g. Isozaki, 2015, 2016). For instance, Japan's 'lesson study' is embedded in the traditional culture of science teachers and may provide significant opportunities for both novice and experienced science teachers to develop appropriate competencies. During their professional development, teachers acquire the paradigm that contains elements of tacit knowledge, which cannot be specified or recognised consciously. In other words, it can be argued that the educational culture of a country regulates its science teachers at a deep level.

Hammond and Brandt (2004), who discussed an anthropological approach to science education, indicated that pedagogical questions of who teaches science, how it is taught, and what ends it serves take on new meanings that can be addressed through research by using a cultural approach that assumes science learning is a cultural as well as a cognitive activity. Since culture is something that be inherited rather than changed, the paradigm possessed by each science teacher inevitably has been inherited to include some room for their improvement; it is not a new creation without an underlying framework. Culture internalised by science teachers in each country involves 'universality' and 'variability'; that is, the former elements which are inherited in the period and society in which they live, and the later elements which are more individualised. What is the universal culture inherited by science teachers in a specific country? Generally, teachers understand their students' cultural experiences, scientific practice (ways of knowing, doing, and talking science), and habits of mind (scientific values, attitudes, and worldviews). Thus, they are able to relate science to students' background experiences (Carlone, Johnson, & Eisenhart, 2014). Japanese science teachers, for instance, have taught science based on Western culture to their students living in Japanese cultural world (Kawasaki, 1996; Ogawa, 1986, 1989, 1995). Specifically, '[c]ultural differences in cognition could affect the way the learner approaches the subject matter of science education because of presuppositions about the nature of the world that the learner brings to the learning situation' (Erickson, 1986, p.121). In other words, teachers have taken on the role of culture brokers (Jegede & Aikenhead, 1999). Such sociocultural contexts are inherited implicitly as universal elements by science teachers, thereby regulating traditional science teaching in Japan directly.

ACKNOWLEDGEMENT

The authors would like to thank the University of Leeds for its helpful support. In particular, we are deeply grateful to Professor Jim Ryder for his insightful suggestions. This research was supported by JSPS KAKENHI under grant numbers JP15K17405, JP19K14344.

ADDITIONAL NOTES

This study has been significantly revised by adding new analysis based on the data presented at EASE2016, EASE2018.

REFERENCES

Barnett, J., & Hodson, D. (2001). Pedagogical context knowledge: Toward a fuller understanding of what good science teachers know. *Science Education*, *85*(4), 426–453. https://doi.org/10.1002/sce.1017

Carlone, H. B., Johnson, A., & Eisenhart, M. (2014). Cultural perspectives in science education. In N. G. Lederman & S. K. Abell (Eds.), *Handbook of research on science education* (Vol. II, pp. 651–670). New York, NY: Routledge. https://doi.org/10.4324/9780203097267

Dillon, J., & Manning, A. (2010). Science teachers, science teaching: Issues and challenges. In J. Osborne & J. Dillon (Eds.), *Good practice in science teaching: What research has to say* (2nd ed.) (pp. 6–19). Maidenhead, UK: Open University Press.

Erickson, F. (1986). Culture difference and science education. *The Urban Review*, *18*(2), 117–124. https://doi.org/10.1007/BF01108432

Fensham, P. J. (2009). The link between policy and practice in science education: The role of research. *Science Education*, *93*(6), 1076–1095. https://doi.org/10.1002/sce.20349

Goodson, I. F., & Dowbiggin, I. R. (1994). Curriculum history, professionalization and the social organization of knowledge. In I. F. Goodson (Ed.), *Studying curriculum* (pp. 40–50). Buckingham, UK: Open University Press.

Hammond, L., & Brandt, C. (2004). Science and cultural process: Defining an anthropological approach to science education. *Studies in Science Education*, *40*(1), 1–47. https://doi.org/10.1080/03057260408560202

Hanley, P., Ratcliffe, M., & Osborne, J. (2007, August). Teachers' experiences of teaching 'ideas-about-science' and socio-scientific issues. Retrieved from http://eprints.soton.ac.uk/57904/1/esera_21C_paper.pdf#search=%27Teachers'+experiences+of+teaching+'ideasaboutscience'+and+socioscientific+issues%27

Isozaki, T. (2015). Lesson Study research and practice in classroom. In R. Gunstone (Ed.), *Encyclopedia of science education* (pp. 615–618). Dordrecht, The Netherlands: Springer Reference.

Isozaki, T. (2016). How have Japanese *Rika* (School science) teachers traditionally formed their own cultures and improved their teaching competencies through research and practice? In M.-H. Chiu (Ed.), *Science education research and practice in Asia: Challenges and opportunities* (pp. 517–538). Singapore: Springer.

Jegede, O. J., & Aikenhead, G. S. (1999). Transcending cultural borders: Implications for science teaching. *Journal for Science & Technology Education*, *17*(1), 45–66.

https://doi.org/10.1080/0263514990170104
Jenkins, E. W. (2000). Changing science teachers' work: A question of professionalism. *School Science Review*, *81*(297), 15–22.
Kawasaki, K. (1996). The concepts of science in Japanese and Western education. *Science & Education*, *5*, 1–20.
Kind, V. (2009). Pedagogical content knowledge in science education: perspectives and potential for progress. *Studies in Science Education, 45*(2), 169–204. https://doi.org/10.1080/03057260903142285
Lloyd-Staples, C. (2012). *Implementation and impact of the secondary science national strategy*. Saarbrücken, Germany: LAP LAMBERT Academic Publishing.
Lumpe, A. T., Haney, J. J., & Czerniak, C. M. (2000). Assessing teachers' beliefs about their science teaching context. *Journal of Research in Science Teaching*, *37*(3), 275–292. https://doi.org/10.1002/(SICI)1098-2736(200003)37:3<275::AID-TEA4>3.0.CO;2-2
Lunn, S., & Solomon, J. (2000). Primary teachers' thinking about the English national curriculum for science: Autobiographies, Warrants, and Autonomy. *Journal of Research in Science Teaching*, *37*(10), 1043–1056.
Magnusson, S., Krajcik, J., & Borko, H. (1999). Nature, sources, and development of pedagogical content knowledge for science teaching. In J. Gess-Newsome & N. G. Lederman (Eds.), *Examining pedagogical content knowledge* (pp. 95–132). Dordrecht, The Netherlands: Kluwer Academic Publishers.
Nespor, J. (1987). The role of beliefs in the practice of teaching. *Journal of Curriculum Studies*, *19*(4), 317–328. https://doi.org/10.1080/0022027870190403
Nozoe, S., & Isozaki, T. (2016). A comparative study of science teachers' beliefs on lessons between Japan and England. In *Innovations in science education research & practice: Strengthening international collaboration. The Official E-proceedings EASE 2016 Tokyo*, (p. 51). Tokyo, Japan: Tokyo University of Science.
Nozoe, S., & Isozaki, T. (2018). What affects Japanese science teachers' pedagogical perspectives in lower secondary schools? *2018 International Conference of East-Asian Association for Science Education Conference Program*, (pp. 115–117). Hualien, Taiwan: National Dong Hwa University.
Ogawa, M. (1986). Toward a new rationale of science education in non-western society. *European Journal of Science Education*, *8*(2), 113–119. https://doi.org/10.1080/0140528860800201
Ogawa, M. (1989). Beyond the tacit framework of 'science' and 'science education' among science educators. *International Journal of Science Education*, *11*(3), 247–250. https://doi.org/10.1080/0950069890110301
Ogawa, M. (1995). Science education in a multiscience perspective. *Science Education*, *79*(5), 583–593. https://doi.org/10.1002/sce.3730790507
Pajares, M. F. (1992). Teachers' beliefs and educational research: Cleaning up a messy construct. *Review of Educational Research*, *62*(3), 307–332. https://doi.org/10.3102/00346543062003307
Ryder, J., & Banner, I. (2013). School teachers' experiences of science curriculum reform. *International Journal of Science Education*, *35*(3), 490–514. https://doi.org/10.1080/09500693.2012.665195
Shulman, L. S. (1986). Those who understand: Knowledge growth in teaching. *Educational Researcher*, *15*(2), 4–14. https://doi.org/10.3102/0013189X015002004
Shulman, L. S. (1987). Knowledge and teaching: Foundations of the new reform. *Harvard Educational Review*, *57*(1), 1–22. http://dx.doi.org/10.17763/haer.57.1.j463w79r56455411
Simmons, P. E., Emory, A., Carter, T., Coker, T., Finnegan, B., Crockett, D., . . . Labuda, K. (1999). Beginning teachers: Beliefs and classroom actions. *Journal of Research in Science Teaching*, *36*(8), 930–954. https://doi.org/10.1002/(SICI)1098-2736(199910)36:8<930::AID-TEA3>3.0.CO;2-N
Van Driel, J. H., Beijaard, D., & Verloop, N. (2001). Professional development and reform in science education: The role of teachers' practical knowledge. *Journal of Research in Science Teaching*, *38*(2), 137–158. https://doi.org/10.1002/1098-2736(200102)38:2<137::AID-TEA1001>3.0.CO;2-U

FACTORS INFLUENCING TEACHER RESPONSE TO EXTERNALLY DRIVEN CURRICULUM REFORM. A CASE STUDY

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In the framework of the curriculum reforms, the literature emphasizes the importance of contemplating the beliefs of teachers and their perceptions toward it, with aspects that influence the integration of proposed changes in teacher professional identity. This work presents a case study, which examines the factors that manifest a science teacher of secondary education at different stages during the participation in a training program designed to meet the challenges that the reform of the education system poses for science education in Spain. This program involved the completion of tasks of design, implementation, and evaluation of own teaching proposals to promote the development of the scientific competences, using the context-based science teaching approach. For the analysis and categorization of the responses of the teacher, expressed in two individual interviews and a focus group, has been used the proposal of Ryder (2015), complemented with the establishment of the qualifier character, facilitator or obstacle, of the assessments made. The teacher analysed focuses mainly on personal factors, which seems logical considering his short teaching experience. Some of his ideas change, during the training process, to other more in line with the approaches of the reforms, detecting the influence of the peers´ opinions in his own during the focus group.

Keywords: Curriculum reform; In-service Teacher Training; Context-based learning.

INTRODUCTION

In the framework of the curricular reforms, the literature describes a great diversity of factors that determine the integration of the changes required in the teacher professional identity (Donnelly & Jenkins, 2002; Ryder, 2015). To understand the teacher´s responses , numerous investigations highlight the importance of contemplating their beliefs and perceptions toward these reforms (Wallace, 2011; 2016). This work is part of a broader study which analyses the implications for the teaching of sciences of important aspects that are considered by teachers to apply educational reform raised in Spain (Ministry of Education, 2006 & 2013), around the development of scientific competences (Lupión-Cobos, López-Castilla & Blanco-López, 2017) addressed in this research through the use of context-based science teaching (Avargil, Herscovitz & Dori, 2012; Gilbert, Bulte & Pilot, 2011; Pilot & Bulte, 2007).

Among the factors that influence and condition the development, and possible success, of the curricular reforms proposed by the educational administrations, numerous investigations highlight the importance of contemplating teachers' responses to them (De Boer, 2014; De Jong, 2015; Ryder and Banner, 2013) shaped by their beliefs and perceptions about their intentions and their role in them. The specialized literature describes a great diversity of professional factors that participate and condition the teachers' responses and their integration in the face of the changes that their implementation requires in science teachers (Maguire, Ball, & Braun, 2013; Rigano & Ritchie, 2003; Ryder, 2015, 2018).

Ryder (2015), has reviewed the literature that has dealt with the responses of science teachers to curricular reforms from the vision of "what we know about the experiences and reflections of teachers in the enactment of externally driven school science curriculum reform" (Pg. 87). This characteristic of 'Externally driven' is very common in most school curriculum reform processes that make up types of teacher responses, for which it proposes a scheme that includes a large number of factors, in terms of personal, internal and external focus of teachers' work.

The professional identity of the teacher is constructed contemplating his work context, as a socially constituted result and in continuous reformulation process (Squire et al., 2003; Luehmann, 2007), being necessary to contemplate not only the personal perspective but also the social and institutional context in which they produce in the schools (Aikenhead, 2006; Bowe, Ball and Gold, 1992; Spillane, 2006) with aspects of their performance, associated with the social processes involved in the interactions that occur at school and in their relationship with educational structures (Beijaard, Verloop, & Vermunt, 2000; Day, Kington, Stobart, & Sammons, 2006; Leander & Osborne, 2008).

In the search for appropriate strategies to collect the opinions and assessments of teachers, use a variety of scenarios in which teachers participate from more interrogative and individual situations such as the one offered by the interviews, to others that allow the exchange and discussion about the same (Kaplowitz, 2000; Potter & Hepburn, 2005; Guest et al.,2017), as the one contributed by the shared reflection in focus groups (Bloor et al., 2001). The intragroup comparisons promote discussions and a peer contrast that allows access to simultaneously expanded information on their individual identities and makes a collective representation for the researcher (Callaghan, 2005) highlighted differences in the interviewees´ perspectives (Hanley, Maringe & Ratcliffe, 2008; Osborne & Collins, 2001).

With these considerations, in this framework of curriculum reform, this work raised the following issues:

a) What factors do teachers consider that influence the implementation of approaches focused on the development of scientific competences through context-based science teaching?
b) Which of these factors are considered as facilitating and which as obstacles?
c) How these factors evolve along with a training program?

CONTEXT OF STUDY AND DESIGN

As part of a larger project that aims to help science teachers develop the scientific competencies of students in compulsory secondary education (12-16 years) in Spain (Blanco, Franco & Spain, 2016), through the use of a program Long-term training course during the school year (one semester) whose main purpose was to help teachers in the exercise of designing, applying and evaluating their teaching proposals, with which, through the use of the science teaching approach in context (Van Driel, Bulte & Verloop, 2008; Van Driel, Merink, Van Veen & Zwart, 2012), work in the classroom scientific competences (Blanco-López & Lupión-Cobos, 2015; Lupión-Cobos & Blanco-López, 2016).
Four phases were planned (Table 1) that included face-to-face and non-face-to-face training sessions, collecting data from this research at different times during its development with the instruments indicated.

Table *1.* **Phases of the training programme.**

STAGES	TRAINING PROGRAM
1	Scientific competences & Context-based teachings
2	Training in preparing the design
INTERVIEW 1	
3	Design, Implementation & Assessment
INTERVIEW 2	
4	Exchange of Views & Opinions
FOCUS GROUP	

methodology

This research has been carried out in the framework of a training program (Author, 2017), to help secondary science teachers to design, apply and evaluate their teaching proposals, with which to work in the classroom the scientific competences through context-based education (Vos, Taconis, Jochems, & Pilot, 2011).

Participants

It was selected a representative sample of participants composed of four teachers, with different degrees of teaching and professional experience in the design of materials and participation in innovation activities and research. In this work, it is presented, as a case study, the analysis of the interventions of one of those teachers.

Instruments

Two individual interviews were conducted with each teacher, the first one after stage 2 (I1) and the second (I2) after stage 3, and also a focus group (FG) meeting, held after the last interview and after completing the teacher training.

In this way, different moments and scenarios (individual and group) were provided to help teachers express and share different types of reflections and also focus them on the professional level of relationships with their classmates, environment and educational community (Vázquez, Jiménez & Mellado, 2007; Mellado, Ruiz, Bermejo & Jiménez, 2006).

Procedure

The analysis started with the identification, in the transcripts of two individual interviews and focus group, of the fragments considered relevant (units of meaning) for the research questions raised, reaching a consensus of the whole team. Then, the categorization of these units was carried out according to the focus (personal, internal and external) and its factors, proposed by Ryder (2015), being complemented by the establishment, the facilitator or qualifier character, namely as facilitating and obstacle (F/O), depending on the orientation given by the teacher in its manifestation, as shows the following extract of next transcript:

> *Unit 061, FG: "As my unit has been an island in the middle of the sea, I am an island in the middle of the sea of companions, because everyone is going to their own, and when I have commented on seeing what you think, look what I have done, they have answered me, yes, they are going to tell you in the Teacher Trainer Centre that it is very good, that you continue, but this in three days you forget about this".*

The categorization considered by the researches was Focus: Internal; Factor: School and departmental leadership style; Character: Obstacle

Contingency tables were developed to study the evolution of the contributions of the teacher, using Fisher's test, with the program R Commander 3.5.0., to study the possible existence of significative differences between the variables analysed (dimensions according to Ryder (2015) and the qualifier character). All tests were performed with a 95% confidence level.

RESULTS

Table 2 shows the results obtained after the categorization of the teacher´s responses in the two individual interviews (I1, I2) and the focus group (FG).

Table 2. Frequency of responses professor in the two individual interviews (I1, I2) and the focus group (FG), in the categories of Ryder (2015) and its character as a Facilitating (F), (O) Obstacle and Total (T).

CATEGORIES		I1			I2			FG		
FOCUS	**FACTORS**	**F**	**O**	**T**	**F**	**O**	**T**	**F**	**O**	**T**
PERSONAL	**P2. Pedagogical Skills**	0	0	**0**	1	0	**1**	1	2	**3**
	P3. Beliefs about the purposes of science education	0	0	**0**	0	0	**0**	0	1	**1**
	P5. Beliefs about how students learn and his/her role in the classroom	2	1	**3**	5	1	**6**	3	3	**6**
	P6. Beliefs about the intentions of the curriculum reform	1	0	**1**	2	0	**2**	3	1	**4**
	P7. Perceived audiences for his/her work	0	0	**0**	0	0	**0**	0	1	**1**
	P8. Professional and personal biography	0	0	**0**	0	1	**1**	0	3	**3**
	P9. Professional identity	0	0	**0**	1	0	**1**	1	1	**2**
TOTAL PERSONAL		**3**	**1**	**4**	**9**	**2**	**11**	**8**	**12**	**20**
INT	**I4. Availability of teaching resources**	1	2	**3**	0	0	**0**	0	0	**0**

	I7. Science department working practices	0	0	**0**	0	0	**0**	0	1	**1**
	I8. School and departmental leadership style	0	0	**0**	0	0	**0**	0	2	**2**
	I9. What counts as appropriate assessment of student learning	0	0	**0**	0	0	**0**	1	3	**4**
	I10. Local cultural perceptions of the ‘good’, ‘professional’ teacher	0	0	**0**	0	0	**0**	0	1	**1**
TOTAL INTERNAL		**1**	**2**	**3**	**0**	**0**	**0**	**1**	**7**	**8**
EXTERNAL	**E1. Flexible versus prescriptive national/regional curriculum frameworks**	0	2	**2**	0	0	**0**	0	1	**1**
	E3. Other national/regional education reform agendas	0	0	**0**	0	0	**0**	1	0	**1**
TOTAL EXTERNAL		**0**	**2**	**2**	**0**	**0**	**0**	**1**	**1**	**2**
TOTAL CATEGORIES		**4**	**5**	**9**	**9**	**2**	**11**	**10**	**20**	**30**

This teacher is focused mainly on personal factors in the three moments, which, moreover, are increasing throughout the training process. Their responses categorized as (P5) stand out above all.

The qualifier of the references included in P5 changes appreciably from the interviews to the focus group, so that, while the interviews appear with a facilitating nuance, this aspect is balanced in the focus group, as shows the following expression:

> *“The most important idea is perhaps creativity, that is, to realize when you are a student, that you can learn for yourself, and that you can give creative answers to problems that are presented to you. That, in the end, is what one has to know how to do in life, to know how to use the information available so that at any given time, when a situation arises, knowing how to give a new answer.” (I2, Unit 032) (P5F).*

However, in the focus group, there are more obstacles to this category, such as what is indicated in the following intervention about student motivation:

> *“And it is true that you say that the computer, for example, is often said to use it and the motivated student. However, it is not true, it is motivated at the beginning, but then there comes a time when it is the routine, it becomes the same as always, it is not just as motivating”. (FG, Unit 041) (P5O).*

On the other hand, T1 references to project work, group work and student autonomy show a clear identification of this teacher with the intentions of the curriculum reform (P6), almost always with a facilitating character. The personal and professional biography is also important appearing in the second interview and widening its presence in the focus group, as an obstacle element.

The allusions to the pedagogical abilities (P2), appear in the case of T1 in I2 with a facilitating character, while it appears as an obstacle in FG. Also important for T1 is the “professional and personal biography” factor (P8), which appears for the first time in the second interview and is emphasized in the focus group as an obstacle. The evolution that can be justified in a similar way to the P2 factor.

The internal factors appear mainly in the focus group, highlighting two ideas School and departmental leadership style (I8) and What counts as an appropriate assessment of student learning (I9) with an obstacle character. For example, when he says:

> *"I, as I see all the institutes, at least the ones I have known, are very far from doing such work, [...]. I see the environment very far, we will see how it evolves, but with the years that I have been teaching, I see that we are taking a step back, I do not know if I am a little pessimistic, but I began to teach in the 86 or 87, and I saw a different environment" (FG, Unit 067) (I8O).*

On the contrary, references to "availability of teaching resources" (I4) that appear as an obstacle in I1 are no longer cited later. It makes us think that these obstacles did not have a relevant entity since, as the training program has advanced, T1 has not seen them again.

Concerning external factors, highlight the references of T1 to aspects related to "flexible versus prescriptive national/regional curriculum frameworks" (E1), which T1 considers an obstacle in both I1 and FG, an aspect that is raised by this professor in FG. For example:

> *"[...] a proposal made by the administration, as well as an imposition, which becomes law, most teachers have a rejection, and you cannot, there is not even the possibility to discuss the issue, most flats rejects. It seems that one has to feel certain complexes once in a while talking about competencies." (FG, Unit 075) (E1O).*

The results obtained when comparing the manifestations registered for T1 in the three focuses (Personal, Internal and External) are shown in Table 3.

Table 3. Absolut (n) and relative (f) frequencies for each focus at each time of data recording (I1, I2 and GF) for T1

	I1		I2		FG	
	n	f	n	f	n	f
Personal	4	44,4	11	100,0	20	66,7
Internal	3	33,3	0	0,0	8	26,7
External	2	22,2	0	0,0	2	6,7
Total	9	100,0	11	100,0	30	100,0

The analysis by pairs of moments and focus, show statistically significant differences:

a) between I1 and I2 interviews for personal and internal focus (p-value = 0.04 α = 0.05), since in I1 a similar frequency of personal and internal factors appears, while in I2 only personal factors appear. This significant difference may be because Professor T1 has focused on personal factors in I2 given the emphasis of the training program at this time of its development, on the design and implementation of the didactic proposal.

(b) for the qualifiers (F and O) between the second interview and focus group (p-value = 0.01, α = 0.05) and between personal and internal focus (p-value = 0.04, α = 0.05).

CONCLUSIONS

We can consider, with the caution to be dealt with on a case study, that the data obtained confirm to us that the Ryder´s proposal (2015) has been presented as a useful tool to analyse teachers' beliefs, which can be framed in the Personal, Internal, External focus that include various factors associated with each one of them, that are relevant for the teaching staff and show different frequency along the different moments of the study.

The results obtained show the influence of the reflection and communication environment in which the teaching manifestations occur, which allows teachers to make a reflection that allows greater depth and richness to their assessments and beliefs. Personal factors are the focus of the teacher analysed, which seems logical considering his short teaching experience. The training process seems to have helped him to incorporate ideas more in line with the intentions of the reform after the implementation of the didactic proposal given the progress shown about the facilitating character on how students learn and his role in the class. This trend changes in the focus group, a scenario in which shared reflections with other more experienced teachers, emerging obstacle aspects that had not previously referred to.

We have also been able to complement this proposal, qualifying the teacher´s responses with a F/O character according to the trends shown by the expressions analysed.

In this context of curriculum reform, we understand important to continue deepening in the teachers´ assessments whose knowledge will allow us to detect typology of teaching needs and investing in training designs to help them address the challenges posed by current scientific education.

In this sense, we believe that the analysis scheme used can be very useful for designers of training programs, as well as for those responsible for educational policies. It allows an approach to the knowledge of their ideas about how their students learn and to share more the intentions of the curriculum reform.

On the other hand, training programs that involve teachers in the analysis, design and implementation of didactic proposals, focused on the development of skills through the context of teaching approach, as the scenario of this study has helped teachers to reflect on your beliefs about these aspects.

LIMITATIONS

The limitations of the study include the sample size and the non-random teacher sampling method used. The nature of the sample also limits the results. Given that the results show the influence of the setting (i.e., individual interviews vs focus group) on the views that the teachers express, we think it is important to explore the use of other data collection instruments.

ACKNOWLEDGEMENT

This work was supported by the Spanish Government [grant number 2017 [EDU2017-82197-P].

REFERENCES

Avargil, S., Herscovitz, O., & Dori, Y. (2012). Teaching thinking skills in context-basic learning: Teachers' challenges and assessment knowledge. *Journal of Science Education and Technology,* 21, 207–225.

Aikenhead, G.S. (2006). *Science education for everyday life*. New York, NY: Teachers' College Press.

Beijaard, D.; N Verloop, N. & Vermunt, JD. (2000). Teachers' perceptions of professional identity: An exploratory stu.dy from a personal knowledge perspective. *Teaching and teacher education*, 749-764

Blanco-López, A., Franco-Mariscal, A., & España-Ramos, E. (2016). A competence-based approach to the design of a teaching sequence about oral and dental health and hygiene: A case study. *Journal of Biological Education*, 50(2), 196–206.

Blanco-López, A., & Lupión-Cobos, T. (Eds.). (2015). *La competencia científica en las aulas: Nueve propuestas didácticas* [Scientific competence in the classroom. Nine teaching proposals]. Santiago de Compostela: Andavira Editora.

Bloor, M., Frankland, J., Thomas, M., & Robson, K. (2001). *Focus Groups in Social Research*. London: Sage.

Callaghan, G. (2005). Accessing habitus relating structure and agency through focus group research. Sociological Research Online, 10(3). Retrieved 5 December 2018, from: **HTTP://WWW.SOCRESONLINE.ORG.UK/10/3/CALLAGHAN.HTML**

Copello, L., & Sanmartí, N. (2001). Fundamentos de un modelo de formación permanente del profesorado de ciencias centrada en la reflexión dialógica sobre las concepciones y las prácticas. *Enseñanza de las Ciencias*, 19(2), 269-283.

Day, C., Sammons, P., Stobart, G., Kington, A., & Gu, Q. (2007). *Teachers matter: Connecting lives, work and effectiveness*. Maidenhead: Open University Press.

De Boer, G. E. (2014). The history of science curriculum reform in the United States. In N. Lederman & S. K. Abell (Eds.), Handbook of research on science education (Vol. II, pp. 559–578). Abingdon: Routledge.

De Jong, O. (2015). Chemistry teachers as stakeholders of a national context-based curriculum reform project. Lumat: *Research and Practice in Math, Science, and Technology Education,* 3, 258-268.

Donnelly, J., & Jenkins, E. (2001). *Science education: Policy, professionalism and change*. London: Sage

Hanley, P., Maringe, D., & Ratcliffe, M. (2008). Evaluation of professional development: Deploying a process-focused model. *International Journal of Science Education*, 30(5), 711-725.

Gilbert, J., Bulte, A., & Pilot, A. (2011). Concept development and transfer in context-based science education. *International Journal of Science Education*, 33(11), 817–837.

Guest, G., Namey, E., Taylor, J., Eley, N., & McKenna, K. (2017) Comparing focus groups and individual interviews: findings from a randomized study. *International Journal of Social Research Methodology*, 20(6), 693-708. DOI:10.1080/13645579.2017.1281601.

Kaplowitz, M.D. (2000). Statistical analysis of sensitive topics in group and individual interviews. *Quality & Quantity*, 34, 419–431.

Krueger, R., & Casey, M. (2015). *Focus groups: A practical guide for applied research* (5th Ed.). Thousand Oaks, CA: Sage.

Leander, K. M., & Osborne, M. D. (2008). Complex positioning: Teachers as agents of curricular and pedagogical reform. Journal of Curriculum Studies, 40, 23–46.

Luehmann, A. L. (2007). Identity development as a lens to science teacher preparation. Science Education, 91(5), 822–839.

Lupión-Cobos, T., & Blanco-López, A. (2016). Viewpoints of in-service science teachers about the development of scientific competence. In J. Lavonen, K. Juuti, J. Lampiselkä, A. Uittoy and K. 14/Strand *14 In-service science teacher education, continued professional development* /14 (Co-editors: A. Berry & D. Couso), (pp. 2387-2392). Helsinki, Finland: University of Helsinki.

Lupión-Cobos, T.; López-Castilla, R. & Blanco-López, A. (2017). What do science teachers think about developing scientific competences through context-based teaching? A case study. *International Journal of Science Education*. 39(7), 937-963.

Maguire, M., Ball, S. J., & Braun, A. (2013). What ever happened to …? 'Personal learning' as a case of policy dissipation. *Journal of Educational Policy*, 28 (3), 322-338.

Mellado, V., Ruiz, C., Bermejo, M. L., & Jiménez, R. (2006). Contributions from the philosophy of science to the education of science teachers. *Science & Education*, 15(5), 419-445.

Ministry of Education. (2006). Ley Orgánica 2/2006, de 3 de Mayo, de Educación [Education Law 2/ 2006 of 3 May]. BOE n. 104, 4 May 2006. Madrid, Spain.

Ministry of Education (MEC). (2013). Ley Orgánica 8/2013, de 9 de Diciembre, para la mejora de la calidad educativa [Law 8/2013, of 9 December, on improving quality in education]. BOE, no. 295, 10 December 2013. Madrid, Spain.

Osborne, J., & Collins, S. (2001). Pupils' views of the role and value of the science curriculum: a focus-group study. *International Journal of Science Education*, 23 (5), 441- 467.

Potter, J., & Hepburn, A. (2005). Qualitative interviews in psychology: Problems and possibilities. *Qualitative Research in Psychology*, 2, 281–307.

Rigano, D., & Ritchie, S. (2003). Implementing change within a school science department: Progressive and dissonant voices. *Research in Science Education*, 33, 299–317.

Ryder, J., & Banner, I. (2013). Schoolteachers' experiences of science curriculum reform. *International Journal of Science Education*, 35, 490–514.

Ryder, J. (2015). Being professional: accountability and authority in teachers' responses to science curriculum reform. *Studies in Science Education*, 51(1), 87-120.

Ryder, J., Lidar, M., Lundqvist, E., & Östman, L. (2018) Expressions of agency within complex policy structures: science teachers' experiences of education policy reforms in Sweden. *International Journal of Science Education*, 40(5), 538-563. DOI:10.1080/09500693.2018.1435921

Spillane, J. P., Reiser, B. J., & Reimer, T. (2002). Policy implementation and cognition: Reframing and refocusing implementation research. *Review of Educational Research*, 72(3), 387–431.

Squire, K. D., MaKinster, J. G., Barnett, M., Luehmann, A. L., & Barab, S. L. (2003). Designed curriculum and local culture: Acknowledging the primacy of classroom culture. *Science Education*, 87, 468–489

Van Driel, J. H., Bulte, A. M. W. & Verloop, N. (2008). Using the curriculum emphasis concept to investigate teachers' curricular beliefs in the context of educational reform. *Journal of Curriculum Studies*, 40(1), 107–122.

Van Driel, J. H., Merink, J. A., Van Veen, K., & Zwart, R.C. (2012). Current trends and missing links in studies on teacher professional development in science education: a review of design features and quality of research. *Studies in Science Education*, 48(2), 129-160.

Vázquez, B., Jiménez, R., & Mellado, V. (2007). La reflexión en profesoras de ciencias experimentales de enseñanza secundaria. Estudio de casos. *Enseñanza de las Ciencias*, 25(1), 73–90.

Vos, M., Taconis, R., Jochems, W., & Pilot, A. (2011). Classroom implementation of context-based chemistry education by teachers: The relation between experiences of teachers and the design of materials. *International Journal of Science Education, 33, 1407–1432.*

Wallace, C. S., & Priestley, M. (2011). Teacher beliefs and the mediation of curriculum innovation in Scotland: A socio-cultural perspective on professional development and change. *Journal of Curriculum Studies*, 43, 357–381.

Wallace, C. S., & Priestley, M. (2016). Secondary science teachers as curriculum makers: Mapping and designing Scotland's new curriculum for excellence. *Journal of Research in Science Teaching*, 54 (3), 324–349.

50 YEARS OF POLICY INFLUENCES ON UPPER SECONDARY PHYSICAL SCIENCES CURRICULA IN IRELAND

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Over the past half-century free second level has been introduced in the Irish education system and as a result a steady increase in the number of students completing a third level education has been observed. In tandem with this widening participation in second level education, curricula have been adapted to accommodate the varying needs and abilities of students while at the same time addressing the changing role of science education in the national economy. Between 1966 and 2016 three physics and three chemistry syllabi have been implemented in Irish schools. The focus of this study was to examine what were the cognitive demands of upper secondary level physics and chemistry Leaving Certificate examination questions from 1966-2016. Bloom's taxonomy of educational objectives was used in the analysis of the examination questions, as it had been used by the Irish Department of Education in the drawing up of the examination questions. A sample of ten physics and ten chemistry Leaving Certificate higher-level examinations papers were selected as representative samples of the different syllabi spanning the fifty years. Despite clear changes in both syllabi and in the question styles of the examinations during this time, there was not a notable change in the cognitive demand levels. The cognitive domain 'remember' was the highest for both physics and chemistry (ranging from 65% to 41% for physics and from 75% to 39% for chemistry. Notably, no question or question-part was coded for the higher order domains of 'evaluate' or 'create' in either physics or chemistry.

Keywords: Physics Syllabus, Chemistry Syllabus, Bloom's Taxonomy

INTRODUCTION

Being one of the founder members of the Organization for Economic Development (OECD) in 1960, enabled Ireland to move from its protectionist-isolationist position to being more open and receptive to external influences (Fleming and Harford, 2014). In 1962, the Irish Minister of Education, in cooperation with the OECD, commissioned the *Investment in Education* survey. While the report was analytical and factual, concentrating on the future economic needs in terms of setting targets for the educational infrastructure to ensure sufficiently skilled work force, it nonetheless paved the way for transforming Ireland's education system

(Department of Education, 1965; Loxley et al., 2014; Murray, 2012). In 1963 the Minister of Education announced the establishment of a new type of second level school – comprehensive schools- which would be administered by the Department of Education and referred to as state-run schools. The curricula offered in these state-run schools were that of both the secondary and vocational systems (Clarke, 2010; McKernan, 1984). In 1966, free access to secondary level education was introduced for all students. Up to this time the secondary (academic) education system was regarded as 'purely private institutions' by the Department of Education which 'were built up without any help from the State …which did not exercise any power of veto …over the management of the schools' (An Roinn Oideachais, 1926, p. 7).

The format of the Irish secondary education system in 1966 consisted of two courses – the Junior Course and the Senior Course. The Junior Course was compulsory and was of three years duration, at the end of which students (usually aged sixteen) sat the Junior Certificate Examinations. The Senior Course was of two to three years duration and culminated with the Leaving Certificate Examinations, which provided access to further and third level education programmes. This introduction, in 1966, of free secondary level education for all led to a sharp increase in the number of students seeking admission to universities and third level institutions, with demand outstripping the availability of places. As a consequence, the Leaving Certificate Examinations quickly started to influence the focus of schools rather than a focus on teaching and learning processes (Lorenz et al., 2016). The focus of this study is to examine the impact of changes made in the curriculum and assessment of two Leaving Certificate subjects, namely physics and chemistry, over a fifty-year period from 1966 to 2016.

Leaving Certificate science subject choices, 1966-2016

The widening of second level education to all in 1966, irrespective of financial means or academic ability, presented many opportunities to adapt second level curricula to meet the needs of both students and the economy. However, it resulted in a reduction in the availability of science orientated subjects to just Physics, Chemistry, Physics-Chemistry combination, Agricultural Science and Biology and the discontinuation of General Science, Botany, and Physiology & Hygiene as illustrated in Table 1 below.

Table 1 List of available Leaving Certificate science subjects in 1966 and 2016

Upper secondary science choices in 1966	Upper secondary science choices in 2016	
Physics	Physics	
Chemistry	Chemistry	
Physics-Chemistry combination	Physics-Chemistry combination	
General Science	-discontinued in 1969	
Botany	-discontinued in 1969	Replaced with Biology in 1969
Physiology & Hygiene	-discontinued in 1969	
Agricultural Science	Agricultural Science	

(Source: An Roinn Oideachais 1966; Department of Education & Skills 2016)

Assessment of Leaving Certificate Examinations, 1966 to 2016

The Leaving Certificate examinations, first introduced in 1925, were considered as high-stakes assessments and the students results were "*accepted by a considerable number of universities, professional bodies, training colleges in Ireland and elsewhere"* (An Roinn Oideachais, 1931, p. 57). The examinations branch of the Department of Education had sole responsibility for the setting, administrating, correcting and issuing results of these examinations. Examination statistics, which focused on total number of candidates sitting the various subjects and numbers achieving pass or higher (honours) level were published by the department on an annual basis. However, the department did not publish or make available what was considered sensitive information regarding the marking schemes used or the depth of knowledge required or being assessed by the examinations. This lacuna resulted in teachers using the examination papers to interpreted the subject syllabi (Madaus and MacNamara, 1970, pp. 94, 98).

Overview of Physics syllabus, 1966 to 2016

Syllabus One

The physics syllabus, introduced in 1962 by the Department of Education, consisted of an itemised list of topics to be studied with little indication as to depth of knowledge required, as illustrated by excerpt from the Mechanics topic shown in Figure 1 (Department of Education, 1963).

Mechanics

1. Displacement. Vectors and Scalars. Addition and resolutions of vectors. Velocity and accelerations
2. Newton's laws. Force. Mass. Weight. Conservation of momentum.
3. Force as a vector. Moments. Gravitation.

Figure 1 Extract from the 1962 Leaving Certificate Physics syllabus

Other topics such as Light, Sound, Magnetism, Electrostatics, Magnetism, Current electricity and Modern Physics were similarly presented (An Roinn Oideachais, 1963, pp. 81–82). This succinctness of defining content was in keeping with the Department of Education's long-established policy of maintaining a distance from class room delivery of all syllabi, thus preserving the Department's independence and impartiality in the administration of the state examinations (An Roinn Oideachais, 1926)

Syllabus Two

A revised physics syllabus was introduced in 1984 and first examined in 1986. Background subject information was included in this syllabus, e.g. list of books suitable either as references for teachers or as textbooks for students. This revised syllabus, while retaining the topics of the 1962 syllabus, now contained details as to the depth of knowledge expected of students including a list of 'suitable experiments to be undertaken…essential for a proper understanding of the syllabus content' (An Roinn Oideachais, 1984). The excerpt in table 2 below is an example of the changes, with reference to corresponding topics as present in the 1962 syllabus.

The style of the Leaving Certificate examination questions also varied – multi-choice questions, presentation of data, graphs and diagrams were incorporated in the questions with allocation of marks for question-parts identified in the relevant sections (Malone and Murray, 2016)

Table 2 Extracts illustrating changes between physics Leaving Certificate syllabi of 1962 and 1984

Physics – introduced in 1962	**Revised physics - introduced in 1984**	
Electrostatics	Topic	Notes
Charges. Conductors and insulators. Electroscopes. Induction. Coulomb's law. Electric fields. Field strength and potential. Condensers. Energy of system of charges.	Electric field 1.Coulomb's law	Coulomb's law as an example of the inverse square law. Forces between coplanar charges.
	2.Electric fields	Demonstration of field patterns using oil and semolina or other method. Idea of lines of force. *Electric field intensity, electric flux.*

(Sources: An Roinn Oideachais, 1984, 1962)

Syllabus Three

The Department presented a revised physics syllabus for physics in 2000 in the form of two booklets - the first booklet outlined the syllabus content in a four-column format and included a new component - *Science, Technology and Society* (STS) in order to 'place the content within a relevant context' (An Roinn Oideachais agus Eolaíochta-NCCA, 1999, p. 2). The second booklet '*Guidelines for Teachers'* – provided context for this revised syllabus (An Roinn Oideachais agus Eolaíochta-NCCA, 1999). The syllabus included a list of mandatory experiments as well as associated activities to enhance student learning and to include the component of *Science & Technology in Society.*

There were also changes to the style of the Leaving Certificate examination papers, which were now divided into sections A and B. Questions in Section A focussed on the mandatory experiments while questions in Section B focussed on theoretical and practical applications of physics. From 2006 onwards, students were permitted to bring and use approved calculators during the examinations. A *Formulae and Tables* booklet was available to students during all State examinations from 2011, thus reducing the necessity of memorising all relevant formulae etc.

Overview of Chemistry syllabus, 1966 to 2016

Syllabus One

The chemistry syllabus, introduced in 1962, was first examined in 1966. In the Department of Education's annual report of 1963 inspectors reported that the *transition from the old to the new (modernised courses in Chemistry) has work with great smoothness … great credit is due to the teachers for the enthusiasm with which they have adapted themselves to these changes* (An Roinn Oideachais, 1963, p. 66). The syllabus consisted of list of topics to be studied by all students (at either ordinary- and higher-level) and included additional topics to be studied only at higher-level as shown in table 2 below. There was no guidance as to the depth of knowledge required by students.

Pass level (ordinary level) 1. Properties of gases, liquids and solids; elements. Compounds and mixtures. 2. Atomic theory: the structure of the atom, electrons, protons, neutrons, atomic number, isotopes. 3. Structure of simple molecules; covalent, electrovalent and metallic bonds, crystal structure as exemplified by the sodium chloride lattice; electronegativity. **Honours level** (higher level) As for the Leaving Certificate Pass Course and in addition: - 11. Concepts of energy levels. Ionization potential and electron affinity. 12. the shape of simple summetrical molecules (organic and inorganic; tetrahedral, planar and linear), reference to orbitals and hybridisation. 13. the Periodic Table in relation of Atomic Structure. (An Roinn Oideachais, 1963, pp. 82–84)

Figure 1 Extract from the 1962 Leaving Certificate syllabus 1962

The examination question papers were very text-heavy, with no use of diagrams or tables. The paper consisted of ten questions printed on one to two A4 sized pages. Students were required to answer six out of ten questions within a two- and half-hour examination period. The overall mark achievable was 400 marks, with six of the questions carrying a maximum of 66 mark and the remaining four questions carrying a maximum of 67 marks. There was no indication given as to how these marks were distributed for each part of a question.

Syllabus Two

In 1983, a revised syllabus for chemistry was introduced and first examined in 1985. This syllabus contained details as to the depth of knowledge expected of students in contrast to that of the previous syllabus of 1962 as illustrated in Table 3 below. For example, understanding of the sulphur and its compounds featured in both syllabi- in 1962 six compounds were listed as indicated in the table. However, in the 1983 further details were included. By way of emphasising that laboratory work was intrinsic to the syllabus, the Department of Education recommended that about 40% of teaching time should be devoted to practical work, with a number of related experiments to be carried out by the students (An Roinn Oideachais, 1984).

Table 2 Sulphur as presented in Leaving Certificate Chemistry syllabi of 1962 and 1983

Chemistry – introduced in 1962	**Revised chemistry -introduced in 1983**	
7(a) study of the following compounds	Topic	Notes
Sulphur, hydrogen sulphide, sulphur dioxide, sulphurous acid, sulphur trioxide, sulphuric acid, sulphates	(b) Sulphur -combustion, forming SO_2, reaction of SO_2, sulphites, general properties. Catalytic oxidation of SO_2 to SO_3. Manufacture of sulphuric acid and its properties	SO_2 as acidic oxide. Bleaching as a reduction reaction; reaction of sulphites with acids.

The Leaving Certificate examination paper was now laid out over five to eight pages and included labelled diagrams of apparatus, data tables and detailed chemical reactions. The marks allocated for each question-part were identified in each question. The duration of the exams was increased from two and half hours to three hours.

Syllabus Three

In 2000, a revised syllabus in chemistry was introduced and first examined in 2002. This syllabi and accompanying Guidelines *for Teachers - Chemistry* were issued as separate booklets (NCCA, 1998, 1998). The syllabus was presented as having a Core element and two Options. The Core element consisted of nine topics with each topic further subdivided. Two of the aims of the revised chemistry syllabus were

- *To encourage an appreciation of the scientific, social, economic, environmental and technological aspects of chemistry and an understanding of the historical development of chemistry*
- *To illustrate generally how humanity has benefited from the study and practice of chemistry* (p.2)

These aims were inteded to be addressed by adding the topic of *Social & Applied Aspects* (STS) in the syllabus. There were also changes to the style of the Leaving Certificate examination papers, which were divided into sections A and B. Questions in Section A focussed on the mandatory experiments while questions in Section B focussed on theoretical and practical applications. From 2006 onwards students were permitted to bring and use approved calculators during the examinations. A *Formulae and Tables* booklet was available during all State examinations from 2011 thus reducing the necessity of learning off all relevant formulae etc.

THEORETICAL BASIS

The context and background presented above outlines an historical overview of the physics and chemistry syllabi and the Leaving Certification examinations in Ireland between 1966 and 2016. Over this period, only three studies which focused on analysing the cognitive abilities of Leaving Certificate examination subjects have been reported. In 1970, Madaus and Macnamara published the findings of their study of nine Leaving Certificate examination papers from 1967, which included the subjects of physics and chemistry (Madaus and Macnamara, 1970). This study was sponsored by the Irish Department of Education. One of the aims of their study was to ascertain what level of cognitive abilities were assessed in the Leaving Certificate examinations. Using Bloom's Taxonomy of Educational Objectives (Biehler and Snowman, 1986, pp. 245–246), they presented a profile of the cognitive abilities being demanded across these subjects. Among their findings was a dearth of questions that assessed higher order thinking skills. Although the following comments were made in respect of physics in the light of the findings of this research, they were equally applicable to chemistry …

> *The emphasis in both papers was on the recall of specific items of information. If knowledge of such items was the main purpose for studying physics, then the examinations had a high content validity. If, on the other hand, the courses were aimed at introducing students to the scientific method, if they were aimed at developing in students a general problem-solving ability which would transcend the details of their course and transfer to a wide range of problems in physics, then both examinations failed badly.* (Madaus and Macnamara, 1970, p. 99)

Nearly thirty years later, in 2014, the Irish State Examinations Commission (SEC) sponsored a research study on the *Predictability in the Irish Leaving Certificate* (Baird et al., 2014). Six Leaving Certificate subjects (physics was not one of the six) were analysed using Bloom's taxonomy. The previous nine years' examination papers and accompanying marking schemes formed the basis of this study.. While the 'concerns about predictability of question content in the examinations were not sustained, the authors did highlight several areas for future consideration – more frequent review of syllabi, more emphasis on assessment of higher order thinking skills within the examinations.. The third study was an independent study carried out by Burns et al. in 2018. This study used Bloom's Revised Taxonomy to analyse 23 Leaving Certificate subjects (which included physics and chemistry) over a five-year period 2005-2010. The findings of this study were similar to the previous studies –'the frequency of lower order skills were between 4 and 14 times higher than those of higher order (Burns et al., 2018, p. 359).

In summary, between 1966 and 2016, the physics and chemistry syllabi were revised twice, and changes were made in the Leaving Certificate examination papers of these subjects. The findings of three studies reported over this period indicate that the examination papers focus on assessing lower order skills. These findings inform the research questions examined in this study-

1. What were the cognitive demand of the physics and chemistry Leaving Certificate examinations questions during 1966-2016?
2. Were there differences in the cognitive demands of the physics and chemistry examinations of the various syllabi?

METHODOLOGY

This study analysed the level cognitive abilities assessed in the Irish Leaving Certificate examination in physics and chemistry across a fifty-year period from 1966 to 2016. Table 4 provides details of three years of consecutive examination papers selected as representative samples of the three physics and chemistry syllabi over this period. Each examination paper consisted of ten to twelve questions, which contained several sub question-parts. The number of question-parts ranged from N = 113 to N=391 for physics and from N=132 to N=322 for chemistry, as shown in Table 4.

Table 3 Total number of question-parts coded from samples of each of the syllabi

Syllabus One	Syllabus Two	Syllabus Three

(1962-1983) Physics/Chemistry	(1984-1999) Physics/Chemistry	(2000- to present) Physics/Chemistry
1966, 1967, 1968	1986, 1987, 1988	2006. 2007, 2008
$N_{physics}$ = 113	$N_{physics}$ = 210	$N_{physics}$ = 391
$N_{chemistry}$ = 132	$N_{chemistry}$ = 248	$N_{chemistry}$ = 322

Coding using Bloom's taxonomy

Bloom's Taxonomy of Educational Objectives (Remember, Understand, Analyse, Apply, Evaluate, Create) was the tool used to classify the level cognitive abilities of the physics and chemistry examination questions (Bloom et al., 1971; Krathwohl, 2002). Firstly, Bloom's Taxonomy was the criterion employed in the previous analysis of physics and chemistry examinations and secondly, the State Examination Commission's publication, *A Manual for Drafters, Setters and Assistant Setters,* highlighted that the type of skills to be measured should be within the framework of Bloom's Taxonomy of Educational Objectives. This manual also included a list of cue words recommended to use when compiling the questions. (SEC, 2018, pp. 25–26, 49). he following coding process was adopted in this study. All question items were classified with relevant question cues being highlighted and then assigned to the relevant cognitive level as shown in Figures 3 and 4.

Leaving Certificate Examination Question – 1986 Section C question		Cognitive level
9. Describe an experiment to show that sound is a wave motion.	(15)	Remember
Explain the physical principles underlaying each of the following:		
(i) Sounds can be heard more clearly on a cold night than on a warm day. Understand	(12)	
(ii) A glass can be shattered by a singer singing a high note. Understand	(12)	
When the source of a note moves past a stationary observer the pitch of the note seems to change. What is the name given to this phenomenon?	(6)	Remember
A whistle which is emitting a note of 1kHz is whirled in a horizontal circle on the end of string 1.2m long at a constant angular speed of 50 rad s^{-1}. What is the highest and lowest frequencies heard by a person standing some distance away? (Speed of sound in air = 340 m s^{-1})	(21)	Analyse

Figure 2 Higher-level Leaving Certificate Physics examination paper 1986, Section C, question 9

Leaving Certificate Examination Question – 2008, Section B, question 8 (a).	Cognitive level
8. (a) (i) Write an expression for the self-ionisation of water. (5)	Remember
(ii) Define K_w, the ionic product of water	Remember
The value of K_w at 25 0C is 1.0 x 10-14. Show that the pH of pure water is 7.0 at 25^0C. (12)	Understand
(iii) Calculate the pH of a 0.5M solution of a strong monobasic (monoprotic) acid.	Apply
Calculate the pH of a 0.5M solution of a weak monobasic acid with a Ka value of 1.8×10^{-5}. (12)	Apply

Figure 3 Higher-level Leaving Certificate Chemistry examination paper 2008, section B, question 8 (a)

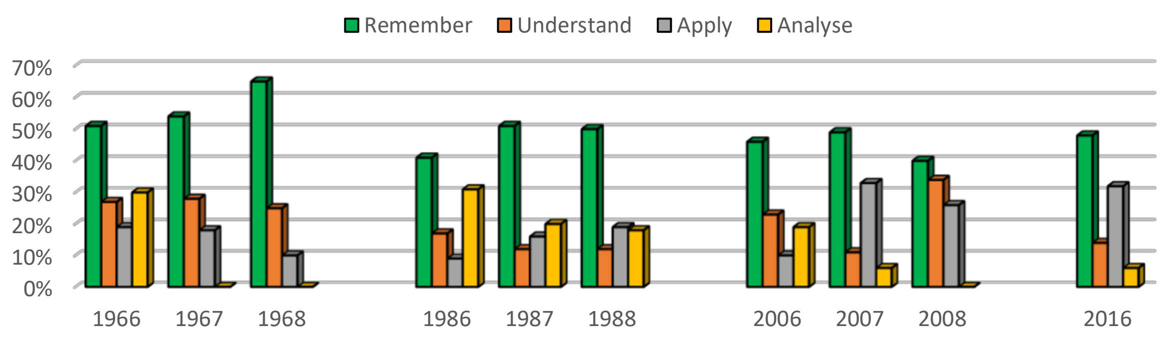
Having coded all question-parts for their respective cognitive levels, the marks - as indicated on examination papers -were then applied. The total marks for each cognitive level were calculated as a percentage of maximum marks available for each paper. For example, analysis of the 1987 Leaving Certificate physics showed that total marks available were 690. Of this total, 41% of the marks coded for the cognitive level **remember**, 17% for **understand**, 9% for **apply**, and 31% for **analyse**. There were no question-parts code for either of the cognitive levels of **evaluate** and **create.**

The selected examination papers for each subject, were analysed independently by three qualified second level teachers of physics and chemistry whom were familiar with Bloom's taxonomy and its levels of cognitive demand. Any discrepancies in coding that arose on the classification or the allocation of question-part marks were discussed by the group and the final classification of cognitive level and assignment of question-part marks were agreed by consensus.

FINDINGS

Cognitive demand level changes in Leaving Certificate physical sciences examinations, 1966-2016

Figure 5 presents the analysis of the representative nine higher-level Leaving Certificate physics examinations over the three syllabi. The examination papers were dominated by questions which were coded for the cognitive domain '**remember**' across all the three syllabi e.g. for the years 1966-1968 on average 57% of the questions were classified in this domain. Twenty years later, for years 1986-1988, the average in this domain was 47% and another twenty years later the average proportion was 46%.
For the three-year period of 1966-1968, on average 27% of the questions were classified in the '**understand**' domain. For the subsequent periods, 1986-1988 and 2006-2008 the average proportion for this domain were 14% and 21% respectively. As there were no question-parts within any of the nine papers which merited classification of 'evaluate' or 'create', these levels



were not included in the graphs in Figure 5.

Figure 2 Cognitive levels of higher-level Leaving Certificate Physics Examinations 1966-2016

The analysis of the representative nine higher-level Leaving Certificate chemistry examinations are shown in figure 6. The examination papers were dominated by questions which coded for the cognitive domain '**remember**' across all the three syllabi e.g. for the years 1966-1968, on average, 68 % of the questions were classified for this domain. Twenty years later, for years 1986-1988, the average proportion of questions classified in this domain was 42% and another twenty years later this average proportion was 59%.

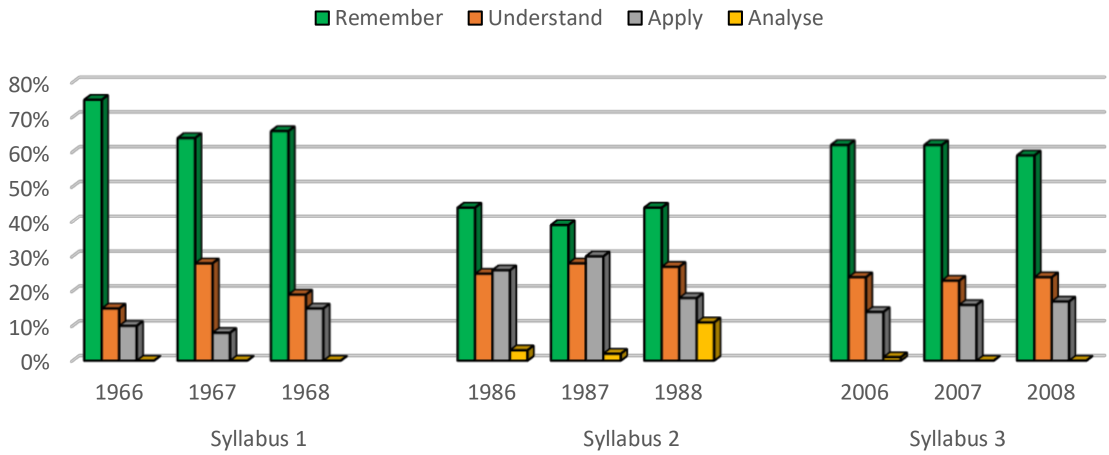


Figure 3 Cognitive levels of higher-level Leaving Certificate Chemistry Examinations 1966-2016

For the three-year band of 1966-1968, on average 21% of the questions/question parts were classified in the '**understand**' domain. For the subsequent years, 1986-1988 and 2006-2008 the average proportion for this domain was 27% and 24% respectively. As there were no question-parts within any of the nine papers which merited classification of 'evaluate' or 'create', they were not included in these graphs.

In the 1960s, students needed to obtain a minimum 60% of the total alloted marks to be awarded an honours grade for a subject. For example, physics and chemistry were each marked out of four hundred marks thus a total of marks greater than 240 merited an honours grade. Based on the annual education statistics published by the Department of Education, Table 4 illustrates the percentage of student who were awarded an honours grade in physics and in chemistry in the nine years 1965-1968, 1986-1988 and 2006-2008.

Table 4 Percentage of students awarded an honours grade in higher-level Leaving Certificate Physics and Chemistry examinations.

Percentage of students awarded an honours grade:	Syllabus One			Syllabus Two			Syllabus Three		
	1966	1967	1968	1986	1987	1988	2006	2007	2008
Physics	42%	42%	41%	No data	62%	58%	77%	72%	71%
Chemistry	47%	43%	44%	No data	60%	62%	76%	79%	79%
Minimum Honours Mark	*60%*	*60%*	*60%*	*55%*	*55%*	*55%*	*55%*	*55%*	*55%*

The cognitive demand levels for the higher-level Leaving Certificate physics and chemistry examinations are shown in Figures 4 and 5, respectively. As an example - in 1968, the analysis of the physics examination paper showed that 65% of the questions were coded for the '**remember**' category. The minimum marks required to achieve an honours grade was set at 60% of the total marks for this examination. However, as shown in Table 8, only 41% of all students who sat the 1968 examination achieved an honours grade – despite the majority of the paper requiring only lower order thinking skills , i.e. the domain of remember was 65% and understand was 25%.

An overall reorganisation of the grading system for Leaving Certificate examinations took place in 1973 and the percentage of total marks required for the awarding of an honours grade was lowered to 55%. This change may explain the increase in the number of proportion of students achieving an honours grade in later years. Table 4 shows that more than three-quarters (76%) of those who sat the 2006 higher-level Leaving Certificate chemistry examination were awarded an honours grade and for the two following years 79% of those sitting this examination obtained an honours grade. The analysis of cognitive demand levels for those years (figure 5) show that 62% of the question-parts coded for remember and 24% for understand levels, again indicating a high reliance on memory and lower order cognitive levels.

CONCLUSION

It was not until 2000 that both the marking schemes used in these examinations and Chief Examiners' reports were published by the State Examinations Committee. Prior to 2000, the only information concerning the examinations was the annual examination statistics issued by the Department of Education. This synoptic review of the higher- level Leaving Certificate examination of two physical sciences, physics and chemistry, over the fifty years period from 1966 to 2016, shows a persistent high reliance on the cognitive levels of **remembering** and **applying** and a low focus on the levels of **understanding** and **analysing**. These findings support the anecdotal belief of pedagogical approaches focussing on 'teaching to the test' and the higher percentage of honours awards to students in recent years. However, further analysing is required to confirm if these findings are representative of all Leaving Certificate physical sciences, at both ordinary- and higher- levels, examinations for this fifthy year period.

This analysis of the higher-level Leaving Certificate physics and chemistry examinations papers over a 50-year period revealed that no questions were coded for the higher order cognitive levels of **evaluating** or **creating.** The physics syllabus two had a greater number of marks coded for level of **analysing** (19-31%) than either of the other two physics syllabi (figure 5). This also the case for chemistry, noting that there were no questions during syllabi one or three that coded for the cognitive ability of **analysing** (figure 6). Although detailed information about the marking system has published by the SEC since 2000, the cognitive demand levels of the questions in the higher-level Leaving Certificate physics and chemistry examinations indicate a persistent low focus on higher order cognitive skills, such as **analysing, evaluating** and **creating**.

The context of this study has solely been in the Irish education system. Introducing a motion on the then recently published report *Investment in Education* in Seanad Eireann, Professor

Quinlan, a senator representing the National University of Ireland (NUI) constituency - said he was '*baffled completely how (you) can investigate an education system without seeing how that system compares with systems…in small countries in Western Europe'* (Seanad Eireann, 1967). Currently, a new specification for Leaving Certificate physics and chemistry are in preparation for national implementaiton. The stated objective of these syllabi are to enable students to develop the ability to explain, evaluate and communicate as well as introducing differentiation in the style of questioning to assess these outcomes. The findings of this review of the assessment of physics and chemistry syllabi are highly relevant and timely in development of appropriate pedagogical and assessment practices that recognise and assess higher order thinking skills.

References

An Roinn Oideachais, 1984. Rules and Programme for Secondary Schools - 1984/85. The Stationery Office, Dublin.

An Roinn Oideachais, 1968. Statistical Report 1967-1968. Dublin. https://www.education.ie/en/Publications/Statistics/Statistical-Reports/Annual-Statistical-Reports.html [Accessed on 25/01/2020]

An Roinn Oideachais, 1963. Rules and Programme for Secondary Schools 1962-63. https://www.education.ie/en/Publications/Statistics/Statistical-Reports/Annual-Statistical-Reports.html [Accessed on 25/01/2020]

An Roinn Oideachais, 1931. Statistical 1929-1930. https://www.education.ie/en/Publications/Statistics/Statistical-Reports/Annual-Statistical-Reports.html [Accessed on 25/01/2020]

An Roinn Oideachais, 1926. Report of the Department of Education for the School year 1924-25 and the Financial Adminstrative years 1924-25-26,. The Stationery Office, Dublin. https://www.education.ie/en/Publications/Statistics/Statistical-Reports/Annual-Statistical-Reports.html [Accessed on 25/01/2020]

An Roinn Oideachais, 1926. Report of the Department of Education for the School year 1924-25 and the Financial Adminstrative years 1924-25-26,. The Stationery Office, Dublin.

An Roinn Oideachais agus Eolaíochta-NCCA, 1999. Leaving Certificate - Physics Syllabus (Ordinary level and Higher level). The Stationery Office, Dublin.

Baird, J.-A., Hopfenbeck, T.N., Elwood, J., Caro, D., Ahmed, A., 2014. Predictability in the Irish leaving certificate. OUCEA Report 14.

Biehler, R.F., Snowman, J., 1986. Psychology Applied to Teaching, 5th Edition. ed. Houghton Mifflin Company.

Bloom, B.S., Hastings, J.T., Madaus, G.F., 1971. Handbook on Formative and Summative Evaluation of Student Learning. Mcgraw-Hill Book Company.

Burns, D., Devitt, A., McNamara, G., O'Hara, J., Brown, M., 2018. Is it all memory recall? An emperical investigation of intellectual skill requirments in Leaving Certificate examination papers in Ireland. Irish Educational Studies 37, 353–372.

Clarke, M., 2010. Educational reform in the 1960s: the introduction of comprehensive schools in the Republic of Ireland. History of Education 39, 383–399. https://doi.org/10.1080/00467600902857013

Department of Education, 1965. Investment in Education Report. The Stationery Office, Dublin.

Department of Education, 1963. Rules and Programmes for Scondary Schools 1962-63. The Stationary Office, Dublin.
Fleming, B., Harford, J., 2014. Irish educational policy in the 1960s: a decade of transformation. History of Education 43, 635–656. https://doi.org/10.1080/0046760X.2014.930189
Krathwohl, D.R., 2002. A revision of Bloom's taxonomy: An overview. Theory into practice 41, 212–218.
Lorenz, R., Eickelmann, B., Bos, W., 2016. High-stakes testing and Educational Governance - Insights and innovations in European School systems. Special Issue Editoral. Journal for Educational Research Online 8, 5–9.
Loxley, A., Seery, A., Walsh, J., 2014. Investment in Education and the tests of time. Irish Educational Studies 33, 173–191. https://doi.org/10.1080/03323315.2014.920616
Madaus, G.F., MacNamara, J., 1970. Public Examinations A study of the Irish Leaving Certificate. Educational Research Centre, St. Patrick's College, Dublin.
Malone, D., Murray, H., 2016. Archive of Mathsy State Exam Papers. http://archive.maths.nuim.ie/staff/dmalone/StateExamPapers/ [Accessed 26/01/2020]
McKernan, 1984. Curriculum development in the Republic of Ireland. Journal of Curriculum Studies 16, 233–246.
Murray, P., 2012. 'Can I write to you about Ireland?': John Vaizey, the Ford Foundation and Irish educational policy change, 1959–1962 document study]. Irish Educational Studies 31, 67–75. https://doi.org/10.1080/03323315.2011.601889
NCCA, 1998. Leaving Certificate Chemistry syllabus https://www.curriculumonline.ie/getmedia/7bdd3def-f492-432f-886f-35fc56bd3544/SCSEC09_Chemistry_syllabus_Eng.pdf [Accessed on 25/01/2020]
SEC, 2018. A Manual for Drafters, Setters and Assistant Setters. https://www.examinations.ie/?l=en&mc=au&sc=pb [Accessed on 25/01/2020]
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PART 11: STRAND 11

Evaluation and Assessment of Student Learning and Development

Co-editors: *Lukas Rokos & Mathias Ropohl*

CONTENTS

STRAND 11: INTRODUCTION

EVALUATION AND ASSESSMENT OF STUDENT LEARNING AND DEVELOPMENT

Assessment can be seen as a driving force for student learning and development as it generates and delivers information about their learning progress and learning difficulties that can be used by teachers to adapt teaching. In this sense, strand 11 covers a wide range of issues regarding the assessment ranging from formal to informal types of assessment and from very focused to more broader types of assessment. In total, there are 15 contributions in this chapter from several countries (Austria, Brazil, Cyprus, Czech Republic, Germany, Greece, Spain, USA). In this way, the different chapters present interesting insights into the role of assessments in different educational systems that are useful for the ESERA community. In addition, the respective studies cover various subjects and methodological approaches. The contributions to strand 11 were grouped into five sections according to different foci: 1) formative assessment, 2) comparing students' competences, 3) context-based learning and affective variables, 4) development of specific tests, and 5) assessment in an extra-curricular learning context.

Enjoy reading!

Lukas Rokos & Mathias Ropohl

1) Formative assessment

Formative assessment in the form of on-the-fly interactions is the content of a classroom-based study called *Illustrating the application of interactions on the fly in science teaching with the use of concept maps*. The purpose of this study was to depict, through concept mapping, the depth and coherence of classroom dialogue in upper-secondary physics lessons in which the on-the-fly method was applied.

Peer-assessment as a tool for reflective feedback in pre-service teacher training is a study focusing on pre-service teachers and their ability to provide written formative feedback during their teachers' training in biology lessons at the lower secondary level.

The study called *The use of a mixed methodological approach to analyse the specific coding orientation* describes the use of a mixed approach to analyse the concept of formative assessment. A questionnaire was used in a qualitative part and the data from this part were analysed to characterise the context. In a second part the participants took part in a case study in their real context.

2) Comparing student's competences

Inquiry competence of junior and senior class biology students provides data about inquiry competences in junior and senior classes in Austria and determines whether competences increased.

Science achievement and science motivation of Waldorf students compared to regular students investigated the science learning outcomes of students from Waldorf schools in Austria with curriculum-based emphasis on inquiry-based education and compared them with the outcomes of regular students.

Measuring students' chemistry competences at the transition between primary and secondary school is related to a paper and pencil test referring to content knowledge and procedural knowledge which enables to measure students' chemistry scientific competence.

3) Context-based learning and affective variables

How can the context help to solve a problem? A procedural analysis of contextualized problem solving suggests that the effect of context on performance varies strongly during problem solving in physics lessons.

Identification of chemistry contexts that interest Greek students presents a questionnaire that was used to explore secondary school students' interests in a variety of contexts commonly found in chemistry curriculum documents.

The different typologies describing the interest in science presents Brazil Barometer – a tool which enables to understand students' interest in science and helps to improve the teaching and learning processes. Some specific topics had the greatest potential to boost students' intrinsic motivation.

4) Development of specific tests

Performance analysis of students regarding the complexity and content dimensions of items in the learning of programming logic evaluated with the developed test and quantitative methods high school students' learning with respect to the contents of programming logic.

Development and validation of the negative appraisals of studying school science (NASSS) scale is a study performed with elementary school teachers and it brings evidence to consider NASSS as a valid and reliable instrument for the Spanish educational system.

Evaluation of learning progression on chemical concepts in secondary schools tries to map the hierarchical structure in secondary school chemistry via a strand map and to empirically evaluate this map. Developed performance tests help to analyse the validity of the presupposed interdependencies between the core ideas.

Proposal of the use of scientific literacy indicators to analyse a written evaluation aims at analysing a written evaluation used in the future teacher education sequence related to public health using Scientific Literacy Indicators which was identified as a good instrument to analyse the quality of written evaluations.

5) Assessment in an extra-curricular learning context.

Evaluating divergent thinking among participants of a German science competition is a paper focusing on discovering students' creative potential, divergent thinking abilities and cognitive development in informal learning by using a validated test.

An empirical study on the learning processes and actions of students while interacting with exhibits at a science centre is related to informal learning and primary level. This study clarifies how characteristics of the exhibits and the explanatory media lead to an understanding of selected phenomena.

ILLUSTRATING THE APPLICATION OF INTERACTIONS ON THE FLY IN SCIENCE TEACHING WITH THE USE OF CONCEPT MAPS

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This paper reports on an empirical, classroom-based study focusing on teachers' efforts to draw on interactions on the fly that unfold in the classroom as a means of formative assessment. This form of assessment occurs spontaneously during the course of a lesson when the teacher engages in the process of interpreting assessment data that arise in the classroom, in real time, to make instructional decisions on a moment by moment basis. The purpose of the study is to depict, through concept mapping, the depth and coherence of classroom dialogue when this formative assessment method is applied. The study is situated in the context of upper secondary physics lessons on Newton's laws of motion and focuses on the respective classroom discussions when teachers explicitly sought to draw on "interactions on the fly" as a means of formative assessment. The discussions were videotaped, coded and represented using concept maps that illustrate the connections between the various concepts that arise during the discussions, the depth and coherence at which these were elaborated and whether there have been critical concepts for students' understanding of the scientific phenomenon under discussion that had been ignored or left out of the discussion. This kind of mapping could serve as a productive resource in supplementing the extant research on discourse analysis by providing rich information in relation to the depth and coherence of the classroom dialogue. In addition, it could provide insights into specific pedagogical challenges encountered by teachers in their attempt to draw on students' contributions to the discussion as a means of formative assessment and thus it could inform attempts to better prepare teachers to anticipate and manage such challenges.

Keywords: Formative assessment, concept maps

INTRODUCTION

"On the fly" interaction as a formative assessment method occurs spontaneously during the course of a lesson when "teachable moments" arise in the classroom and teachers have to make inferences on a moment by moment basis (Heritage, 2007). Dialogue with students has a central part in formative assessment so as to clarify their existing ideas and to help them construct the scientifically accepted ideas. This includes instantaneous feedback as the students take part in a learning activity (Yorke, 2003). Duschl (2003) adopted the term assessment conversation to refer to these daily instructional dialogues that embed assessment into an activity already occurring in the classroom. "On the fly interaction" for assessment is important because it enables the teacher to identify learning problems during the presentation of information while there is an opportunity to recognize and correct misconceptions (Bell & Cowie, 2001). To do so, the teacher must find questions to ask which will help students externalize their understanding or confusion. When students provide feedback on their ongoing learning, they are giving the instructor an opportunity to highlight concepts that require additional explanation (McConnell, Steer & Owens, 2003).

However, there are a number of challenges that teachers encounter when applying such an assessment method. Mastering informal assessment strategies is extremely complex, introducing significant challenges to the assumptions and methods underlying the current practice of most science teachers (Duschl & Gitomer, 1997). Ruiz-Primo & Furtak (2006) proposed the ESRU cycle (Teacher's **E**licitation, **S**tudent's response, Teacher's **R**ecognition of the response, Teacher **U**ses the information collected) for coding and describing teacher – student interaction during informal assessment. Research regarding the use of the ESRU cycle during on the fly interactions that take place in the context of science learning has shown the positive effect that the completion of these cycles has on students' learning outcomes (Ruiz-Primo, 2011).

On the other hand, Coffey et al. (2011) who analysed four publications by prominent researchers in assessment and science education claim that, while researchers and teacher educators seem to believe that strategies are what teachers need first or most to help them engage in formative assessment, there is little focus on the disciplinary substance of what teachers and students assess. There is a need to monitor the learning process and in particular the classroom dialogue during formative assessment in order to assess its quality in terms of responsiveness and focus on the disciplinary substance.

Concept maps have been used extensively as learning products for representing students' understanding in all subject matter fields and for learners of any age. In some cases, students are asked to build their concept maps themselves (Regis et al., 1996), whereas in other cases teachers or researchers construct the concept maps when assessing students, for example by interviewing them (Nicoll, 2001). While concept maps are a qualitative representation of students' conceptual understanding, researchers have attempted to use a variety of scoring techniques on concept maps to be able to quantitate the trends among concept maps. There exists a wide variety of ways to generate and subsequently grade or assess concept maps (Stewart, 1980, Moreira, 1985, Raven, 1985, Stuart, 1985, Shavelson et al., 1993, Liu, 1994). Liu (1994), for instance, proposed using item response theory, which takes into account the number of links, the number of hierarchies, the number of cross-links, and the number of examples when scoring concept maps. The presence of crosslinks in a map reflects the extent of knowledge integration.

We believe that concept maps could be employed also to depict how concepts are discussed in class. This particular study seeks to represent the conceptual completeness, coherence and depth of the classroom dialogue when interaction on the fly is applied, using concept maps. We refer to conceptual completeness of classroom dialogue to describe (a) the degree in which the essential concepts for discussing a scientific phenomenon were brought into the classroom talk when investigating the particular phenomenon; (b) the conceptual coherence of the dialogue to represent the extensiveness of linking concepts in a coherent network and, (c) the conceptual depth of the dialogue to express the extent to which there were multiple references on connections between the relevant concepts during an episode of classroom dialogue.

METHOD

For this purpose, three enactments were applied in Physics classes at higher secondary schools by experienced teachers who had previously participated in a series of three workshops, each lasting about three hours, where they were trained on formative assessment and particularly on the method of "on the fly interaction". Each enactment lasted eleven 45-minute teaching periods and used the contexts of "freefall" and motion on an inclined surface. Teachers focused on the competence of designing and implementing investigations and formative assessment methods were applied for evaluating students' ability on specific components of the competence, as well as their conceptual understanding on the relevant concept that was applied.

These lessons were videotaped and those parts of the classroom dialogue that included interactions "on the fly" were identified and transcribed. The classroom dialogue was then divided to episodes according the theme under discussion (one episode ends and another begins when the theme under discussion changes) and each episode was coded using a concept map developed by the researcher in order to illustrate the conceptual completeness, coherence and depth of each episode of the dialogue. More specifically these maps depict the variety of concepts that emerge in discussion, whether these emerge from the students or the teacher, how much these are interpreted, how well linked they are with each other and the essential but missing or not interpreted concepts.

Dialogues were also coded according to the ESRU (Elicit-Student's response-Recognition-Use) coding scheme (Ruiz-Primo & Furtak, 2006) and examined whether the conceptual completeness, coherence and depth of the classroom dialogue as depicted on the concept maps correlate with the rate of complete ESRU cycles in each episode. In order to do so, aforementioned parameters were quantified as they were depicted on the concept maps. Thereby, the following three dimensions were considered:

- The rate of the essential concepts that were actually used in each episode of the dialogue.
- The rate of connections between concepts that were revisited in at least one more ESRU cycle than the one they appeared in.
- The rate of concepts in each episode that were connected with each other forming loops on the conceptual maps.

To find the rate of the essential concepts that were actually used in each episode of the dialogue, the number of these concepts was divided by the number of concepts that would have been used if concepts were perceived as essential for students' understanding on the particular theme under discussion were also included. The rate of connections between concepts that were revisited in at least one more ESRU cycle than the one they appeared was found by dividing the number of links between concepts in the particular episode which were realised at least in two ESRU cycles with the whole number of links between concepts that were made in the episode. The rate of concepts in each episode that were connected with each other forming loops on the conceptual maps was found by dividing the number of concepts that were included in such loops at each episode by the whole number of concepts that were used in the episode.

Afterwards, Pearson correlation was used to examine whether the rates for the conceptual completeness, coherence and depth of the classroom dialogue relate with the rate of completion of ESRU cycles of each episode.

RESULTS

In an effort to represent the conceptual completeness, coherence and depth of the classroom dialogue, 47 concept maps were developed. Below, three of them are presented as examples in order to illustrate their functionality.

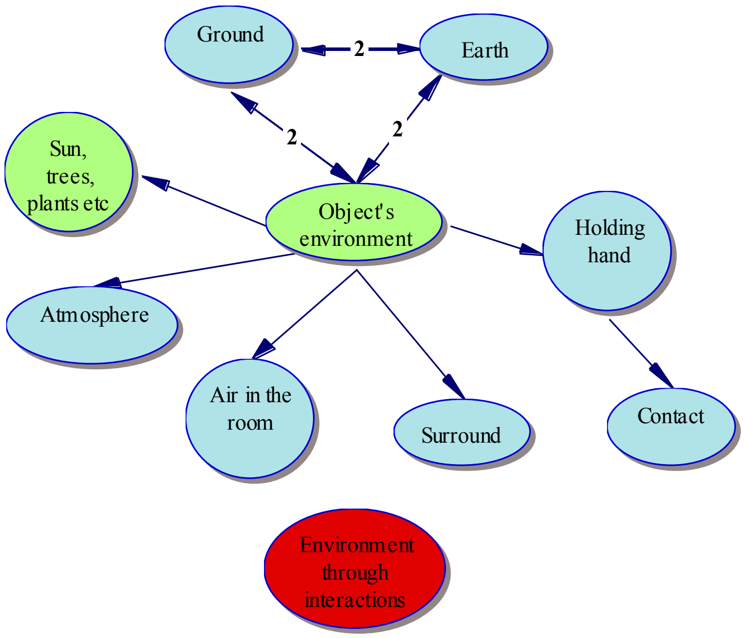

Figure 1. Concept map of an episode of the classroom dialogue in the 2nd implementation

The concept map in Figure 1 is depicting an episode from the 2nd implementation. The theme under discussion is “object’s environment” in terms of forces’ interactions. The main concept (object’s environment) is coloured light green because it was introduced by the teacher. Students link this concept with others, like the atmosphere, the ground etc., which are coloured light blue. During the episode there is no explicit link between the “object’s environment” and the interaction through forces with other objects, which in our opinion should have been made as a key concept in the discussion. That is why the term “environment through” interactions remains unlinked and red coloured on the concept map. The direction of the arrows depicts how concepts were linked, while the number on the arrow declares the number of ESRU cycles that this link was made for (if it was made more than once), indicating the depth of elaboration. In addition, it was observed that that some concepts are connected in some kind of loop, like here for example the terms “object’s environment”, “ground” and “Earth”. These loops can be an indicator of the coherence of the dialogue since concepts are not just connected one by one but in larger groups, forming a more coherent framework related to the phenomenon under discussion.

The next concept map (Figure 2) is also illustrating an episode from the 2nd implementation. The theme of this episode is the discrimination between contact force and force from distance. As can be seen, most of the concepts are provided by the teacher. Nevertheless, weight is thoroughly discussed as an example of field force and it is linked to Earth and mass. This is depicted on the map by the loop between the concepts force from distance, Earth, weight and field, and the multiple visits of some of the links between these concepts in a number of ESRU cycles. Similarly, the term contact force is also mentioned (by students) and well explained. However, despite that the concept of reaction force came up in the particular episode twice by students, the teacher avoided to discuss it. Therefore, this term is depicted crossed on the concept map.

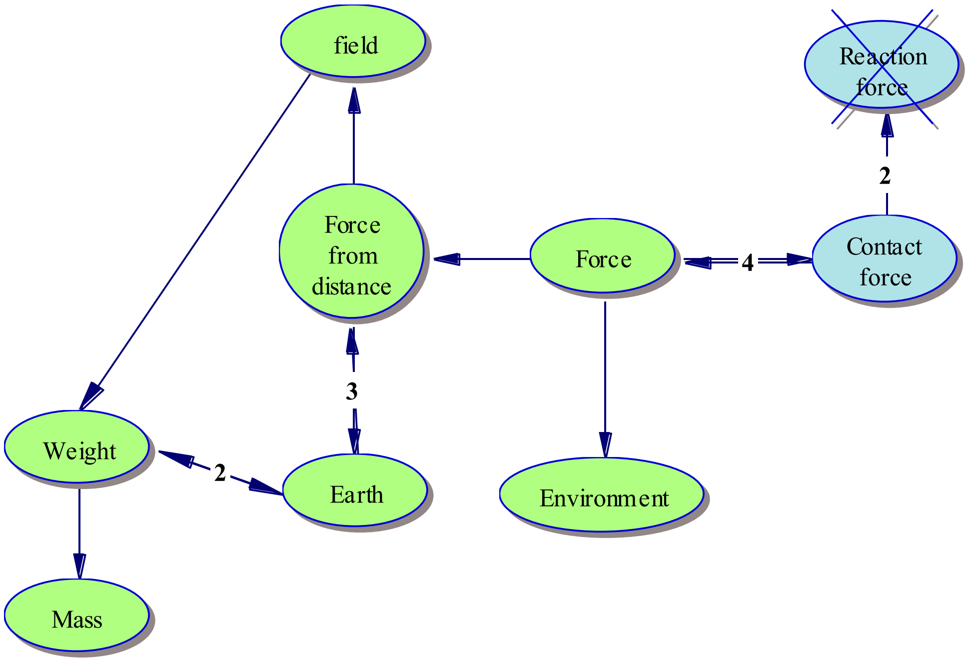

Figure 2: Conceptual map of another episode from the 2nd implementation.

The following concept map (Figure 3) is illustrating an episode from the 1st implementation. The teacher is trying to assess students' understanding on the results of an experiment they did, regarding the factors that influence free fall. As can be observed, it resembles a quite rich discussion, with students introducing half of the concepts that appeared, three loops between some of the concepts and multiple revisits to the links among some of them. However, when students suggested two factors which seemed to influence acceleration to them (because they noticed small differences in measurements for different weight and height), the teacher suggested to round measurements to fewer decimal digits without discussing the significance of any of the digits. Thus, this might have seemed to students mostly like manipulating the numbers the way it suits the teacher. These instances are depicted on the map through the unlinked red boxes. We chose to draw concepts that relate to scientific processes in rectangular shape instead of the oval we use for the concepts that relate with content knowledge in order to discriminate them.

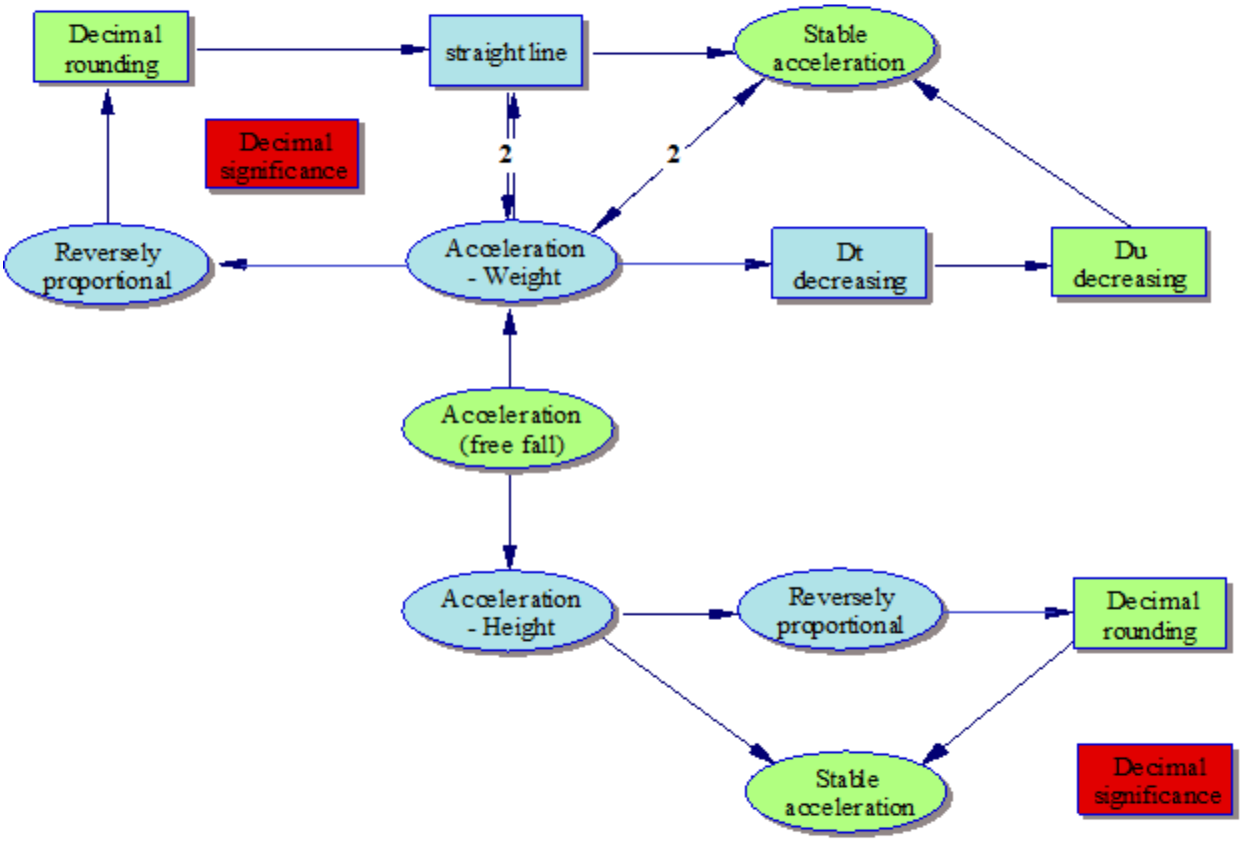

Figure 3: Conceptual map of an episode from the 3rd implementation.

The term "missed opportunities was used to refer to these instances of either not utilizing contributions from students or not doing so in a productive manner. It can be noticed that the previous three examples of concept maps illustrate how different kinds of missed opportunities of using the emergent information can be depicted in these concept maps. At the first and the third case (Figures 1 & 3), concepts that could bridge obvious gaps in students' understanding either related with conceptual knowledge or the scientific method, are depicted as red unlinked boxes, elliptical or rectangular respectively. In addition, by crossing the particular concept on the concept those cases were depicted where the teacher avoids or postpones discussing a concept that emerges in dialogue despite it seems to influence students' understanding.

As mentioned previously, the rate of complete ESRU cycles in each dialogue episode was also found. A complete cycle consists of all four components of ESRU, at least in an implicit way, while broken cycles can be either in ESR format or ES when the teacher does not use the upcoming information of student's response or doesn't even recognize student's contribution. In order to examine how the completion of ESRU cycles relate to the conceptual completeness, coherence and depth of the classroom dialogue, these dimensions were quantified as they were revealed through the parameters that the concept maps consist of. Then, the rate of each parameter was examined in relation to the rate of completion of ESRU cycles of each episode using Pearson correlation. Looking at the correlation of the rate of completion of ESRU cycles of each episode with each one of the three parameters, only for two of them a significance appeared. The correlation is moderate for the coherence of the dialogue ($r=0.45$, $p<0.01$) and weak for the depth of discussion ($r=0.32$, $p<0.05$), while it is insignificant ($p=0.41$) for the rate of the concepts discussed.

These results indicate that the rate of completion of ESRU cycles of each episode can be an indicator for the conceptual coherence and depth of the classroom dialogue. Still, there might be missed opportunities to improve students' understanding, particularly because specific critical concepts were not brought up nor discussed during the dialogue, despite a high rate of completion of ESRU cycles.

DISCUSSION AND CONCLUSIONS

Classroom evaluation practices generally encourage superficial and rote learning, concentrating on recall of isolated details, usually items of knowledge which pupils soon forget (Black & William, 1998). This can be attributed to the fact that concepts are not well linked to each other and thus the learning process lucks in coherence and meaning. In many cases, the evidence suggests that teachers are focused on finding out what students already know of the target information (Coffey et al., 2011). However, perhaps out of a desire to have the widest relevance, many studies have focused on strategies that cut across topics and disciplines, such as wait time or ‘‘stop lighting’’ or questioning, without closely examining the ideas and reasoning they reveal. By not delving into the specific substance of student thinking, the literature - and, subsequently, practice - misses and may undermine its fundamental objective. However, there is evidence that the quality of dialogue in a feedback intervention is important (Graesser & Person, 1995) and can, in fact, be more significant than prior ability and personality factors combined (Clarke, 1988).

An exception is the research by Clarke (1988) on classroom dialogue in science classrooms. He analyzed the discourse of three teachers in four classrooms, grading the quality of the discourse by summation over four criteria. These included the numbers of interpretable themes, the numbers of cross-correlations (an indicator of coherence) and proportions of themes explicitly related to the content of the lessons. As he claims, such a sophisticated analysis of dialogue indicates specific areas of weakness, which could be remedied by appropriate training. It could also be used to produce ideal "templates" of various models of teaching (e.g. Brady; 1985) for the use as a guide for lesson planning.

Recent work in science and math teacher education (Coffey, Edwards & Finkelstein, 2010; Kazemi et al., 2009; Levin, Hammer & Coffey, 2009), has presented evidence of novice teachers' attention to student thinking, novices whose preparation emphasized awareness and interpretation of student thinking as evident in video records and written work. By this reasoning, much depends on how teachers frame what they are doing, and a primary emphasis on strategies may be part of the problem. Assignments that direct teachers and teachers in training to what they are doing may inhibit their attending to what students are thinking.

The presented concept maps enabled us to represent the conceptual completeness, coherence and depth of the classroom dialogue in four dimensions:

- The variety of concepts that emerge in discussions
- The extent to which they are interpreted
- The extent of how well they are linked with each other
- The necessary concepts that are missing or are not interpreted

More specifically the various concepts that emerged in discussions were depicted in boxes that were coloured differently (light blue or light green) to denote whether they were brought into the discussion by the teacher or a student. This allows us to illustrate whether all the essential concepts for describing the phenomenon or scientific process under discussion, in the particular episode, are included in the dialogue. As the concept maps reveal, some episodes were long and rich in concepts relevant to the phenomenon under discussion while other episodes were short and included very few concepts. Often, the teacher seems to assume or to operate under the impression that the students have made the connection with a missing concept in their minds without explicitly referring to it. As observed, in some episodes, necessary concepts for the understanding of the phenomenon were missing from the discussion. These were depicted in red colour in order to illustrate the lack of completeness of the dialogue episode.

Concepts are linked with arrows on the concept maps. The direction of the arrows depicts the order the concepts appeared in the dialogue, while the number on the arrow declares the number of ESRU cycles in which this link was made (if it was made more than once). This number is considered as an indicative measure of the depth to which the particular concepts were discussed. Again, the concept maps developed suggest that episodes of classroom dialogue vary from one another. Some of the maps illustrate that concepts were linked various times to each other, suggesting that the relevance between them and with the phenomenon was well discussed. Other maps show that concepts were just mentioned serially one after the other without much discussion about the relations between them. In addition, concepts that are depicted on the concept maps as crossed are concepts that were mentioned by students but were ignored by the teacher and thus not discussed at all. These items relate to cases when the teacher does not respond to an issue that comes up during discussion, considering it as not part of the particular lesson.

Furthermore, the concept maps developed depict the coherence of the classroom dialogue during each episode. Coherence is indicated with the loops that concepts form when each concept is linked with other concepts, which are also linked with each other. These robust connections suggest that the dialogue included a holistic approach to understanding the phenomenon under discussion instead of a fragmented presentation of various concepts.

Overall, we claim that the concept map illustrations form a representation of the dialogue that indeed reveals the quality of each episode of the classroom dialogue in three dimensions: the completeness of the dialogue, the depth that concepts were discussed and linked to each other and, the coherence of the dialogue. These representations also revealed that the dialogue episodes can be very different between each other regarding several of the aforementioned dimensions, even if they were realized by the same teacher in the same class.

Concept maps developed by a researcher who is observing a class discussion can illustrate additional information regarding the depth and coherence of the dialogue in relation to the disciplinary substance. Such concept maps can be a useful tool for pre-service and in-service teacher educators giving the opportunity to teachers to reflect on their lessons from a different perspective, in their effort to improve their teaching practice. In addition, the results show that that the parameters that comprise the concept maps can be quantified in order to be compared to other dialogue coding schemes. Analyzing the score of each parameter can also help to identify the challenges that teachers encounter when applying informal formative assessment.

Concept maps that depict the completeness, the depth and the coherence of the dialogue might be helpful tools for teacher coaches also in their efforts to assess a lesson they have observed and provide teachers with valuable feedback. On the other hand, the teachers themselves could benefit by developing such concept maps for their own lessons with the purpose to create a holistic representation and reflect on their teaching practice. Further research could explore possible ways to improve the representation of the completeness, the depth and the coherence of the dialogue using concept maps and to triangulate with other classroom observation methods.

ACKNOWLEDGEMENT

This study was conducted as part of research project ASSIST-ME, which was supported financially by the European Union through the FP7 program, Grant Agreement No. 321428.

REFERENCES

Araceli Ruiz-Primo, M. & Furtak, E. M. (2006). Informal formative assessment and scientific inquiry: Exploring teachers' practices and student learning. *Educational Assessment*, *11*(3–4), 237–263.

Bell, B. & Cowie, B. (2001). The characteristics of formative assessment in science education. *Science education, 85*(5), 536–553.

Coffey, J. E., Hammer, D., Levin, D. M. & Grant, T. (2011). The missing disciplinary substance of formative assessment. *Journal of Research in Science Teaching*, *48*(10), 1109–1136.

Constantinou, C. P., Tsivitanidou, O. & Rybska, E. (2018). What Is Inquiry-Based Science Teaching and Learning? In: Tsivitanidou, O.E., Gray, P., Rybska, E., Louca, L. & Constantinou C. P. (Eds.) *Professional development for inquiry-based science teaching and learning* (pp. 1–23), Springer.

Constantinou, C. P. & Papadouris, N. (2012). Teaching and learning about energy in middle school: an argument for an epistemic approach. *Studies in Science Education*, *48*(2), 161–186.

Duschl, R. A. & Gitomer, D. H. (1997). Strategies and challenges to changing the focus of assessment and instruction in science classrooms. *Educational Assessment*, *4*(1), 37–73.

Duschl, R.A. (2003). Assessment of inquiry. In J. M. Atkin & J. E. Coffey (Eds.), *Everyday assessment in the science classroom* (pp. 41–59). Washington, DC: National Science Teachers Association Press.

Heritage, M. (2007). *Formative assessment*. EED Winter Conference: Informing Instruction, Improving Achievement. Anchorage, AK.

McConnell, D. A., Steer, D. N. & Owens, K. D. (2003). Assessment and active learning strategies for introductory geology courses. *Journal of Geoscience Education, 51*(2), 205–216.

Nicoll, G. (2001). A three-tier system for assessing concept map links: a methodological study. *International Journal of Science Education*, *23*(8), 863–875.

Papadouris, N., Vokos, S. & Constantinou, C. P. (2018). The pursuit of a “better” explanation as an organizing framework for science teaching and learning. *Science Education,* 102(2), 219–237.

Papadouris, N. & Constantinou, C. P. (2017). Integrating the epistemic and ontological aspects of content knowledge in science teaching and learning. *International Journal of Science Education*, 39(6), 663–682.

Regis, A., Albertazzi, P. G. & Roletto, E. (1996). Concept maps in chemistry education. *Journal of Chemical Education*, *73*(11), 1084.

Ruiz-Primo, M. A. (2011). Informal formative assessment: The role of instructional dialogues in assessing students’ learning. *Studies in Educational Evaluation, 37*(1), 15–24.

Yorke, M. (2003). Formative assessment in higher education: Moves towards theory and the enhancement of pedagogic practice. *Higher education*, *45*(4), 477–501

PEER-ASSESSMENT AS A TOOL FOR REFLECTIVE FEEDBACK IN PRE-SERVICE TEACHER TRAINING

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This study presents implementation of formative assessment, specifically peer-assessment, into the pre-service teacher training. Students of the Faculty of Education used structured assessment forms to evaluate their peers' performance during a pedagogical practice placement, which is a mandatory part of MSc degree in teaching branches in the Czech Republic. This paper deals with the quality of provided written feedback. We found that pre-service teachers have problems with providing supportive feedback to their peers and they rather tend to assess using scales without comprehensive verbal comments. Written comments represented rather a description of observed lesson instead of constructive feedback and only in few cases it had attributes of formative assessment with advice on next steps to make better progress. Only a minimum amount of forms contained justification of students' assessment. It was also found that pre-service teachers have problem identifying instructional goal of the lesson and often mistake it for topic of the lesson or they aim the goal at the teacher instead of students.

Keywords: peer-assessment, pre-service biology teachers, pre-service teacher training

THEORETICAL BACKGROUND

The pre-service teachers practice placement is a mandatory part of a MSc degree in teacher training study programmes at faculties in the Czech Republic. Future teachers visit so-called faculty schools where they perform few lessons under the tutelage of in-service teacher and university teacher. Although the insufficient number of teaching classes incorporated in study programme is the main problem, quality of this placement is also an important issue, mainly the poor connection between theoretical subjects at faculty and pedagogical reality at schools. Implementation of formative assessment methods into the teacher training programme is one possibility to ensure this connection and also to strengthen the diagnostic competencies of future teachers.

The diagnostic competence of pre-service teachers is low in general perspective (Buck, Trauth-Nare & Kaftan, 2010; Plake, Impara & Fager, 1993). Future teachers have to learn how to provide supportive feedback containing an advice on next steps to make better progress and to reach the selected goal (Hattie & Timperley, 2007), but also to define the instructional goal correctly. So, we understand the teachers' diagnostic competence as ability to interpret observed situation, provide informational and constructive feedback and feedback related to improvement of the next lesson (according to the definition of Hattie & Timperley, 2007).

The feedback is one of most important factors in affecting teaching-learning process and the effect on students‘ learning and achievements is also documented (Hattie & Timperley, 2007).

The possibility to try providing the feedback is one of key aspects for successful implementation of this process in education (Ducasse & Hill, 2019). When the feedback is connected with the peer formative assessment the benefit could be seen in better understanding of provided comments because peers have similar point of view and use the same language without complicated academic terminology (Jonsson, 2013; Winstone et al., 2016). The peer assessment is said to be more supportive and easier understandable than the assessment from teacher, mainly because of peers' language (Gibbs & Simpson, 2004; Nicol, Thomson & Breslin, 2014). Although teachers provide the feedback based on their own experience and they are focused on the crucial aspects in the teaching process this feedback is sometimes quite complicated formulated for the students (Mathan & Koedinger, 2005). Providing informational and constructive feedback is important for better understanding of problems for assessors as well as those being assessed (Furtak & Ruiz-Primo, 2008). However, it is useful to provide students the scaffolding at the beginning of their experience with peer-assessment (e.g. Brookhart, 2008; Hattie & Timperley, 2007) because it could help them to pay attention to crucial aspects of their peers' teaching. As it is mentioned by some authors (e.g. Cho & MacArthur, 2011; Meusen-Beekman, Josten-ten Brinke & Boshuizen, 2015) it is possible to improve assessing skills of students if we present them the assessing criteria. It is beneficial to illustrate selected criteria with specific examples (Cho & MacArthur, 2011).

STUDY OBJECTIVE

The main aim was to consider if pre-service teachers are able to recognize important aspects in teaching process performed by their peers and provide them with supportive feedback. We were inspired by research of Ropohl and Rönnebeck (2017), therefore we measured the quality of written feedback provided by pre-service teachers. Three research questions were defined for this purpose: RQ1) Are pre-service teachers able to advice their peers on what steps they need to take to better reach the instructional goal?; RQ2) Do pre-service teachers write justification of their assessment?; RQ3) Are students able to identify the instructional goal?

METHODOLOGY

Sample

In total 29 students from biology MSc degree in teaching were involved in this study – 18 pre-service biology teachers for lower-secondary level schools and 11 pre-service teachers for upper-secondary level schools. All students were studying at the Department of Biology at Faculty of Education, University of South Bohemia in Ceske Budejovice. We worked with 133 assessing forms (80 from pre-service biology teachers for lower-secondary level schools and 53 from pre-service teachers for upper-secondary level schools).

Assessing forms

The assessment form was focused on five dimensions related to conducting a lecture during teaching practice placement. Students commented on performance of a student giving a lesson, specifically in the field of a) preparation of the lesson, b) realization of the lesson, c) didactical transformation of biological topics, d) communication with students and e) organization of particular activities. The assessors had statements available (in total 25, examples are presented in Tab. I) related to each dimension and were to select the level of their agreement or disagreement on the Likert scale 0 – 4 (1 – totally agree; 2 – rather agree; 3 – rather disagree; 4 – totally disagree; 0 – not applicable). The assessing students also had some space for own comments on each dimension to express the strengths and weaknesses of their peer's performance. At the end of the assessment form students were asked to justify their assessment and provide a summarizing feedback for the assessed.

Table 1. The examples of selected statements in the assessing form

Dimension	**Example of statement** **Teaching student…**
I. Preparation	… had well-arranged time schedule for all activities. … prepared clear presentation and/or wrote clear notes on the board.
II. Realization	… explained the instructional goal of the lesson. … used various teaching methods and forms. … fulfilled the selected instructional goal.
III. Didactical transformation	… did not commit mistakes in his or her lesson. … managed to introduce students the curriculum clearly and adequately to their age.
IV. Communication	… spoke lively and adequately loudly. … listened to students and gave them enough space for their opinions and answers. … provided feedback to students.
V. Organization	… managed to keep discipline in the class and responded to disturbing behaviour adequately. … responded to situation in the class and current needs and possibilities.

Data collection and analysis

Students filled the assessment forms on PC after the peer's lesson so they had time to focus on his or her performance. They had five days to submit the form by mail to the placement tutor who summarized all assessments and sent an anonymous summary to the teaching student. Particular assessments were coded using open codes and similar codes were summarized into clusters. The code frequency was then observed. All forms were coded by two coders and the discrepancy level was then considered.

RESULTS

The presented findings were obtained from 29 respondents and there were 133 assessment forms analysed so we do not want to generalize our results.

In relation to RQ1 (*Are pre-service teachers able to advice their peers on what steps they need to take to better reach the instructional goal?*) we found out that future teachers still have problems with providing supportive formative feedback. Their comments often consisted of the observed lesson description. Sometimes they avoided to write comments and assessed the performance using a scale only. We are not able to say whether this reason was caused by their incompetence or laziness – this should be clarified in follow-up interviews with students. On the other hand, they tried to provide advice for their peers in summary of their assessment (in more than 40 % of all cases). We found formative aspects in these commentaries with specific advices on future steps in their next lessons. The level of formative comments in the provided feedback is shown in Figure 1.

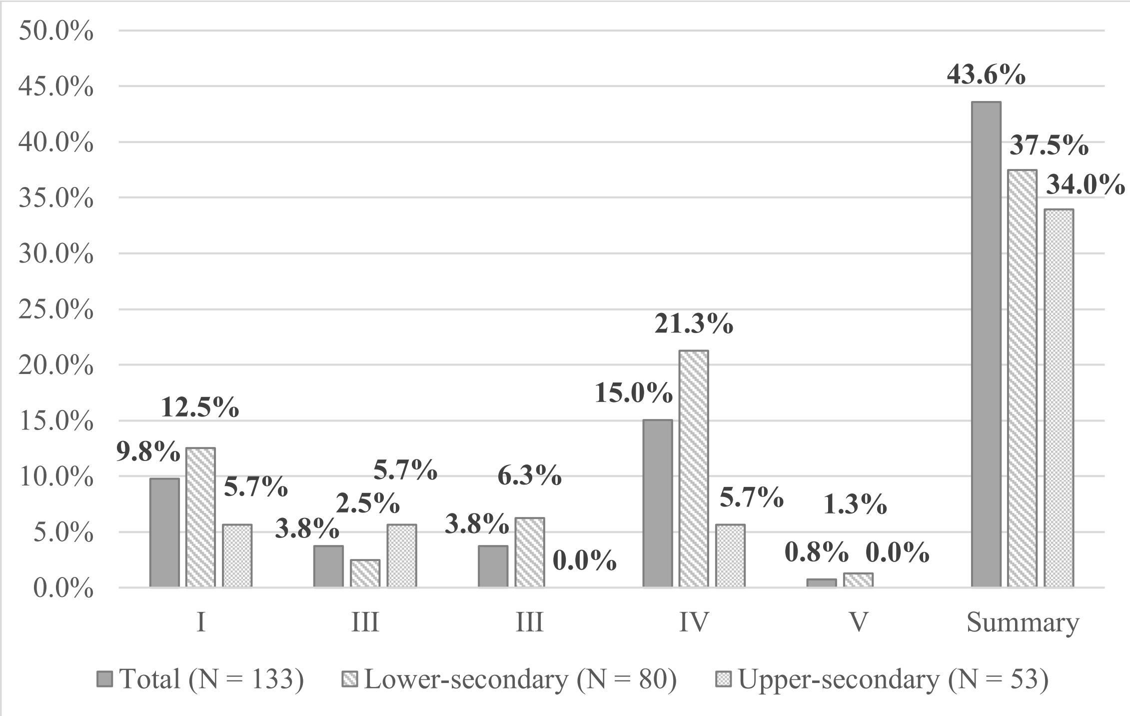

Figure 1. The level of formative comments in the provided feedback.
Legend: Selected dimensions to assess: I – Preparation; II – Realization; III – Didactical transformation; IV – Communication; V – Organization

It is possible to see that the level of formative comments was low. The highest level of these comments was found in the summary at the end of assessing form. It is not surprising conclusion because students are very often used to sum their decisions and overall assessment up. Communication had most frequent formative comments from all dimensions but it was still very low percentage (only 15.0 %). The lowest level of these comments was found in relation to organization dimension but this was often caused by the fact that there were no problems in the classroom and students organized their teaching well so there was no need to provide any comments.

We add some illustrative examples of supportive feedback found in the assessing forms:

- *„I think you should better plan the activity in the way of introducing the steps to students. The order of steps was not clear. If you explain every step and its outcome at the beginning, students will be able to work alone and they will not have so many clarification questions."*

On the other hand, there were also found comments with non-supportive or vague feedback:

- *„It was OK, I like it."*
- *„Some steps were not clear."*

RQ2 (*Do pre-service teachers write justification of their assessment?*) clarified that students tried to attach justification to their assessments. As it was mentioned in the previous paragraph the level of justifications with the formative feedback was quite low. Students often described the lesson and added some assessing phrase to it. A positive finding is the fact that assessors did not focus on mistakes only but tried to praise their peers for their success in practical activities (approx. half of the forms contained praise on the assessed). The assessors also did not reflect any personal relationships into the feedback. If there was found emotional comment it was positive in all cases (e.g. *"I really like your way of teaching"* or *"I would like to be a good in questioning students as you are. Your performance was great!"*). If we compare the level of adequate comments in the feedback provided by future teachers for lower-secondary and upper-secondary level (Fig. 2), there was found no significant difference with exception of two dimensions (Realization and Organization). The lower level of adequate comments was found at the group of future teachers for upper-secondary level. This fact corresponds with the level of non-providing feedback (see Fig. 3).

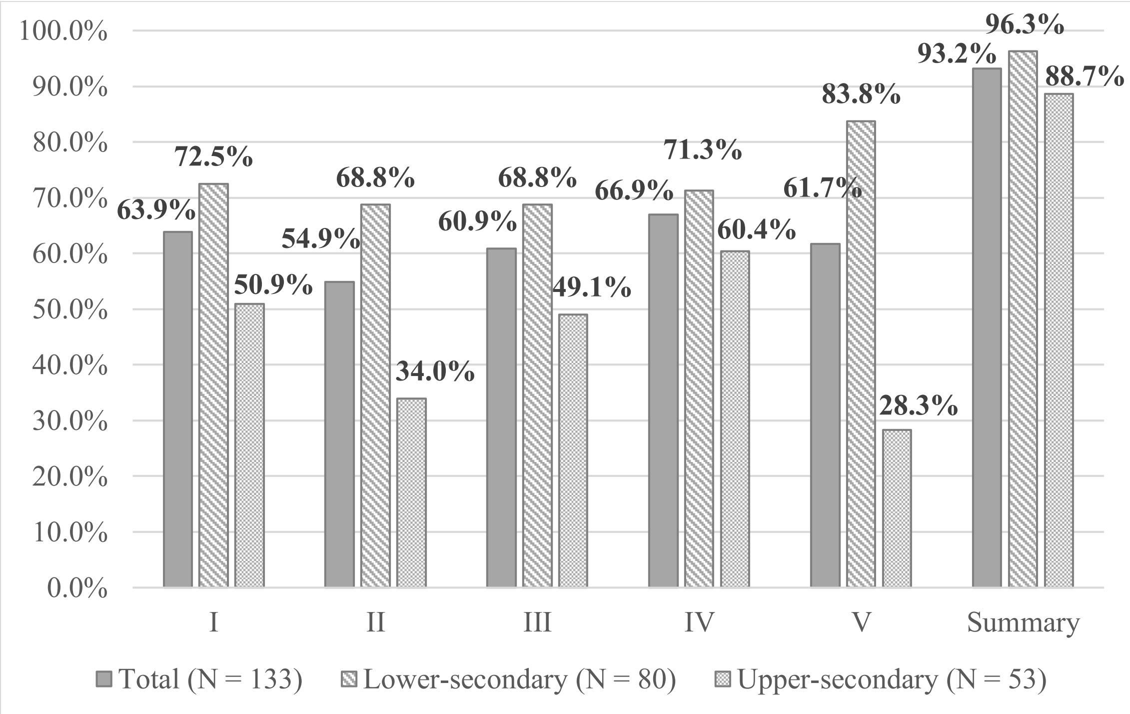

Figure 2. The level of adequate comments in the provided feedback.
Legend: Selected dimensions to assess: I – Preparation; II – Realization; III – Didactical transformation; IV – Communication; V – Organization

The second perspective related to this research question was level of feedback without provided comments. We found that future teachers for upper-secondary level avoided the providing of comments more often that future teachers for lower-secondary level (Fig. 3). The obvious difference was found in the dimension related to Organization of the classes. It was possible to see that assessors skipped these fields in the form and use only the scales and then provide the final commentaries at the end of the assessing form. If we look into the graph it is positive that the final commentaries were provided in almost all cases. However, this still reflects the tradition in the Czech educational system where the teachers are focused mainly on the outcomes and provide the final summative feedback.

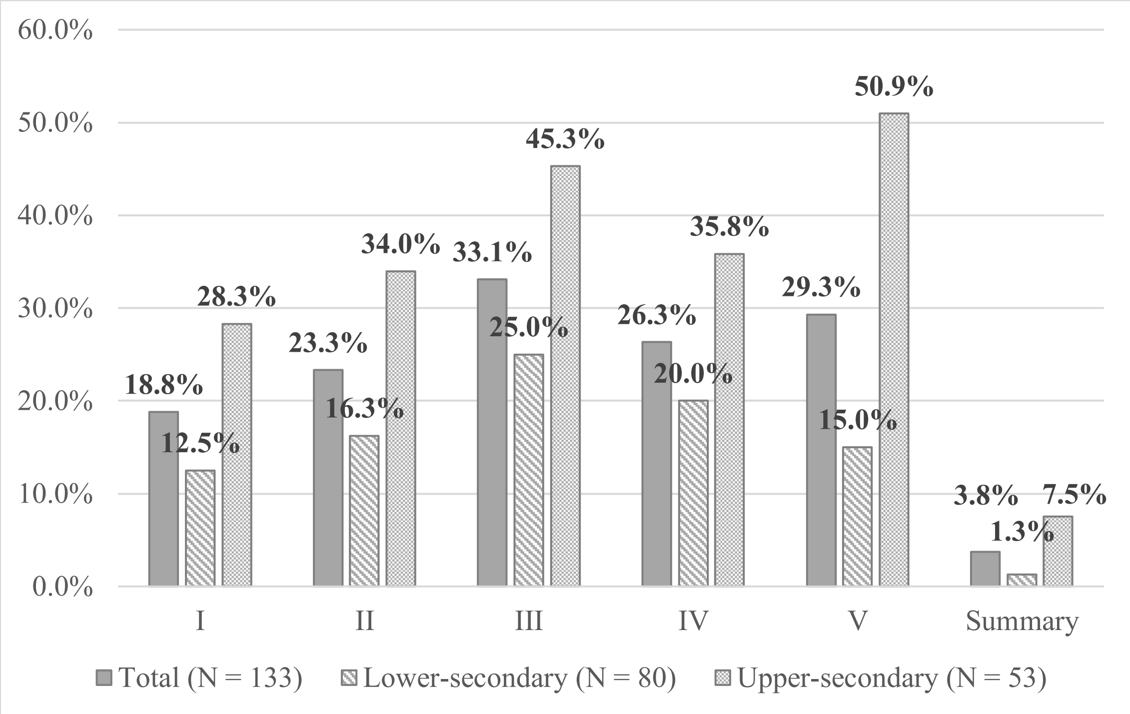

Figure 3. The level of feedback without provided comment.
Legend: Selected dimensions to assess: I – Preparation; II – Realization; III – Didactical transformation; IV – Communication; V – Organization

RQ3 (*Are pre-service teachers able to identify the instructional goal?*) was focused on the level of instructional goal identification. The reorganization of instructional goal was found to be a very significant problem for students (Fig. 4). Only in 27.8 % of all forms the instructional goal was recognized correctly (according to the definition by Prucha, Walterova and Mares, 2013 – commonly used in the Czech educational system). Students often mistook instructional goal for the lesson topic (26.3 %) or they aimed the goal at the teacher instead of pupils (33.1 %). It is necessary to add that in almost all observed lessons the teaching student did not mention and explained the goal to pupils, therefore this field could be said as very problematic for both, teaching students as well as observing students. The higher level of aiming the goal at the teacher was found at future teachers for upper-secondary school. In this case this situation could be caused by lower experience with pedagogical and psychological subjects at general (future teachers for lower-secondary level have these subjects during their bachelor studies). The assessor also mentioned in limited number of cases that the teaching students had not mentioned the goal so the assessor is not able to recognize it.

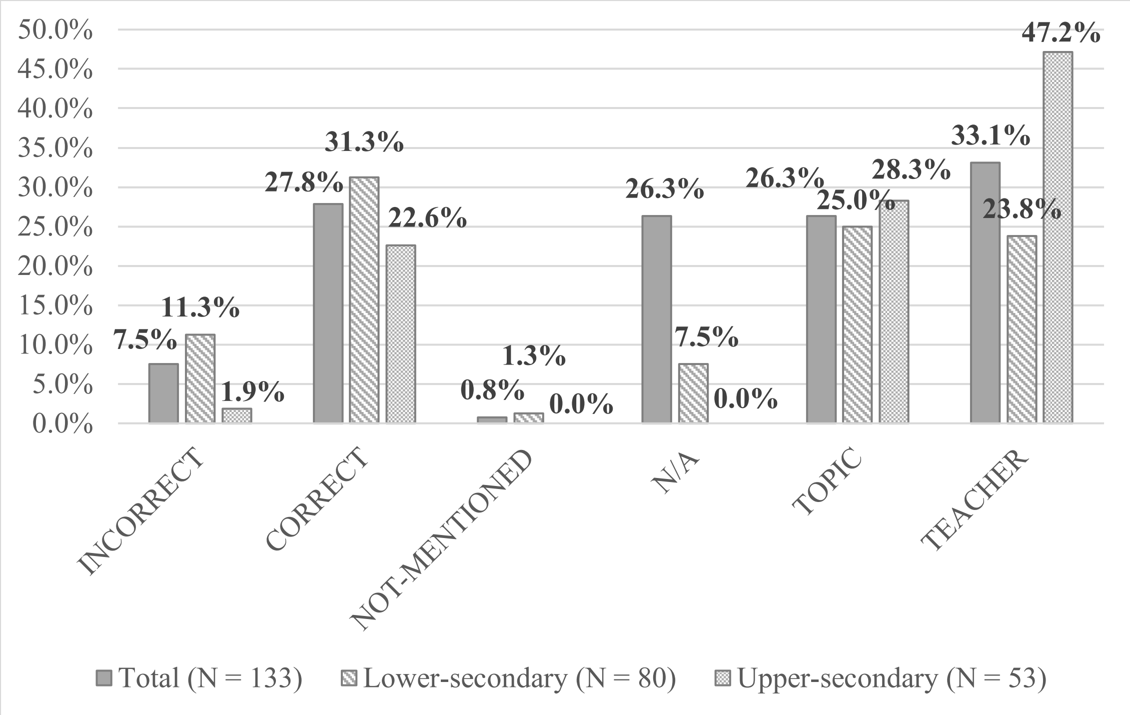

Figure 4. Ability to recognize the instructional goal of the lesson.
Legend: N/A (not available – nothing written in the assessing form); TOPIC – educational goal mistook for topic of the lesson; TEACHER – educational goal oriented on teacher performance instead of students

CONCLUSION AND IMPLEMENTATIONS

Our study showed that peer-assessment is a sufficient form of reflection in pre-service teacher practice placement. It is obvious that students need more experience with this approach to be able to provide supportive feedback with attributes of formative assessment. Students provided supportive feedback mainly in final summaries of their assessments however, lack of relevant justification was found in most of their comments. In addition, a problem with identification of instructional goal was found, the goal was mentioned only in one fifth of the forms. Pre-service teachers often mistook the instructional goal with the lesson topic or they addressed the goal to the teacher instead of the students.

Of course, we know about some limits of this study. At first, the sample is not really representative so the plan is to repeat this study with more students and mainly with the students from different faculties and universities. This time the comparative study is prepared in cooperation with the Department of Chemistry at Charles University in Prague. This also will test the validity of the measurement tools, which were set by our research team. More departments at University of South Bohemia in Ceske Budejovice will be involved in the reflective teachers' training so we are expecting more data from the assessing forms as well as from different fields in the relation to various studying programmes. The need for improving the quality of teachers' training as well as detailed introduction of formative assessment to future teachers are crucial aspects of new accreditation for teaching programmes in the Czech Republic. As it was found in this study, the future teachers need more training to provide appropriate formative feedback so this is a signal for innovations in teachers' preparation and strengthen the position of formative assessment in general as well as branch didactics during the teachers' training at faculties.

ACKNOWLEDGEMENT

The study was funded by grant of the Grant Agency of University of South Bohemia in České Budějovice (GAJU 123/2019/S).

REFERENCES

Amy Trauth-Nare, A. & Buck, G. (2011). Using reflective practice to incorporate formative assessment in a middle school science classroom: a participatory action research study, *Educational Action Research*, *19*(3), 379–398.

Brookhart, S. M. (2008). *How to Give Effective Feedback to Your Students*. Alexandria, VA: ASCD.

Buck, G. A., Trauth-Nare, A. & Kaftan, J. (2010). Making Formative Assessment Discernable to Pre-Service Teachers to Science. *Journal of Research in Science Teaching*, *47*(4), 402–421.

Cho, K. & MacArthur, C. (2011). Learning by Reviewing. *Journal of Educational Psychology, 103*(1), 73–84, DOI: 10.1037/a0021950.

Ducasse, A. M. & Hill, K. (2019). Developing student feedback literacy using educational technology and the reflective feedback conversation. *Practitioner Research in Higher Education*, *12*(1), 24–37.

Furtak, E. M. & Ruiz-Primo, M. A. (2008). Making students' thinking explicit in writing and discussion: An analysis of formative assessment prompts. *Science Education, 92*(5), 799–824.

Gibbs, G. & Simpson, C. (2004). Conditions under Which Assessment Supports Students' Learning. *Learning and Teaching in Higher Education,* 1, 3–31, DOI: 10.1007/978-3-8348-9837-1.

Hattie, J. & Timperley, H. (2007). The Power of Feedback. *Review of Educational Research, 77*(1), 81–112, DOI: 10.3102/003465430298487.

Jonsson, A. (2013). Facilitating productive use of feedback in higher education. *Active Learning in Higher Education, 14*(1), 63–76.

Meusen-Beekman, K. D., Joosten-ten Brinke, D. & Boshuizen, H. P. A. (2015). Developing Young Adolescents' Self-Regulation by Means of Formative Assessment: A Theoretical Perspective. *Cogent Education, 2*(1), 1071233, DOI: 10.1080/2331186X.2015.1071233.

Nicol, D., Thomson, A. & Breslin, C. (2014). Rethinking Feedback Practices in Higher Education: A Peer Review Perspective. *Assessment & Evaluation in Higher Education, 39*(1), 102–122, DOI: 10.1080/02602938.2013.795518.

Plake, B., Impara, J. C. & Fager, J. J. (1993). Assessment Competencies of Teachers: A National Survey. *Educational Measurement: Issues and Practice*, *12*(4), 10–12.

Prucha, J., Walterova, E. & Mares, J. (2013). *Pedagogicky slovnik* [Pedagogical Dictionary]. Prague: Portal.

Ropohl, M. & Rönnebeck, S. (2017). The quality of pre-service teachers' feedback. *Presentation at ESERA Conference 2017*, Dublin, Ireland, August, 24, 2017.

Winstone, N. E., Nash, R. A., Parker, M. & Rowntree, J. (2016). Supporting learners' agentic engagement with feedback: A systematic review and a taxonomy of recipience processes. *Educational Psychologist, 52*(1), 17–37.

THE USE OF A MIXED METHODOLOGICAL APPROACH TO ANALYSE THE SPECIFIC CODING ORIENTATION

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The aim of this study is to describe the use of a mixed methodological approach to analyse the concept of formative evaluation. Thus, we did a pilot test with the application of questionnaires followed by statistical validation. The clarification of the research question occurred through the triangulation of qualitative and quantitative methods, each one appropriate to a certain part of the process. The formulation of the questionnaire was a qualitative part and its statistical analysis was part of a quantitative stage. The analysis of the data and its context characterise the case study in which the participants are studied in their real context from multiple sources of evidence, proper when the context is complex and has a large set of variables. We defined the parameters and criteria for the formulation of the questionnaire using specific bibliography. The questionnaire was analysed and validated internally by factor analysis and externally by members of a research group focused on science education. Therefore, it was possible to make explicit the evaluation conceptions of the respondents by the specific coding orientation. In this work, we can see the principles of maintenance of the social relations that permeate the classroom. We can also see the potential of going the opposite way to building a more equitable society through the practice of teachers.

Keywords: Formative assessment, Statistics, Equity

INTRODUCTION

School tends to reproduce the excluding social relations present in our society in its dynamic and space. It includes the evaluative practice, that tend to exclude and silence students, cultures and processes of knowledge construction, devaluing different types of knowledge and giving strength to the dominant culture. Besides that, assessment is an essential and central feature of teaching (Black & Wiliam, 2006) and the formative assessment is an alternative way. This type of evaluation contributes to teaching-learning process and it is essential for the democratization because it can improve student's learning and autonomy. The teacher is a social agent directly involved in educational process, including in the evaluative context and, as such, their formation strongly influences the actions in classroom (Nascimento, 2018). The absence of this issue and its discussion in formation courses leads to the acceptance and of the exclusion of students as a natural thing. A traditional assessment comes from the conception of knowledge as fixed and unchangeable. This, allied to a reproductive teacher formation leads to a practice where the search for social transformation is absent. In this pedagogy, teaching consists in the transmission of knowledge from teacher to student and the knowledge is evaluated with a method considered safe and precise. Instead, we defend that the pedagogical practice must be based on a dialectical conception of knowledge, focusing on the process of knowledge construction and not just the results.

Saying that, learning must be in a permanent and continuous assessment, and the education that aims student's development must be based on cooperation between teachers and students. One of the basic characteristics of formative evaluation is its articulation with the teaching-learning process. It can provide deep learning of the contents and elevate the understanding of students' own reality (Crooks, 1988). This kind of teaching is democratic and enable a process of emancipation (Deutsch, 1979). Thereunto, the teacher must share the responsibility with the students, guarantee an efficient and constant model of feedback and be clear about evaluation established criteria. This kind of practice can result in an interfering posture of the individual in his context, likewise in the scientific literacy (DeBoer, 2000), which places the student in the centre of the educational process. Scientific literacy (SL) is one of the aims of science education, seeking to insert students in the scientific culture by providing meaning in the scientific language based in the student's previous knowledge (Lorenzetti & Delizoicov, 2001; Cobern & Aikenhead, 1997). It also helps students to develop the capacity of organising thought in a logical way, helping the construction of a critical view above the world (Hurd, 1997). The results of science – even provisional - must be understandable by students, at least at the level of scientific literacy (Chassot, 2000). In that way, science should be treated as a human activity, subject to influences of all kinds, unlike the often publicized image of science as a neutral and disinterested practice performed by exotic or genius beings.

The practiced evaluation has many characteristics that keep the maintenance of the social hierarchy and the teachers are still reproducing the principles of power in the society with low inclusive actions. Behind those actions it is possible to see the code, it regulates the relations between the contexts and generates principles that guide actions and text production adequate to each context. The specific coding orientation (SCO) is the evidence of the code in a subject level, defined in function of the values acquired in social groups which they are part (social class, graduation, participation in others groups). It defines the transmission mode, acquisition or practice in a determinate context (Bernstein, 1990).

So it is important to analyse if pre-service teachers have democratic and formative views about the evaluation in science classes. Also if pre-service teacher's practices are categorically related with their didactic proposals, especially in assessments. In order to ensure the dissemination of the proper characteristics of the scientific doing in favor of the formation of conscious and critical citizens. Thus, the objective of this research was to investigate the SCO of respondents in order to elucidate the re-contextualization of the code of our interest: formative evaluation and evaluation tools.

METHODS

Morais & Neves (2007) says that the internal validly of research depends on the methodology path, which must be solid between the research objectives and the data collection. Then, we formulated a questionnaire as a data collection instrument that aimed to see the participants' performance in light of the theoretical framework. It was applied to 25 licentiate undergraduate students, 27 post-graduate students with social sciences (Education) background and 14 post-graduate students without any background in social sciences.

The questionnaire and its qualitative validation

The theoretical framework is fundamental to guarantee internal validity of the methodology, providing conceptual accuracy and explanatory power to the data (Morais & Neves, 2007). Thus, the questionnaire was elaborated using specific bibliography of the area of evaluation and teaching (Black & Wiliam, 1998; 2009; Hadji, 2001; Luckesi, 2011). The questionnaire had two parts. The first had objective assertions about evaluation, some with traditional perspectives and others with a more formative view. The second part was about the efficiency of some evaluation tools used in science and biology classes. The level of agreement with the questions was marked in a 5-point Likert-scale. The questionnaire was validated by a research group in which public school teachers, professor doctors, doctoral, master's and undergraduate students participate. The questions should gather the reasons for a specific behaviour or attitude of the interviewee, showing their level of information on the issue (Flick, 2014). The criteria established for validation were: Are the questions necessary? Are they redundant, ambiguous or opposite? Are they biased? Are they formulated in an appropriate, easy and clear way?

The first questionnaire had 21 initial questions and 15 were approved by the research group. After further work with literature and reformulation of the questions, it returned to the group for another validation. Fourteen questions were approved at the end. In the subsequent validation phase, a pilot test was applied to undergraduate and graduate students, which allowed us to verify difficulties in interpreting the questions, which are important in their final adjustment (Nascimento, 2018; Nascimento, Castro, Motokane, 2019). The successive reformulations of the instruments allow a progressive adjustment, clarifying the relationship between the research objectives and the data to be obtained (Morais & Neves, 2007).

Statistical validation and analysis

Statistical validation of the questionnaires consisted of factor analysis using the RStudio® software version 1.0.136. This analysis aims to describe a set of original variables through the creation of a smaller number of variables called factors. Those factors try to explain the correlation between the variables just as good as the original number of variables (Freire & Motokane, 2016). The suitability of matrix data was verified by the Kaiser-Meyer-Olklin (KMO) and Bartlett tests, linearity and collinearity were tested by Pearson's correlation coefficients. The Scree test was used to extract the number of factors. The factors were retained and rotated by the Varimax orthogonal rotation method. In this way, the data treatment allowed us to interpret the results in the light of the theoretical framework on formative evaluation and its sociological perspective. Such interpretations were conducted in a consistent manner with the theoretical aspects of the investigation, allowing the reliability of the methodology. The comparison between data obtained from several sources (triangulation) provides internal validity to it (Morais & Neves, 2007).

RESULTS

Tables 1 and 2 presents the questions and the factor loading of each: table 1 for the questionnaire about formative evaluation and table 2 for the one about evaluation tools. The loadings indicate which variables (questions) are most related to each other. The symbol "-" represents that the loading in that question were less than 0.10.

Table 1. Questions and the factor loading of the factor solution in the questionnaire 01 about formative evaluation.

Factor loading – Questionnaire 01: Formative evaluation

Question	Factor 1
The evaluation criteria should be restricted to the teacher's choice	**0.523**
Assessment tools should be used at the end of the didactic sequence	**0.371**
Any intervention of the teacher in the classroom should have clear objectives for his students	**0.399**
The purpose of the assessment is to compare student performance	**0.395**
The student is aware of his grade guarantees the learning	**0.310**
The moments of evaluation must occur during the didactic sequence	**0.647**
The results of the evaluation process bring to the teacher a diagnosis of his own action in the classroom	**0.401**
Using the same assessment tool facilitates the analysis of students' abilities	**0.308**

Table 2. Questions and the factor loading of the factor solution in the questionnaire 02 about evaluation tools used in science classes.

Factor loading – Questionnaire 02: Evaluation tools

Question	Factor 1	Factor 2
Evaluation with essay questions	-	**0.458**
Experimental report	0.480	**0.570**
Field Notebook	0.473	**0.572**
Seminar	0.200	**0.551**
Oral test	-	**0.678**
Practical Test	0.432	**0.658**
Leisure activities (games)	**0.641**	0.171
Participation in theoretical class	**0.731**	**-**
Participation in practical class	**0.822**	**-**
Seeing the notebook	0.207	**0.373**
Classroom Exercises	**0.599**	0.360
Case study	**0.636**	0.294
Fittings	0.392	**0.420**
Debate	**0.764**	0.264
Extra class research	**0.595**	0.347
Assessment	**0.503**	0.362
Portfolio	**0.633**	0.398

A total of 66 answers were obtained. In the first questionnaire, statistical tests of correlation showed that 32.1% of the number of bivariate correlations was significant ($p<0.05$), so the linearity was proper to factor analysis. All the correlations were inferior to 0.9 in the multicollinearity presuppose. The values in the KMO test was superior to 0.5, and in the Bartlett test, the questionnaire had statistical significant value ($p<2.2e-16$), reinforcing the suitability of the patterns of correlation. In the second questionnaire, 50% of the number of bivariate correlations was significant, all the correlations were inferior to 0.9 in the multicollinearity presuppose. The values in the KMO test was superior to 0.5, but in the Bartlett test, the questionnaire had no statistical significant value ($p>0.1297$). This shows that there is a gradient of tacit knowledge regarding evaluation instruments in Science and Biology classes among the respondents, it overlaps in a way that the difference between them is not significant.

DISCUSSION AND CONCLUSION

The factor analysis of the first questionnaire results in only one factor associated with evaluation in a broad way. It showed that all the questions were related, so the participants tend or to agree or to disagree with all questions. Thus, we can see the evaluation conception of respondents as a spectrum of answers going from more formative to less formative. In the further analysis with cluster script, we should see a gradient of respondents' SCO, from the highest to the lowest recognition.

In the second questionnaire, we obtained two factors that group related questions. In the first factor, we see the measure of different abilities in the students such as writing, resume, reflection, reason, research, communication, and others. Those kinds of evaluation are closer with a formative form, giving students more autonomy to think, reflect and answer. It can also give to the teacher a better opportunity to achieve student's learning construction. The second factor is measuring the same abilities with different tools, it mostly looks on to students' production in order to retake what was spoked by the teacher. This kind of tools gives less autonomy to the student, reinforcing a heteronomy thought. Black & Wiliam (1998) found that most assessments have this characteristic: little focus on outcomes such speculation and critical reflection and more focus on student getting through tasks. This kind of evaluation tent to compare the students and create a large gap between the ones that could achieve the teacher objective and the ones that could not. However, the type of tool is not what makes difference in formative evaluation. The assessments must give feedback about learning instead of ranking in a traditional summative test. When the teacher is committed with student's cognitive and intellectual development the evaluative practice takes a formative dimension, which can help in the formation of class consciousness and emancipation of the student.

In order to answer the questionnaires with a formative form, the participant needed to recognize the micro context of formative evaluation in the questionnaires and knew how to position themselves, evidencing the SCO for this topic. Probably the contact with the social sciences and its discussions influence the SCO of the participants, but often this is not enough for a change. They also need to identify themselves with the theories and internalize it through socio-affective ties.

Bernstein's research (1996) highlights mechanisms that can lead to situations of potential social and cultural transformation. Teachers that have knowledge about the formative assessment and intent to use it to help student's learning has a transformative potential. So we stress the importance of pre-service and in-service teachers to have formative practices that allows their students to appropriate different codes of different social groups. The teacher's practice should be characterized by a formative process, committed with the development of students, helping them to reach different and privileged knowledge.

We concluded that the applied questionnaire and the statistical validation of the data contributed to the elucidate the evaluation conception of the participants. In further analysis, we will apply the data in a cluster separation script to evidence the scores of each group of respondents. Basil Bernstein's theory helps us to explain the hierarchical maintenance mechanism of social relations, and with this kind of analysis, we can see the transforming potential of visions and educational practices with a formative perspective. The appropriation of that code allows us to behold a scenario where teachers are committed to student development and to democracy, helping overcome social inequalities.

ACKNOWLEDGEMENT

We thank CAPES for financing the project, the Interdepartamental Graduate Program in Science Teaching of Physics Institute of University of São Paulo. We also thank colleagues from the LINCE research group for their help and support in this work. A special thanks Rafael Gil de Castro who assisted this research, and teacher Marcelo Tadeu Motokane for his patience, direction and attention.

REFERENCES

Bernstein, B. (1990). *Class, codes and Control, Vol. IV: The structuring of pedagogic discourse*. London: Routledge.

Black, P. & Wiliam, D. (1998). Assessment and Classroom Learning. *Assessment in Education*, *5*(1), 7–74.

Black, P. & Wiliam, D. (2009). Developing the theory of formative assessment. *Educational Assessment, Evaluation and Accountability*, *21*(1), 5–31. https://doi.org/10.1007/s11092-008-9068-5

Crooks, T. J. (1988). The Impact of Classroom Evaluation Practices on Students. *Review of Educational Research*, *58*(4), 438.

DeBoer, G. E. (2000). Scientific literacy: Another look at its historical and contemporary meanings and its relationship to science education reform. *Journal of Research in Science Teaching*, *37*(6), 582–601.

Deutsch, M. (1979). Education and distributive justice: Some reflections on grading systems. *American Psychologist*, *34*(5), 391–401.

Flick, U. (2014) *An introduction to qualitative research*. London: SAGE Publications Ltd.

Freire, C. C. & Motokane, M. T. (2016). Análise fatorial e análise de cluster no mapeamento de concepções epistemológicas de professores sobre a ciência e a ecologia. *Investigações Em Ensino de Ciências*, *21*(3), 152.

Morais, A. M. & Neves, I. P. (2007). Fazer investigação usando uma abordagem metodológica mista. *Revista Portuguesa de Educação*, *20*(2), 75–104.

Silva, J. L. P. B., & Moradillo, E. F. de. (2002). Avaliação, ensino e aprendizagem de ciências. *Ensaio Pesquisa Em Educação Em Ciências*, *4*(1). Retrieved from https://www.redalyc.org/html/1295/129523721003/

INQUIRY COMPETENCES OF JUNIOR AND SENIOR CLASS BIOLOGY STUDENTS

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Inquiry, as a fundamental part of science education, can be found in all international science standards. In the development process of Austrian science standards, competency levels based on Austrian science competency models were developed. The aim of the presented study is to provide data about inquiry competences of 8th, 10th and 12th grade students in Austria, as no data about senior class students' inquiry competences (e.g. 10th and 12th grade) exists for German speaking countries so far. Therefore, competency levels defined by Austrian science standards were used to develop questionnaires for inquiry competences. These questionnaires examine levels of inquiry competences based on eight fundamental biological topics (e.g. cells, animals, plants and ecology) and were given to 558 students. Summing up the results, inquiry competences of Austrian students in junior and senior classes are situated on a basic level, with most students reaching level 1 or 2 (out of 4 for all examined inquiry competences (asking research questions, disposing hypotheses, planning an experiment and analyzing data)). Although inquiry competences increase from 8th to 12th grade, the results indicate a lack of inquiry competences, especially concerning the use of basic terminology of inquiry and the connection between inquiry and biological knowledge – even for 12th grade students.

Keywords: science standards, inquiry competences, competence levels

THEORETICAL BACKGROUND

Inquiry-based teaching has become a fundamental part of modern science education (Anderson, 2002). Although it is not conceptualized consistently, inquiry based teaching approaches normally involve at least two of the following core elements (Cairns, 2019):

- knowledge about the nature of science and the processes of generating scientific knowledge
- science investigation skills for generating and manipulating data
- simulation of the inquiry process in classroom

For simulating the inquiry process in classroom specific phases of inquiry are used frequently forming an inquiry circle (figure 1).

Inquiry-based teaching is associated with a broad range of benefits for students' understanding of science and scientists' work as it "gives students a better ownership of their learning and allows them to actively navigate the routes of increased understanding, greater motivation, improved attitudes to scientific endeavor and growth in their self-esteem and their ability to handle new data in an increasingly complex world" (Bevins & Price, 2016, p. 19). If it comes to students' achievement, empirical evidence supporting the benefits of inquiry based learning approaches is not that clear. On the one hand, studies which compare the effectiveness of inquiry-based teaching approaches to traditional teaching support the superiority of inquiry-based teaching (Alfieri, Brooks, Aldrich & Tenenbaum, 2011; Minner, Levy & Century, 2010; Schroeder et al., 2007). On the other hand empirical evidence from international large scale assessments revealed a negative relationship between inquiry-based teaching and students' achievement (Cairns & Areepattamannil, 2017). Bringing together these conflicting results, studies proved a curvilinear relationship between inquiry-based teaching and students' achievement, with an increased use of inquiry-based teaching until it reaches an optimum and reduced achievements if inquiry was used more often than that (Cairns, 2019; Teig, Scherer & Nilsen, 2018).

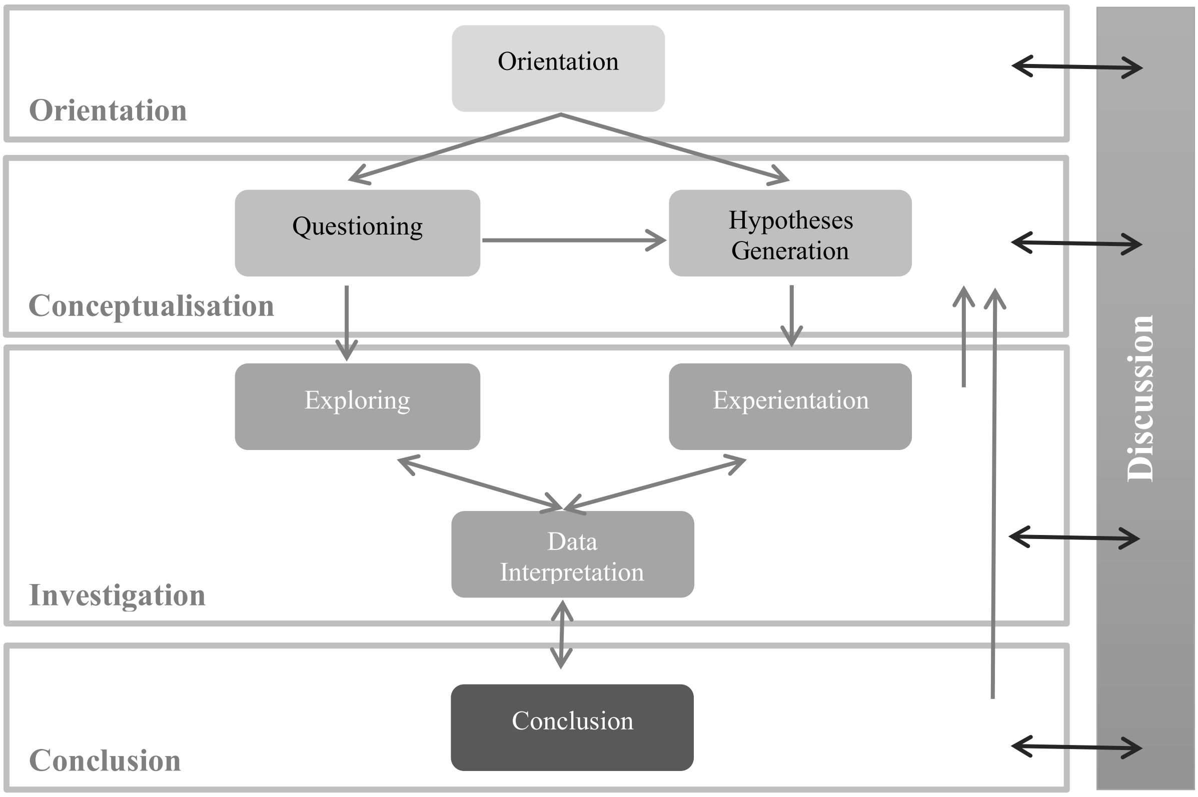

Figure 1. Inquiry based learning phases (Pedaste et al. 2015, p. 56).

International large scale assessments (PISA, TIMSS) emphasize the importance of inquiry competences for science teaching and learning science as well as national science standards (Centurino & Jones, 2017; Department for Science Education, 2014; KMK, 2004; National Research Council, 2012; OECD, 2019a; Singapore Ministry of Education, 2014; Education Bureau Hong Kong, 2016). A common way of integrating inquiry in science standards is by splitting up inquiry in competences which represent the different phases of inquiry (figure 1; BIFIE, 2011; Bybee, 2011; Centurino & Jones, 2017; KMK, 2004).

In Austria, inquiry is one of three subscales of the national science standards. It contains four inquiry competences: (1) asking research questions and deposing hypotheses, (2) planning and performing experiments, (3) writing experimental records and (4) analyzing and interpreting data (BIFIE, 2011). For each inquiry competence, competency levels were specified statistically using RASCH-analysis (table 1; Schiffl, 2016), but as no standardized testing takes place in Austria, students' inquiry competences only have been measured in international studies like PISA, so far.

Table 1. Competency levels for selected inquiry competences of the Austrian competence model for science (Schiffl, 2016).

competence	asking research questions	disposing hypotheses	planning an experiment	analyzing data
level 1	choosing research questions	choosing hypotheses	choosing a correct plan for an experiment	choosing conclusions
level 2	phrasing research questions	phrasing hypotheses	phrasing an experimental plan	phrasing conclusions
level 3	identifying dependent and independent variables	justifying hypotheses	include repeated measures **or** confounding variables	justifying conclusions
level 4	phrasing questions based on a biological concept	phrasing alternate hypotheses	include repeated measures **and** confounding variables	drawing conclusions from statistical data

In PISA 2015, Austrian students reached below OECD-average performance scores in evaluating and designing scientific research, whereas the results of the subscale "interpret data and evidence statistically" was average and the subscale "explain phenomena scientifically" was above average (OECD, 2016). On the whole scientific competences were declining from PISA 2006 to PISA 2018 (OECD, 2019b). The same pattern of competence distribution can be found for German students, who also scored better in knowledge-related tasks than in inquiry tasks (OECD, 2016, Pant et al., 2013). But as international student assessments like PISA or TIMSS and German's national science standards assessments focus on students in 8th and 9th grade, no data is available for inquiry competences of senior class students.

RESEARCH QUESTIONS

The present study addresses the following questions:

- What competence levels (with reference to Austrian science standards, see table 1) do 8th grade, 10th grade and 12th grade students possess when it comes to inquiry competences?
- Are the inquiry skills of 12th grade students more developed than those of 8th grade and 10th grade students?

In PISA 2015, 73 % of the students scored at competence level three and below (OECD, 2016). Therefore we expect to find mostly basic competence levels (level 1 or 2) for 8th grade students. For senior class students, no empirical data is available, but as inquiry is a major part of the Austrian science curriculum for senior classes, we expect an increase in inquiry competence from 8th to 12th grade (BGBl. II 219/2016).

METHODS

558 students from 8th, 10th and 12th grade of Austrian junior and senior high schools participated in the study. They were given a questionnaire for inquiry competences that had to be answered in 50 minutes time (one school lesson). Eight different biological topics (e.g. cells, animals, plants and brain) were used to create these questionnaires. Each questionnaire contained the following competences: asking research questions, disposing hypotheses, planning an experiment and analyzing data from experiments. Levels of competences were rated afterwards from the students' answers. The interrater-reliability (computed using Cohens Kappa), therefore, is satisfying and reaches from .87 for asking research questions to .94 for planning experiments. Data was computed using SPSS 22.0.

RESULTS

When asked to formulate a research questions, about 90 % of the students were able to choose a correct research question for a given experiment (level 1), about 70 % were able to phrase a research question on their own (level 2) and only a third of the students could name dependent and independent variables (level 3). Almost no students were able to phrase correct research questions based on biological concepts (level 4). Students from the three different grades differ in all four competency levels (level 1: $\chi^2 = 17{,}77$; $p \leq .001$; level 2: $\chi^2 = 94{,}71$; $p \leq .001$; level 3: $\chi^2 = 77{,}03$; $p \leq .001$; level 4: $\chi^2 = 65{,}66$; $p \leq .001$) with more students from higher grades reaching each level (each student can reach more than one level, if he/she meets the criterion of the level; figure 2). Concerning the highest reached student level, the median for 8th grade students is 1,00, for 10th grade students it is 2,00 and for 12th grade students it is 3,00.

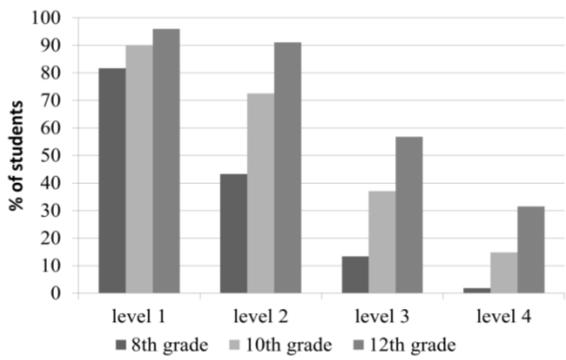

Figure 2. Percent of students on each competence level for asking questions

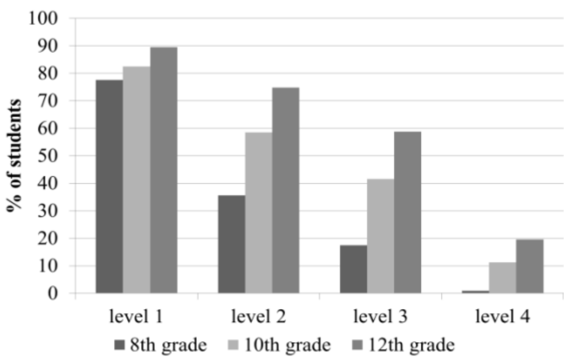

Figure 3. Percent of students on each competence level for disposing hypotheses

In the competence 'disposing hypotheses' 82,3 % of the students over all grades were able to choose a correct hypotheses for a given experiment (level 1). About half of the students phrased a correct hypothesis on their own (level 2) and a third of the students was able to justify their hypothesis in a scientific manner (level 3). Less than 10 % were able to phrase the alternate hypothesis (level 4). Students from the three different grades differ again in all four levels (level 1: $\chi^2 = 8{,}25$; $p \leq .05$; level 2: $\chi^2 = 55{,}47$; $p \leq .001$; level 3: $\chi^2 = 66{,}25$; $p \leq .001$; level 4: $\chi^2 =$

32,67; $p \leq .001$) with more students from higher grades reaching each level (figure 3). If only the highest level a student reached is taken into account, the median for 8th grade is 1,00, for 10th grade is 2,00 and for 12th grade is 3,00.

About 85 % of the students were able to choose a correct experimental plan (level 1), but only half of the students were able to create one on their own (level 2). About a quarter of the students considered confounding variables or repeated measures (level 3) and only five percent considered both (level 4). Students from the three different grades once more in all four levels (level 1: $\chi^2 = 51,27$; $p \leq .001$; level 2: $\chi^2 = 63,46$; $p \leq .001$; level 3: $\chi^2 = 53,72$; $p \leq .001$; level 4: $\chi^2 = 23,33$; $p \leq .001$), with more students from higher grades reaching the levels (figure 4). If the highest level a student reached is concerned, the median for 8th grade is 1,00, for 10th grade and 12th grade it is 2,00.

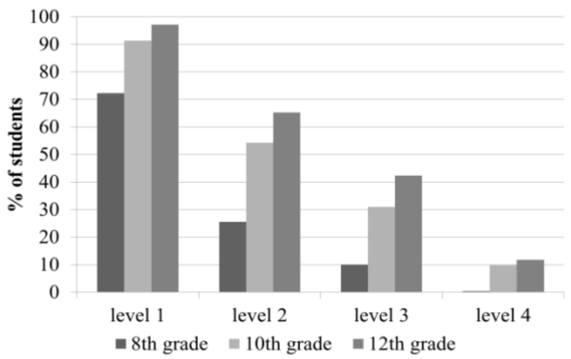

Figure 4. Percent of students on each competence level for planning an experiment

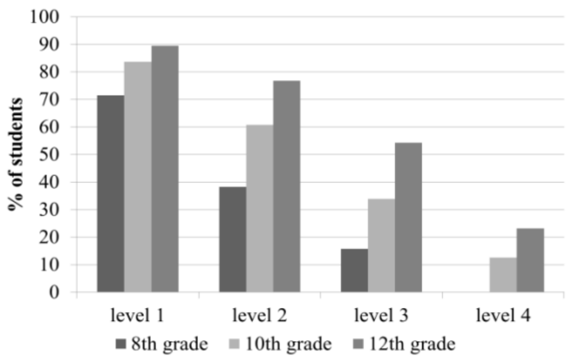

Figure 5. Percent of students on each competence level for analysing data

As far as analyzing data from experiments is concerned, 80 % of the students chose correct conclusions from the given data (level 1) and about half of the students phrased their own conclusions (level 2). 30 % were able to justify their conclusions in a scientific manner (level 3) and about 10 % were able to analyze statistical data correctly (mean and deviation – level 4). Finally, students of the three grades differ in all four levels (level 1: $\chi^2 = 19,28$; $p \leq .001$; level 2: $\chi^2 = 53,48$; $p \leq .001$; level 3: $\chi^2 = 58,06$; $p \leq .001$; level 4: $\chi^2 = 51,38$; $p \leq .001$) with more students from higher grades reaching the levels (figure 5).
If only the highest level a student reached is taken into account, the median for 8th and 10th grade is 1, for 12th grade it is 3.

DISCUSSION AND CONCLUSIONS

Consistent with PISA, Austrian students from 8th grade showed limited inquiry skills in the present study (OECD, 2016; OECD, 2019b). About 70 % of 8th graders reached level 1 on all four inquiry competences which were addressed in this study, about a third reached level 2, 10 to 15 % level 3 and almost no students reached level 4. On level 1, students in this study had to identify appropriate questions, hypotheses, experimental plans or data analysis so it can be compared to maximum level 2 from the PISA levels of proficiency (OECD, 2018). In PISA

2015, 46 % of Austrian students reached this level of competence (OECD, 2016). In Germany´s standard testing, students reach minimal standards, if they are able to phrase research questions or hypotheses, complete experimental plans or choose correct conclusions (Mayer, Wellnitz, Klebba & Kampa, 2019). About one third of the students from 9th grade reached minimal standards as far as inquiry competences in biology are concerned (Weirich, Becker & Holtmann, 2019). These results are consistent with the present study, where 42 % of the students from 8th grade were able to phrase a research question and 35 % of the same students were able to dispose hypotheses.

In the present study inquiry competences increased in high school, but fell short of expectations. Even in 12th grade only about 20 % of the students reached the highest competency level. Students in high school classes showed problems in using biological concepts for asking questions and were not familiar with common concepts of inquiry. As no data for senior classes from German speaking countries is available, US data is used for comparison, because in PISA Austrian and US students virtually reach the same science scores. Data from the United States National Assessment of Education Progress (NAEP) indicate that in 12th grade only about 60 % of the students reach basic or above levels of achievement as far as inquiry is concerned (NAEP, 2015). Although**,** the presented study shows that competency levels have increased from 8th grade to 12th grade, Austrian students at the end of high school showed comparable levels of competence with only 70% percent of students in their last year before university being able to phrase hypotheses and only 60 % being able to plan experiments. When biological background knowledge is necessary**,** the performance is even worse. The inquiry specific terminology (dependent/independent variable, alternate hypotheses and deviation) appears to be unknown to many students (Baur, 2018; Hammann et al., 2008).

Taking into account that even students from 12th grade, who should be able to attend university afterwards, do not possess solid inquiry competences, teaching these competences in school should be given higher priority. With respect to the findings of this study, science teaching should especially contain three aspects of inquiry: building up basic knowledge about inquiry (e.g. terminology, procedure, nature of science), doing inquiry and linking inquiry to biological knowledge. Building on these three aspects of inquiry, teaching concepts have to be implemented and evaluated that could be used by science teachers to pay more attention to teaching inquiry.

REFERENCES

Alfieri, L., Brooks, P. J., Aldrich, N. J. & Tenenbaum, H. R. (2011). Does discovery-based instruction enhance learning? *Journal of Educational Psychology, 103,* 1–18.

Anderson, R. D. (2002). Reforming science teaching: What research says about inquiry. *Journal of Science Teacher Education, 13*(1), 1–12

Baur, A. (2018). Fehler, Fehlkonzepte und spezifische Vorgehensweisen von Schülerinnen und Schülern beim Experimentieren [Errors, pre-concepts and special approaches of students doing inquiry]. *Zeitschrift für Didaktik der Naturwissenschaften*, *24*(1), 115–129.

Bybee, R. W. (2011). Scientific and engineering practices in K-12 classrooms: Understanding a framework for K-12 science education. *Science and Children*, *49*(4), 10.

Bevins, S. & Price, G. (2016). Reconceptualising inquiry in science education. *International Journal of Science Education, 38*(1), 17–29.

BIFIE (2011). *Kompetenzmodell Naturwissenschaften 8.* Schulstufe [Science competency model for 8th grade]. Retrieved from https://www.bifie.at/system/files/dl/bist_nawi_kompetenzmodell-8_2011-10-21.pdf

Bundesgesetzblatt für die Republik Österreich (2016). *BGBl II, 219/2016: Änderung der Verordnung über die Lehrpläne der allgemeinbildenden höheren Schulen geändert wird; Bekanntmachung der Lehrpläne für den Religionsunterricht [Curriculum changes for high school classe; curriculum for religious education],* ausgegeben am 09.08.2016.

Cairns, D. (2019). Investigating the relationship between instructional practices and science achievement in an inquiry-based learning environment. *International Journal of Science Education*, *41*(15), 2113–2135.

Cairns, D. & Areepattamannil, S. (2017). Exploring the relations of inquiry-based teaching to science achievement and dispositions in 54 countries. *Research in Science Education*, *49*(1), 1–23.

Centurino, V. A. & Jones, L. R. (2017*). TIMSS 2019: Science Framework. In I. V. Mullis & M. O. Martin (eds.), TIMSS 2019 assessment framework*. Retrieved from http://timss2019.org/wp-content/uploads/frameworks/T19-Assessment-Frameworks.pdf

Department for Education (2014). *The national curriculum in England: Framework document.* Retrieved from https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/ 381344/Master_final_national_curriculum_28_Nov.pdf

Education Bureau Hong Kong (2016). *Science (Secondary 1-3) curriculum framework.* Retrieved from http://www.edb.gov.hk/attachment/en/curriculum-development/kla/science-edu/ Science_curriculum_framework_20160831.pdf

Hammann, M., Phan, T. T. H., Ehmer, M. & Grimm, T. (2008). Assessing pupils' skills in experimentation. *Journal of Biological Education, 42 (2),* 66–72.

KMK (2005). *Bildungsstandards im Fach Biologie für den Mittleren Schulabschluss: Resolution of16 December 2004* [Standards for life science in secondary education]. Munich: Luchterhand.

Mayer, J., Wellnitz, N., Klebba, N. & Kampa, N. (2019). Kompetenzstufenmodelle im Fach Biologie [Competency level models]. In In P. Stanat, S. Schipoloski, n. Mahler, S. Weirich & S. Henschel (eds.*), IQB-Bildungstrend 2018: Mathematische und naturwissenschaftliche Kompetenzen am Ende der Sekundarstufe 1 im zweiten Ländervergleich* (pp. 72–81). Münster: Waxmann.

Minner, D. D., Levy, A. J. & Century, J. (2010). Inquiry-based science instruction—what is it and does it matter? Results from a research synthesis years 1984 to 2002. *Journal of Research in Science Teaching*, *47*(4), 474–496.

NAEP (2015). *Science Assessment*. Retrieved from https://www.nationsreportcard.gov/science_2015/ #scores/chart_loc_1?grade=12

NRC (2012). *A framework for K-12 science education: Practices, crosscutting concepts and core ideas.* Washington, DC: National Academies Press.

OECD (2016). *PISA 2015 Results (Volume I): Excellence and Equity in Education*. Paris: OECD Publishing.

OECD (2018). *Summary description of the seven levels of proficiency in science in PISA 2015*. Retrieved from http://www.oecd.org/pisa/test/summary-description-seven-levels-of-proficiency-science-pisa-2015.htm

OECD (2019a). *Assessment and analytical framework*. Paris: OECD Publishing.

OECD (2019b). *Results from PISA 2019: Country Note Austria*. Paris: OECD Publishing.

Pant, H.A. et al. (2013). *IQB Ländervergleich 2012.* Münster: Waxmann.

Pedaste, M. et al. (2015). Phases of inquiry-based learning: Definitions and the inquiry cycle. *Educational Research Review, 14,* 47–61.

Schiffl, I. (2016). Science Standards in Austria: From prototypic tasks to diagnosis. In J. Lavonen, K. Juuti, Lampiselkä, A., Uitto & K. Hahl (Eds.), *Science Education Research: Engaging Learners for a sustainable future* (Proceedings of ESERA 2015) (p. 2 773 – 2784). Retrieved from http://www.esera.org/media/eBook%202015/eBook_Part_17_links.pdf

Schroeder, C. M., Scott, T. P., Tolson, H., Huang, T. Y. & Lee, Y. H. (2007). A meta-analysis of national research: Effects of teaching strategies on student achievement in science in the United States. *Journal of Research in Science Teaching*, *44*(10), 1436–1460.

Teig, N., Scherer, R. & Nilsen, T. (2018). More isn't always better: The curvilinear relationship between inquiry-based teaching and student achievement in science. *Learning and Instruction, 56,* 20–29.

Weirich, S., Becker, B. & Holtmann, M. (2019). Kompetenzstufenbesetzung in den naturwissenschaftlichen Fächern [Competency levels cast]. In P. Stanat, S. Schipoloski, n. Mahler, S. Weirich & S. Henschel (eds.*), IQB-Bildungstrend 2018: Mathematische und naturwissenschaftliche Kompetenzen am Ende der Sekundarstufe 1 im zweiten Ländervergleich* (pp. 169–199). Münster: Waxmann.

SCIENCE ACHIEVEMENT AND SCIENCE MOTIVATION OF WALDORF STUDENTS COMPARED TO REGULAR STUDENTS1

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Although inquiry-based science education (IBSE) is a highly valued and recommended instructional approach, its efficacy has been continually challenged. Recently, PISA 2015 results showed that higher levels of IBSE are associated with lower science achievement in almost all participating countries. The present study investigates if students of schools with a strong, curriculum-based emphasis on IBSE (Waldorf schools) show more positive science learning outcomes than regular students. We applied propensity score matching to control for Waldorf students' more advantageous social background using the Austrian PISA 2015 sample (N = 7,007 15-year old students). After propensity score matching, 1107 matched controls were included alongside all 149 Waldorf students. The results show that Waldorf students report higher enjoyment in learning science and more interest in broad science topics than matched controls. On the other hand, they demonstrate lower science achievement.

Keywords: PISA, inquiry-based science education, Waldorf education

CONTEXT AND THEORETICAL FRAMEWORK

Inquiry-based science education (IBSE) has become a highly valued and recommended instructional approach (Artigue, Dillon, Harlen, & Léna, 2012; European Commission, 2007; Flick & Lederman, 2006; National Research Council, 2000, 2012). Despite this emphasis, the efficacy of IBSE, has been continually challenged (Kirschner, Sweller, & Clark, 2006; Mayer, 2004, Steffens, 2007), although recent meta-studies have supported the effectiveness of IBSE (Minner, Levy, & Century, 2010; Furtak, Seidel, Iverson, & Briggs, 2012). However, most of the evidence was collected in experimental or quasi-experimental research settings rather than in daily teaching and learning settings and many of the (quasi-)experimental investigations into the effectiveness of IBSE performed so far have limitations. These limitations concern the varying operationalization of IBSE (e.g., Furtak et al., 2012, Minner et al., 2010), the short time span covered in many (quasi-) experimental studies (e.g. Echevarria, 2003, Cobern et al., 2010), a lack of differentiation between cognitive and attitudinal student outcomes (as in Furtak et al., 2012), and/or very narrow outcome measures (e. g., understanding the concepts of

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1 Results of this manuscript are the basis of an article that has been submitted to Large-scale Assessments in Education. This article investigates IBSE as possible reason for the special achievement – motivation constellation of Waldorf students found in the present manuscript.

"floating and sinking" as in Hardy, Jonen, Möller, & Stern, 2006). Therefore we lack information about the effects of long-term curriculum-based IBSE on different forms of learning outcomes, especially on general science achievement.

The present study aims to close this research gap by investigating whether students attending a school type with high emphasis on IBSE in the curriculum demonstrate higher science achievement and more positive attitudes towards science than regular students with similar background characteristics. We include attitudinal outcomes (enjoyment of learning science and interest in broad science topics) in our analysis because developing positive science-related attitudes is an important educational goal alongside fostering science achievement (e.g., Osborne, 2003; Schiepe-Tiska, Roczen, Müller, Prenzel, & Osborne, 2016).

The present study is based on PISA 2015 data. The Programme for International Student Assessment (PISA) 2015 asked students about the amount of IBSE in their everyday science instruction. Results showed that the average amount of IBSE differs decisively by country and that students in Austria, Japan, Korea, and Finland report the lowest amount of IBSE across OECD countries (OECD, 2016a, p. 72). Furthermore, PISA revealed that more IBSE was associated with lower science achievement in most countries (Mostafa, Echazarra, & Guillou, 2018; OECD, 2016a). This result led to ongoing discussions in the science education research community (Osborne, Tiberghien, Le Hebel, Dolin, & Millar, 2017; Sjøberg, 2017).

Based on PISA 2015 data this study follows a different research approach in determining the effectiveness of IBSE. We compare learning outcomes of students who attend a school type with a curriculum-based very high amount of IBSE (Waldorf schools) to regular Austrian students, who typically have very limited contact with IBSE (Krainer & Benke, 2009) by propensity score matching. This method is recommended when determining the effect of a treatment (i.e. high amount of IBSE) in observational data (e.g., Rutkowski, 2016; Stuart, 2010). In addition, the present study systematically differentiates between the effects of IBSE on cognitive outcomes (science achievement) and attitudinal outcomes (enjoyment of learning science and interest in broad science topics).

COMPARISON OF SCIENCE-RELATED LEARNING OUTCOMES BETWEEN WALDORF STUDENTS AND REGULAR STUDENTS

Waldorf schools represent a school type with high emphasis on IBSE. Globally available, this private school system follows concepts outlined by Rudolf Steiner (1861–1925). Waldorf science education is characterized by a high emphasis on the observation and inquiry process. The correctness of an answer is evaluated mainly with respect to the available observation and evidence. The teacher does not perform as the sole bearer of expert knowledge, but provides opportunities to inquire, observe, and negotiate ideas. Indeed a very high prevalence of student investigations in science instruction has been reported by Waldorf students in PISA 2006 (Wallner-Paschon, 2009).

Concerning motivational-affective student outcomes, it was shown that Waldorf students report decisively more enjoyment of learning science, more interest in broad science topics, and a higher science self-concept than regular students (Wallner-Paschon, 2018). Concerning cognitive outcomes, it was shown that Waldorf students slightly outperform Austrian regular students in reading and science but they perform slightly below the population mean in mathematic (Wallner-Paschon, 2018). Considering that Waldorf students' socioeconomic status (SES) is decisively higher than regular students' SES, these results indicate underachievement in Waldorf students as their actual achievement is lower than expected by their SES. Studies that control for the higher SES of Waldorf students when comparing achievement outcomes between Waldorf and regular students were missing until now.

The present study investigates whether IBSE affects science-related learning outcomes when it is a general curriculum-based educational approach that is not only applied for a limited time-span and restricted to specific topics (like in [quasi-]experimental studies).

Provided Waldorf students and regular students are matched by relevant covariates (gender, immigration background, parental education, parental occupational status, and cultural possessions at home), we will look at the prevalence of IBSE in Waldorf schools and compare the two groups concerning important science related aspects like science achievement, science enjoyment and broad interest in science topics.

RESEARCH METHODS AND DESIGN

The present sample is based on the Austrian PISA 2015 sample. PISA assesses country-representative samples of 15-year old students. In Austria all 15-year old students from all ten Austrian Waldorf schools were added to the PISA sample, thus achieving a census of 15-year old Waldorf students in Austria. This resulted in a PISA sample of 6,858 regular students and 149 Waldorf students. As measures we used the PISA 2015 Science Proficiency Scale, Interest in Broad Science Topics Scale, Enjoyment of Learning Science Scale and IBSE Scale. The reliability of the PISA scales were very good to excellent in Austria (ρ between .77 and .93; OECD, 2017).

Propensity score matching was used as a pre-processing strategy to control for systematic differences between Waldorf students and regular students on various background characteristics (SES). If subject groups can reasonably be regarded as statistically equivalent on relevant covariates, average differences on the outcomes could plausibly be attributed to the treatment (Rutkowski, 2016). After matching, standardized mean differences of all covariates were below d = 0.1 and therefore far below the criterion of d = 0.25 for acceptable group differences after matching. For the present study this means that, after statistical equivalence in background characteristics is established, average differences on science achievement and science motivation can plausibly be attributed to Waldorf science instruction.

RESULTS AND DISCUSSION

After matching, standardized mean differences of all covariates were below d = 0.1 and therefore far below the criterion of d = 0.25 for acceptable group differences after matching (Stuart, 2010). Altogether, matching was very successful as group differences in background characteristics were close to zero after matching.

As expected, differences in science achievement increased as a result of matching: While the science achievement gap was d = 0.09 in favor for Waldorf students before matching, it was d = -0.32 to the detriment of Waldorf students after matching. The advantages of Waldorf students in terms of interest (d = 0.30) and enjoyment (d = 0.24) however were still remarkable after matching. Moreover, the much higher level of IBSE reported by Waldorf students was still clear after matching (d = 0.89 before matching and d = 0.82 after matching).

Waldorf education is characterized by a high amount of curriculum-based IBSE, and indeed a very high amount of IBSE was reported by Waldorf students in the present study. Therefore, Waldorf students are an ideal population for revealing the effects of IBSE. In order to investigate the specifics of Waldorf students in terms of IBSE and learning outcomes, we need to compare them to regular students who have – at least in Austria – very limited contact to IBSE. In the present study, students of the regular PISA sample with similar sociodemographic characteristics as Waldorf students were used as the comparison group.

The present study offers new empirical evidence in two substantial respects: First, it showed that Waldorf students are more interested in science topics and report more enjoyment of learning science than regular students. On the other hand, Waldorf students perform remarkably lower in science than expected by their sociodemographic background. In further studies we need to investigate if this conflicting attitude-achievement constellation of Waldorf students may be explained by a higher amount of IBSE in Waldorf education or by general educational principles of Waldorf education rather than in specifics of science instruction (like IBSE). Such general principles may be a lower achievement orientation or a lack of normative achievement feedback (Liebenwein, Barz & Randoll, 2012).

REFERENCES

Artigue, M., Dillon, J., Harlen, W. & Léna, P. (2012). *Learning through inquiry*. Background resources for implementing inquiry in science and mathematics at school. http://www.fibonacci-project.eu/

Cobern, W., Schuster, D., Adams, B., Applegate, B., Skjold, B., Undreiu, A., Loving C. & Gobert, J. (2010) Experimental comparison of inquiry and direct instruction in science. *Research in Science & Technological Education*, *28*, 81–96.

Echevarria, M. (2003). Anomalies as a catalyst for middle school students' knowledge construction and scientific reasoning during science inquiry. *Journal of Educational Psychology*, *95*, 357–374.

European Commission (2007). *Science Education Now: A renewed pedagogy for the future of Europe*. Brussels: European Commission.

Flick, L. B. & Lederman, N. G. (Eds). (2006). *Scientific Inquiry and Nature of Science: Implications for Teaching, Learning, and Teacher Education*. Dordrecht: Kluwer.

Furtak, E. M., Seidel, T., Iverson, H. & Briggs, D. C. (2012). Experimental and quasi-experimental studies of inquiry-based science teaching. *Review of Educational Research*, *82*, 300–329.

Hardy, I., Jonen, A., Möller, K. & Stern, E. (2006). Effects of instructional support within constructivist learning environments for elementary school students' understanding of "floating and sinking." *Journal of Educational Psychology*, *98*, 307–326.

Kirschner, P. A., Sweller, J. & Clark, R. E. (2006). Why minimal guidance during instruction does not work: An analysis of the failure of constructivist, discovery, problem-based, experiential, and inquiry-based teaching. *Educational Psychologist*, *41*, 75–86.

Krainer, K. & Benke, G. (2009). Mathematik – Naturwissenschaften – Informationstechnologie: Neue Wege in Unterricht und Schule? In W. Specht (Ed.), *Nationaler Bildungsbericht Österreich 2009*. (Vol. 2, p. 223–246). Graz, Austria: Leykam.

Liebenwein, S., Barz, H. & Randoll, D. (2012). *Bildungserfahrungen an Waldorfschulen. Empirische Studie zu Schulqualität und Lernerfahrungen*. [Educational experiences in Waldorf schools].

Mayer, R. E. (2004). Should there be a three-strikes rule against pure discovery learning? The case for guided methods of instruction. *American Psychologist*, *59*, 14–19.

Minner, D. D., Levy, A. J. & Century, J. (2010). Inquiry-based science instruction - what is it and does it matter? Results from a research synthesis years 1984 to 2002. *Research in Science Teaching*, *47*, 474–496.

Mostafa, T, Echazarra, A. & Guillou, H. (2018). *The science of teaching science: An exploration of science teaching practices in PISA 2015*. Paris: OECD. http://dx.doi.org/10.1787/f5bd9e57-en

National Research Council (2000). *Inquiry and the national science education standards: A guide for teaching and learning*. Washington, DC: The National Academies Press.

National Research Council. (2012). *A framework for K–12 science education: Practices, crosscutting concepts, and core ideas*. Washington, DC: The National Academies Press.

OECD (2016a). *PISA 2015 Results (Volume II): Policies and Practices for Successful Schools*. Paris: OECD Publishing.

OECD. (2017). *PISA 2015. Technical Report. Paris: OECD Publishing*. Retrieved from http://www.oecd.org/pisa/sitedocument/PISA-2015-technical-report-final.pdf

Osborne, J. (2003). Attitudes towards science: a review of the literature and its implications. *International Journal of Science Education*, *25*, 1049–1079.

Osborne, J., Tiberghien, A., Le Hebel, F., Dolin, J. & Millar, R. (2017). PISA 2015: An analysis of the findings for 4 countries and the implications for policy and practice. *Symposium presented at the ESERA Conference, Dublin, Ireland*. Retrieved from https://keynote.conference-services.net/programme.asp?conferenceID=5233&action=prog_list&session=38986

Rutkowski, L. (2016). Introduction to special issue on quasi-causal methods. Large-scale Assessment in Education 4, 8.

Schiepe-Tiska, A., Roczen, N., Müller, K., Prenzel, M. & Osborne, J. (2016). Science-related outcomes: Attitudes, motivation, value beliefs, strategies. In S. Kuger, E. Klieme, N. Jude, & D. Kaplan (Eds.), *Assessing contexts of learning: An international perspective* (pp. 301–329). Cham: Springer International Publishing.

Sjøberg, S. (2017). *Should we sacrifice inquiry-based science education (IBSE) in order to climb on PISA rankings?* Paper presented at the 17th Nordic Research Symposium on Science Education (NFSUN 2017), Trondheim, Norway, 6–9 June 2017.

Steffens, M. (2007). Memory for goal-directed sequences of actions: Is doing better than seeing? *Psychonomic Bulletin & Review*, *14* (6), 1194–1198.

Stuart, E. A. (2010). Matching methods for causal inference: A review and a look forward. *Statistical Science*, *25*, 1–21.

Wallner-Paschon, C. (2009). Kompetenzen und individuelle Merkmale der Waldorfschüler/innen im Vergleich. In C. Schreiner & U. Schwantner (Eds.), *PISA 2006. Österreichischer Expertenbericht zum Naturwissenschafts-Schwerpunkt* (p. 387–399). Graz: Leykam

Wallner-Paschon, C. (2018). Kompetenzen, Motivation und Selbstwahrnehmung der Waldorfschüler/innen im Vergleich. *Journal for Research and Education*, *9*, 1–13. https://journal.ph-noe.ac.at/index.php/resource/issue/view/23

MEASURING STUDENTS' CHEMISTRY COMPETENCES AT THE TRANSITION BETWEEN PRIMARY AND SECONDARY SCHOOL

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During their learning careers, all students are confronted with transitions between different educational institutions at varying times. Those transitions go hand in hand with general and discipline-specific challenges for students. Referring to chemistry education the transition between different school types is often characterised by the different embedding of chemistry contents in various subjects. In this project subject-specific challenges during the transition from primary school to secondary school in Germany are focused. Aiming at measuring and describing the development of students' chemistry competences at that transition a paper and pencil test referring to content knowledge and procedural knowledge is developed and validated with a sample of 760 students from grade 4 to 8 (at age 9-13). A partial credit model in IRT scaling is used to determine parameters of statistical quality. The results show that the developed paper and pencil test can be used for measuring students' chemistry competences.

Keywords: Primary School, Secondary School, Scientific Competences

INTRODUCTION

An important point in students' learning careers is the transition from primary school to secondary school. At this time students are confronted with different general and also chemistry-specific requirements. The transition often comes along with a change from one integrated subject *science* to separate subjects for all social and natural sciences, which also changes students' perception of chemistry related topics (Möller, 2014). As a result, interruptions in the learning process can arise (Möller, 2010). To find possibilities which ease the transition from primary school to secondary school students' competences are analysed for the transition phase.

In Germany, the transition from primary school to secondary school usually occurs from grade 4 to grade 5 (at age 10). At that time, students leave primary school and start visiting secondary school. Depending on the type of secondary school chemistry contents are either taught in a separate subject *chemistry* or in an integrative subject *natural sciences* (Möller, 2014). *Chemistry* as a separate subject is commonly taught from grade 7 onwards or later (MSW NRW, 2013). Thus, there is a transition phase of two years or longer between *science* in primary school and *chemistry* in secondary school. During that transition phase chemistry contents are either taught in the subject *natural sciences* or not taught at all.

THEORETICAL BACKGROUND

In the context of cumulative learning in chemistry education new contents have to be integrated into students' existing knowledge (Fischer et al., 2007). One example of connecting chemistry contents and creating a cumulative learning process are the learning progressions for the first and second learning year in chemistry education in secondary school developed by Celik and Walpuski (2019). Such a cumulative learning process should not only be ensured in secondary school but also during the transition phase from primary school to secondary school. To avoid interruptions or unrelated repetitions in the learning process, competences acquired at primary school must be aligned with the new requirements of secondary school (Hempel, 2010).

In chemistry education the curricula of primary school and secondary school address competences referring to contents such as combustion, states of matter, substance properties, solutions and energy (MSW NRW, 2013; 2008). The competences stated in the curriculum for secondary school are more complex than in the curriculum for primary school while addressing the same contents. Thus, it should be possible to create a cumulative learning process during the transition phase from primary school to secondary school by means of the curricula of both school types. Due to that cumulative learning process, it would be expected that students' competences develop and improve continuously during the transition phase.

Against these expectations the transition from primary school to secondary school does not always seem to be successful regarding science education as shown in different school comparison studies. While TIMSS 2011 reveals that 78 % of German 4th graders (at age 10) achieve an intermediate or high competence level in science (Bos et al., 2012), only 60.3 % of German 9th graders (at age 15) achieve an intermediate or high competence level in science according to the PISA study of 2015 (OECD, 2016). In large scale assessments in Germany there are similar results for German 9th graders in the subject chemistry for content knowledge (intermediate/high competence level: 56,1 %) as well as knowledge acquisition (intermediate/high competence level: 63,3 %) (Stanat et al., 2019). Thus, the transition from primary school to secondary school in chemistry education should be improved.

To help students manage this transition more successfully primary school as well as secondary school have to be involved. Teachers should know the curricula of both school types to support a productive learning process. The aim of primary school should be to impart the necessary basic competences for students to have a successful start in chemistry education in secondary school (Hempel, 2010). In secondary school then those competences should be taken up and enhanced (Hempel, 2010). To optimise the transition from primary school to secondary school in chemistry education further information about the development of students' chemistry competences at this point of their learning careers are necessary.

AIMS AND RESEARCH QUESTIONS

The aim of this project is to assess the development of students' chemistry competences during the transition phase from primary school to secondary school. To achieve that aim, we designed two studies. In the first study, we developed a test instrument to assess the competences of students at the end of primary school and the beginning of secondary school. This study addresses the following research question:

1. To what extend is the developed test instrument objective, reliable and valid for measuring students' chemistry competences?

In a second study we will use the validated test instrument to assess students' chemistry competences and to describe the development of those competences during the transition phase from primary school to secondary school. This study addresses to the following research questions:

2. Which of the expected chemistry competences have students reached at the end of primary school?

3. How do students' chemistry competences develop in grades 5 and 6 in which chemistry contents are either taught in an integrative subject *natural sciences* or are not taught at all?

4. How do students' chemistry competences – depending on the type of science education in grades 5 and 6 – develop in grades 7 or 8 in which chemistry contents are taught in a separate subject *chemistry*?

The following description of methods, design and results focuses on the first of the two studies referring to the developed test instrument.

METHODS AND DESIGN

In a first step, referring to the curricula of both school systems, we identified chemistry competences described in the curriculum of primary school that are relevant for competences also stated in the curriculum of secondary school. Those competences are regarded as important for assessing the development of competences during the transition phase. In a second step, we used the identified competences to develop a paper and pencil test with 48 items. We designed all items as multiple-choice-items with six answer options. For each option the students have to decide whether it is a right or a wrong answer. If they are not sure, they are asked to tick neither of the boxes. Figure 1 shows the item format.

Question		
	✓ right	✗ wrong
Answer 1	☐	☐
Answer 2	☐	☐
Answer 3	☐	☐
Answer 4	☐	☐
Answer 5	☐	☐
Answer 6	☐	☐

Figure 1. Item format

24 items relate to *content knowledge* which is divided into three categories. We developed eight items for each of the key concepts *chemical reactions*, *structure of matter* and *energy*. 24 items relate to *procedural knowledge* which is – according to the German curriculum – divided into the three categories *knowledge acquisition*, *communication* and *evaluation and judgement*. For each of those categories we also developed eight items. To increase validity of the test seven raters assigned all items to the different categories. Due to an only acceptable interrater reliability ($\kappa_{Fleiss} = .78$) we improved some of the items.

After developing and improving the items we prepared the test booklets for the first study. To reduce test load, we compiled three different test booklets comprising 20 items (for younger students) or 32 items (for older students) each and linked them in an incomplete block design. In each test booklet half of the items refer to two of the key concepts of *content knowledge* and half of the items refer to two areas of *procedural knowledge*. Thus, each item appears in two of the three test booklets.

The data collection for the first study was in May 2019. To secure test objectivity trained testing personnel tested the students. We validated all items in grades 4 to 8 (at age 10-14) because we will assess chemistry competences of students in these grades in the second study. To estimate test quality parameters we aimed at a sample of 150 students per grade. Due to the incomplete block design we expected approximately 100 answers per item per grade which is a sufficient sample size for validating the items (Mendoza, Stafford, & Stauffer, 2000). As a consequence, the whole sample for the first study consists of 760 students.

We used IRT scaling to determine parameters of statistical quality. Based on the results of a preceding pilot study we selected a partial credit model to evaluate the test quality. Additionally, we compared a unidimensional model to a two-dimensional model with the dimensions *content knowledge* and *procedural knowledge*. Based on the results we improved the test instrument for the second study.

RESULTS

Comparing the model fit parameters of the unidimensional and two-dimensional partial credit model reveals that the two-dimensional model with the dimensions *content knowledge* and *procedural knowledge* should be preferred (see Table 1).

Table 1. Comparison of unidimensional and multidimensional partial credit model

Model	Deviance	BIC	Chisq	df	p
Unidimensional	59219.78	61136.81	398.0745	2	0
Two-dimensional	58821.71	60752.00	NA	NA	NA

In the two-dimensional model students' competences are estimated better than in the unidimensional model. Thus, the following results refer to the two-dimensional partial credit model.

Table 2 shows the results of IRT scaling for the dimensions *content knowledge* and *procedural knowledge*.

Table 2. Results for dimension 1 (*content knowledge*) and dimension 2 (*procedural knowledge*)

Dimension	EAP-Reliability	Variance	Infit	Item discrimination
Content knowledge	.761	0.170	0.754 - 1.266	M = 0.211 (CI-95 [0.158; 0.263])
Procedural knowledge	.824	0.204	0.604 - 1.308	M = 0.357 (CI-95 [0.315; 0.398])

The infit values as well as the EAP-reliabilities for both dimensions are satisfying. The variance and the item discrimination, however, are too low for both dimensions. As such, the developed test instrument is objective and valid for measuring students' *content knowledge* and *procedural knowledge*, whereas its reliability, variance and item discrimination should be improved.

IMPLICATIONS

The results of IRT scaling showed that the developed test instrument should be improved. Aiming at increasing reliability, variance and item discrimination we changed the item format shown in figure 1. One possible explanation for many students with high test scores is that they guessed the correct answer instead of not marking an answer if they are not sure. To counteract this we implemented a third box in the answer format. Now there is the option for students to tick a box if they are not sure about an answer. Thus, it should be possible to identify a difference between students who know the right answer and students who do not know the right answer. In this way reliability, variance and item discrimination should increase.

After improving the developed test we will use it for assessing the development of students' chemistry competences in the second study. Aiming at a quasi-longitudinal study from the beginning of grade 5 until the end of grade 7 or 8 we plan to measure the students' competences at different measurement points (see Figure 2).

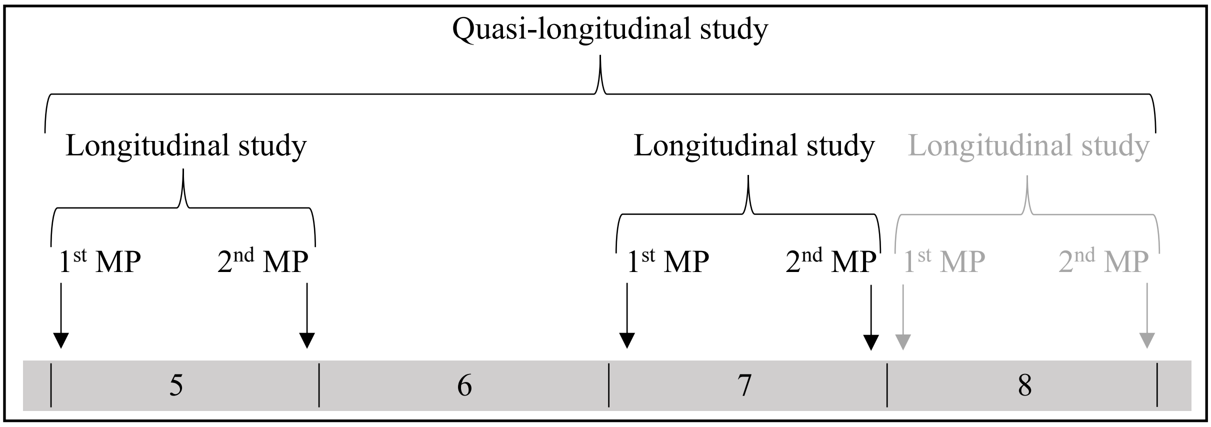

Figure 2. Second study

We will test students at the beginning of grade 5 and 7 and test the same students at the end of grade 5 and 7 again. Thus, there are two longitudinal studies that we can summarise in a quasi-longitudinal study. If the subject chemistry starts in grade 8, we plan to do a third longitudinal study in grade 8 in those schools.

REFERENCES

Bos, W., Wendt, H., Ünlü, A., Valtin, R., Euen, B., Kasper, D. & Tarelli, I. (2012). Leistungsprofile von Viertklässlerinnen und Viertklässlern in Deutschland [Performance profiles of 4th graders in Germany]. In W. Bos, I. Tarelli, A. Bremerich-Vos & K. Schwippert (Eds.), *IGLU 2011: Lesekompetenzen von Grundschulkindern im internationalen Vergleich* (pp. 227–260). München: Waxmann Verlag.

Celik, K. N. & Walpuski, M. (2019). Vernetzung von fachlichen Konzepten im Fach Chemie [Connecting subject-specific concepts in chemistry]. In C. Maurer (Ed.), *Naturwissenschaftliche Bildung als Grundlage für berufliche und gesellschaftliche Teilhabe. Gesellschaft für Didaktik der Chemie und Physik, Jahrestagung in Kiel 2018* (pp. 472–475). Regensburg: Universität Regensburg.

Fischer, H. E., Glemnitz, I., Kauertz, A. & Sumfleth, E. (2007). Auf Wissen aufbauen - kumulatives Lernen in Chemie und Physik [Building on knowledge – cumulative learning in chemistry and physics]. In E. Kircher, R. Girwidz & P. Häußler (Hrsg.), *Physikdidaktik. Theorie und Praxis* (S. 657–678). Berlin, Heidelberg: Springer-Verlag Berlin Heidelberg.

Hempel, M. (2010). Zur Anschlussfähigkeit der Sachfächer an den Sachunterricht - eine Erkundungsstudie [About the connectivity of natural and social science subjects to Sachunterricht]. In H. Giest & D. Pech (Eds.), *Anschlussfähige Bildung im Sachunterricht* (Probleme und Perspektiven des Sachunterrichts, vol. 20, pp. 75–82). Bad Heilbrunn: Klinkhardt.

Mendoza, J. L., Stafford, K. L., & Stauffer, J. M. (2000). Large-sample confidence intervals for validity and reliability coefficients. *Psychological Methods, 5*(3), 356–369.

Ministerium für Schule und Weiterbildung des Landes Nordrhein-Westfalen [MSW NRW]. (2013). *Kernlehrplan für die Gesamtschule - Sekundarstufe I in Nordrhein-Westfalen. Naturwissenschaften Biologie, Chemie, Physik [Curriculum for Gesamtschule – secondary school in North Rhine Westphalia. Sciences Biology, Chemistry, Physics]*. Frechen: Ritterbach.

Ministerium für Schule und Weiterbildung des Landes Nordrhein-Westfalen [MSW NRW]. (2008). *Lehrplan Sachunterricht für die Grundschulen des Landes Nordrhein-Westfalen* [Curriculum of Sachunterricht for primary schools in North Rhine-Westphalia]. Frechen: Ritterbach.

Möller, K. (2014). Vom naturwissenschaftlichen Sachunterricht zum Fachunterricht - Der Übergang von der Grundschule in die weiterführende Schule [From natural science education to discipline-specific education – The transition from primary to secondary school]. *Zeitschrift für Didaktik der Naturwissenschaften,* (20), 33–43.

Möller, K. (2010). Naturwissenschaftliche und technische Bildung in der Grundschule und im Übergang [Science and technical education in primary and at the transition]. In A. Campo (Hrsg.), *Übergänge gestalten.Naturwissenschaftliche und technische Bildung am Übergang von der Primarstufe zur Sekundarstufe* (VDI-Report / Verein Deutscher Ingenieure, Bd. 40, 15–36). Düsseldorf: VDI.

OECD (2016). *PISA 2015 Ergebnisse (Band I): Exzellenz und Chancengerechtigkeit in der Bildung [PISA 2015 Results (Volume 1): Excellence and equal opportunities in education].* OECD. PISA. Retrieved from http://dx.doi.org/10.1787/9789264267879-de.

Stanat, P., Schipolowski, S., Mahler, N., Weirich, S. & Henschel, S. (Eds.) (2019). *IQB-Bildungstrend 2018. Mathematische und naturwissenschaftlich Kompetenzen am Ende der Sekundarstufe I im zweiten Ländervergleich* [IQB-Trends in education 2018. Competences in mathematics and science in secondary school in the second comparison of German states]. Münster: Waxmann.

HOW CAN CONTEXT HELP TO SOLVE A PROBLEM? A PROCEDURAL ANALYSIS OF CONTEXTUALIZED PROBLEM-SOLVING

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Context-based learning in a narrower view (Whitelegg & Parry, 1999) typically includes problem-oriented tasks (e.g. Bennett & Lubben, 2006 or Taasoobshirazi & Carr, 2008) that need to be solved by applying science models. While there is no doubt on the positive effects of such context-based approaches on affective variables (e.g. interest), the variance in performance still remains unexplained. Consequently, Bennett, Lubben and Hogarth (2007) only decide to make a rather wary recommendation based on observations of 61 studies on context from 1980 till 2003: "...there are no drawbacks in the development of understanding of science, and considerable benefits in terms of attitudes to school science." (Bennett et al., 2007, p. 368–368). Several approaches tried to shed light on that issue whether by observing the interplay of manifold task characteristics, such as authenticity or relevance, or by taking into account how task characteristics interact with leaner characteristics (van Vorst et al., 2014). However, they still lack to explain the influence between context-based problem-solving and the resulting effect on performance. Along with that, Löffler (2016) also fails to establish a clear connection of Contextualization and performance in the problem-solving process. Yet, he also examines the distinct phases in the process and thereby finally reveals a possible explanation for the heterogeneous observations in research as stated before. Findings from these multiple regression analyses (N = 123) suggest that the effect of context on performance varies strongly during problem-solving. Consequently, further research must take into consideration the procedural character of problem solving to get a deeper insight on how context works.

Keywords: Context; Problem Solving; Modeling; Performance

CHALLENGING CONTEXT

Context-based problems have become a crucial part of science learning since the last decades (Pilot & Bulte, 2006): They allow teachers to encounter negative attitudes towards science (Bennett et al., 2007), but more importantly, there are also many arguments on how such tasks should foster the development of conceptual understanding (Lubben, Campbell, & Dlamini, 1996; Yager, 1999). Nevertheless, there are as well good arguments that support the opposite (Harp & Mayer, 1998; Taasoobshirazi & Carr, 2008). Consequently, research on this topic draws heterogeneous results (Bennett et al., 2007). Park and Lee address this issue by saying: "According to other studies […], it is difficult to observe a consistent effect of contexts on physics problem-solving." (Park & Lee, 2004, p. 1586–1586). Since then, a lot of effort has been put into unravelling context by examining possible topic effects (Gomez, Pozo, & Sanz, 1995; Kölbach, 2011), task characteristics (Löffler, 2016) as well as their interplay with learners' characteristics (van Vorst et al., 2014) and different notions of context (Finkelstein, 2005; Gilbert, 2006). Taken together, the influence of context on performance still lacks for understanding. One possible reason for this issue lies in the measurement of performance, which is usually based on the outcome of the problem-solving process rather than on the distinct phases of the solving process. Hence, we try to answer the question: 'How does context affect these phases?' by reanalyzing a study by Löffler (2016): Overall performance in this study was measured as sum score by rating typical steps in the problem-solving process (see e.g. Pólya, 1985 for the division of steps), thus allowing a more detailed examination in hindsight.

METHOD

Data is taken from a previous study on the effect of context on performance by Löffler (2016) as explained beforehand. The original study investigates three task characteristics: Contextualization (Löffler & Kauertz, 2015 or Löffler, 2016) of the situation described in the task; the Complexity (Kauertz, 2008) of the scientific model underlying the task; and Transparency (Löffler & Kauertz, 2015 respectively Löffler, 2016), which assesses whether and how the learner can identify this model. All of them are coded dichotomously (high and low). Thus, a 2x2x2 –design is used in the 10th grade of three high track schools in Germany ($N = 123$). Each student works on one out of eight task-versions ($t = 13$ min). Students' performance in the problem-solving process is thereby measured in the six phases of the analytic problem-solving process (Löffler, 2016): (1) Understand the problem, (2) Identify the variables, (3) Justify the selection of variables, (4) Formulate a solution proposal, (5) Give an answer to the problem, (6) Name further arguments for the validity of the solution. Each phase is represented by one item in the open-answer paper-and-pencil test by Löffler (2016). Reasons for the instrument's rather low reliability ($\alpha = 0.58$) include the complex interplay of skills involved in the problem-solving process; the small number of items (due to test-time constraints); and the rating process, which added an extra amount of uncertainty to the results (intercoder reliability Kendall's Tau-b: $.48 \leq \tau\beta \leq .97$, depending on the phase). Nevertheless, since operationalizing process-performance is quite challenging, Schmitt (1996) argued (when referring to an example of $\alpha = 0.49$) that if "a measure has other desirable properties, such as meaningful content coverage of some domain and reasonable unidimensionality, this low reliability may not be a major impediment to its use." (Schmitt, 1996, p. 351-352). The contextualized version of the task used within that test is out of the topic of thermodynamics (Kauertz, Löffler & Fischer, 2015) with a task difficulty of $p = 0.46$. The low-contextualized version contains the same physics-problem and has a task difficulty of $p = 0.47$. For 90 minutes, students work on the test booklets that additionally include instruments to encounter covariates such as cognitive abilities: Subscales of the IST-2000R (Liepmann, Beauducel, Brocke & Amthauer, 2007), reliability as reported by the authors: $0.87 \leq \alpha C \leq 0.96$ (depending on the scale) and conceptual pre-knowledge in thermodynamics: Thermal Concept Evaluation (Yeo & Zadnik, 2001), reliability as reported by the authors: Split half – correlation with Spearman-Brown correction: 0.81. Starting from this, the effect of Contextualization on performance in the six phases of the problem-solving process is initially investigated in a single MANCOVA, as several regressions or ANCOVAS alone would lead to an alpha error inflation and would neglect any relationship between the depended variables. Thereby, the other task characteristics (Complexity and Transparency) are statistically treated as covariates, as we only investigate the effect of Contextualization and consequently need to control other influential factors. The total number of covariates in a MANCOVA is limited by the rule of thumb "Maximum number of covariates = (.10 x Sample size) - (Number of groups - 1)" (Hair, Black, Babin, Anderson, & Tatham, 2006, p. 683). With four covariates, we meet this assumption. Other assumptions for MANCOVA include multivariate normality and homogeneity of covariance matrices (Field, 2009, p. 603). The latter can be disregarded "if the groups are of approximately equal size (i.e., largest group size ÷ smallest group size < 1.5)" (Hair et al., 2006, p. 685). We fulfill this precondition with 57 students in the group with the low-contextualized task and 66 students working on the high-contextualized task ($66 / 57 < 1.5$). Regarding multivariate normality, "no direct test is available" (Hair et al., 2006, p. 686). Consequently, Field (2009) among others suggests alternatively checking for univariate normality of each dependent variable. In our study, we do not meet this assumption: Kolmogorov-Smirnov- as well as Shapiro-Wilks - tests produce significant values ($p < .001$) for all dependent variables. On the other hand, Hair et al. (2006, p. 686) concluded, "violations of this assumption have little impact with larger sample sizes". Given that, Hair et al. (2006, p. 679) demand a sample size equal to the number of dependent variables as a bare minimum and recommended a number of 20 observations per group. With roughly 60 observations per group in our study, we therefore consider our sample size as large enough to disregard the violation of univariate normality, as F-tests are generally robust (Hair et al., 2006, p. 687). Among the different test statistics for MANCOVA, Pillai's trace is especially robust against violations of assumptions in case of equal sample sizes (Field, 2009, p. 605). Consequently, we used Pillai's trace to verify a significant overall effect. Based on that, we subsequently conduct several hierarchical regressions with the same set of covariates to get an idea of the effect of Contextualization on each of the phases of the problem solving process.

RESULTS

Using Pillai's trace, there is a significant overall effect of Contextualization on the performance in the phases of the problem solving process, $V = 0.227$, $F(6, 112) = 5.483$, $p < .001$.

Separate hierarchical regressions on the dependent variables reveal significant effects for

- Item 1/Phase 1: Understand the problem: Covariates do not withstand statistical prove ($F(4, 118) = 0,947$, $p = .439$), including Contextualization in the model (standardized beta: .208) changes R^2 significantly ($p = .023$) up to $R^2 = .034$ ($f^2 = .035$).
- Item 2/Phase 2: Identify the variables: Covariates explain 17,6 % of variance ($F(4, 118) = 7,505$, $p < .001$), including Contextualization in the model (standardized beta: -.198) changes R^2 significantly ($p = .017$) up to $R^2 = .209$ ($f^2 = .042$).
- Item 3/Phase 3: Justify the selection of variables: Covariates do not withstand statistical prove ($F(4, 118) = 2,325$, $p = .060$), including Contextualization in the model (standardized beta: .194) changes R^2 significantly ($p = .030$) up to $R^2 = .072$ ($f^2 = .078$).
- Item 4/Phase 4: Formulate a solution proposal: Covariates explain 13,4 % of variance ($F(4, 118) = 5,700$, $p < .001$), including Contextualization in the model (standardized beta: -.200) changes R^2 significantly ($p = .018$) up to $R^2 = .167$ ($f^2 = .040$).

and non-significant effects for

- Item 5/Phase 5: Give an answer to the problem: Neither the covariates nor the extended model including Contextualization withstand statistical prove ($p = .056$ and $p = .443$ respectively).
- Item 6/Phase 6: Name further arguments for the validity of the solution: Covariates explain 23,2 % of variance ($F(4, 118) = 10,947$, $p < .001$), including Contextualization in the model does not change R^2 significantly ($p = .564$).

The summary in table 1 allows a quick comparison of the reported effects of Contextualization on performance in the phases of the problem solving process.

Table 1. Summary of effects of Contextualization on performance. Significant values are in bold.

	Phase 1	Phase 2	Phase 3	Phase 4	Phase 5	Phase 6
R_I^2	-.002	.176	.042	.134	.043	.232
R_{II}^2	.034	.209	.072	.167	.040	.282
ΔR^2	.034	.033	.072	.033	/	/
p	.023	.017	.030	.018	.443	.564
f^2	.035	.042	.078	.040	/	/
β	.208	-.198	.194	-.200	.069	-.047

As pictured in Figure 1, Contextualization has opposing influence on the performance in the first four phases.

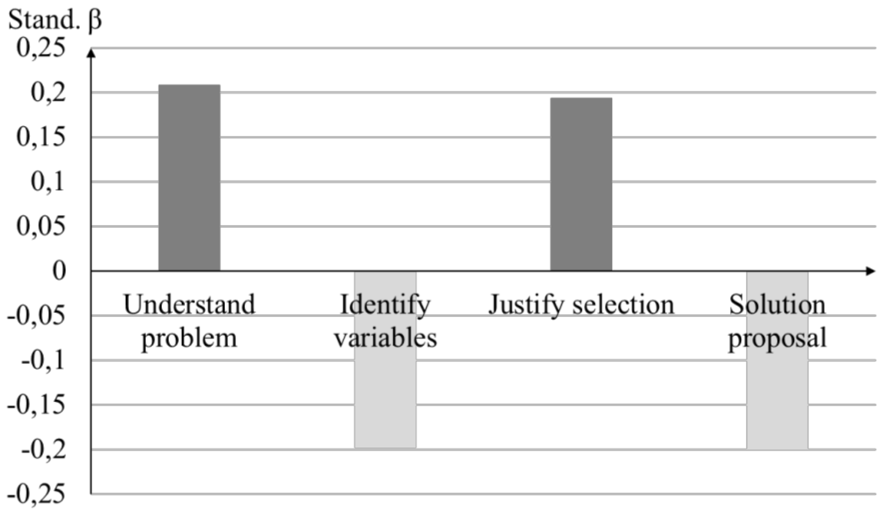

Figure 1. Comparison of standardized betas of the effect of Contextualization on performance in the first four phases of the problem solving process.

DISCUSSION AND CONCLUSIONS

Our results show that the effect of context varies strongly in the problem-solving process: Thus, it fosters students' efforts in understanding the problem while at the same time it hinders them in selecting relevant information to solve the problem. On the opposite, learners seem to benefit from context when it comes to provide a reason for the importance of the selected information. However, context raises the bar for formulating solution proposals. All effects are equally strong and therefore cancel each other out on the process level, which could explain the results in the original study (Löffler, 2016). At the same time, these findings could help to explain the different results in research on context up until now: depending on how performance is measured, either the beneficial effects of context or its drawbacks dominate the outcome, leading to contradicting conclusions, hence making it hard to grasp context. Zhou (2016), for instance, reports: "students in general perform better with physics contexts than with real-life contexts" (Zhou, 2016, p. 12). This conclusion derives from her observation on the amount of additional variables that students consider while working on a task: Whereas students in total came up with five "unnecessary" variables in a physics task, they also brought up 17 additional variables in the real life context. For the latter, Zhou (2016) therefore concludes a tendency for students to consider additional variables other than those given in the problem, which is crucial for the measurement of performance in her study. This finding fits to our observation for phase 2, where context seems to obstruct students in identifying relevant variables. Rennie and Parker (1996) on the other hand reported beneficial effects of context-based problems on performance. However, they focused on the students' ability to understand the given problem, which fits to our findings in phase 1, where context has shown to be helpful. At the same time, Rennie and Parker mention that irrelevant contextual information may confuse students, which goes along with Zhou's and our own observations. Together, these findings strengthen our presumption regarding the origin of heterogeneous results in research on context effects. Consequently, we strongly recommend investigating the impact of context on a more detailed level, that is to say, the distinct phases of the problem solving process.

OUTLOOK

Our findings suggest that students should be supported in identifying relevant variables (Phase 2) as well as in formulating a solution proposal (Phase 4). Transparency can address the first issue (Figure 2) as it facilitates student's access to the underlying scientific model.

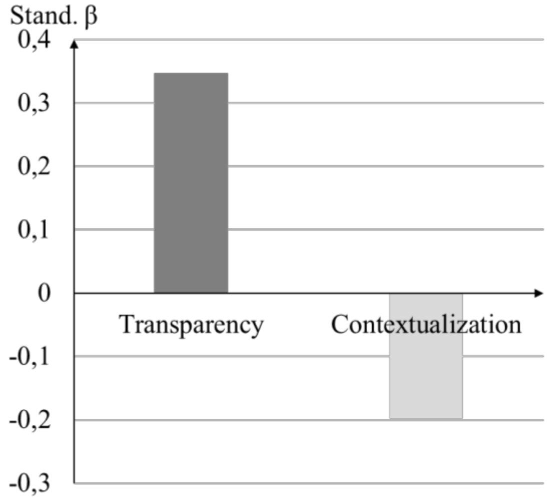

Figure 2. Comparison of standardized betas of the effects of Transparency and Contextualization on performance in Phase 2 of the problem solving process.

Regarding Phase 4, we could surprisingly not observe a positive effect of a low Complexity. However, a proper prior knowledge seems to be especially helpful in formulating a solution proposal (Figure 3).

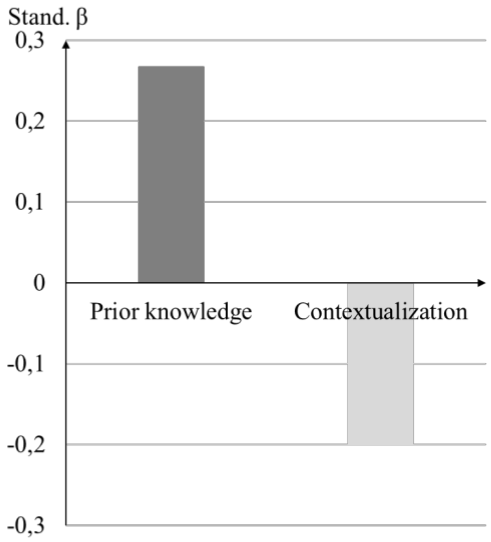

Figure 3. Comparison of standardized betas of the effects of prior knowledge and Contextualization on performance in Phase 4 of the problem solving process.

As it is desirable to compensate the negative effect of context with task characteristics, more research must be done including the analysis of affective variables. In a current project, we therefore analyze the interplay of performance with metacognition, interest and motivation and the task characteristics in different topics (Löffler, Pozas & Kauertz, 2018).

ACKNOWLEDGEMENT

This work is supported by the German Research Foundation (DFG) under the grant "Teaching & Learning Processes" (GRK 1561).

REFERENCES

Bennett, J., Lubben, F. & Hogarth, S. (2007). Bringing science to life: A synthesis of the research evidence on the effects of context-based and STS approaches to science teaching. *Science Education*, *91*(3), 347–370. DOI: 10.1002/sce.20186

Bennett, J. & Lubben, F. (2006). Context-based Chemistry: The Salters approach. *International Journal of Science Education*, *28*(9), 999–1015. DOI: 10.1080/09500690600702496

Field, A. (2009). *Discovering statistics using spss: (and sex and drugs and rock 'n' roll')* (3rd ed.). Thousand Oaks, CA: SAGE Publications.

Finkelstein, N. (2005). Learning Physics in Context: A study of student learning about electricity and magnetism. *International Journal of Science Education*, *27*(10), 1187–1209. doi:10.1080/09500690500069491

Gilbert, J. K. (2006). On the Nature of "Context" in Chemical Education. *International Journal of Science Education*, *28*(9), 957–976. DOI: 10.1080/09500690600702470

Gomez, M.-A., Pozo, J.-I. & Sanz, A. (1995). Students' ideas on conservation of matter: Effects of expertise and context variables. *Science Education*, *79*(1), 77–93. DOI: 10.1002/sce.3730790106

Hair, J. F., Black, B., Babin, B., Anderson, R. E. & Tatham, R. L. (2006). *Multivariate data analysis* (6th ed.). Upper Saddle River, N.J.: Pearson Prentice Hall.

Harp, S. F., & Mayer, R. E. (1998). How seductive details do their damage: A theory of cognitive interest in science learning. *Journal of Educational Psychology*, *90*(3), 414–434. DOI: 10.1037//0022-0663.90.3.414

Kauertz, A. (2008). Schwierigkeitserzeugende Merkmale physikalischer Leistungstestaufgaben. Berlin: Logos.

Kauertz, A., Löffler, P., & Fischer, H. E. (2015). Physikaufgaben. In E. Kircher, R. Girwidz, & P. Häußler (Eds.), Springer-Lehrbuch. Physikdidaktik. Theorie und Praxis (3rd ed., pp. 451–475). Berlin: Springer Berlin.

Kölbach, E. (2011). *Kontexteinflüsse beim Lernen mit Lösungsbeispielen*. Berlin: Logos.

Löffler, P. (2016). *Modellanwendung in Problemlöseaufgaben -- Wie wirkt Kontext? Studien zum Physik- und Chemielernen: Vol. 205*. [Applying models in problem-solving tasks – How does context take effect? Studies on learning physics and chemistry]. Berlin: Logos Berlin.

Löffler, P. & Kauertz, A. (2015). Modellanwendung in kontextualisierten Problemlöseaufgaben [Applying models in contextualized problem.solving tasks]. In S. Bernholt (Ed.), *Heterogenität und Diversität - Vielfalt der Voraussetzungen im naturwissenschaftlichen Unterricht* (Vol. 35, pp. 648–650). Kiel: IPN.

Löffler, P., Pozas, M. & Kauertz, A. (2018). How do students coordinate context-based information and elements of their own knowledge?: An analysis of students' context-based problem-solving in thermodynamics. *International Journal of Science Education*, *63*(3), 1–22. DOI: 10.1080/09500693.2018.1514673

Lubben, F., Campbell, B. & Dlamini, B. (1996). Contextualizing science teaching in Swaziland: some student reactions. *International Journal of Science Education*, *18*(3), 311–320. DOI: 10.1080/0950069960180304

Park, J. & Lee, L. (2004). Analysing cognitive or non-cognitive factors involved in the process of physics problem-solving in an everyday context. *International Journal of Science Education*, *26*(13), 1577–1595. DOI: 10.1080/0950069042000230767

Pilot, A. & Bulte, A. M. (2006). The Use of "Contexts" as a Challenge for the Chemistry Curriculum: Its successes and the need for further development and understanding. *International Journal of Science Education*, *28*(9), 1087–1112. DOI: 10.1080/09500690600730737

Pólya, G. (1985). *How to solve it: A new aspect of mathematical method* (2nd ed.). Princeton, N.J: Princeton University Press.

Schmitt, N. (1996). Uses and abuses of coefficient alpha. *Psychological Assessment*, *8*(4), 350–353. doi:10.1037/1040-3590.8.4.350

Taasoobshirazi, G. & Carr, M. (2008). A Review and Critique of Context-Based Physics Instruction and Assessment. *Educational Research Review*, *3*(2), 155–167.

van Vorst, H., Dorschu, A., Fechner, S., Kauertz, A., Krabbe, H. & Sumfleth, E. (2014). Charakterisierung und Strukturierung von Kontexten im naturwissenschaftlichen Unterricht – Vorschlag einer theoretischen Modellierung. *Zeitschrift für Didaktik der Naturwissenschaften.* DOI: 10.1007/s40573-014-0021-5

Whitelegg, E. & Parry, M. (1999). Real-life contexts for learning physics: Meanings, issues and practice. *Physics Education*, *34*(2), 68–72. DOI: 10.1088/0031-9120/34/2/014

Yager, R. E. (1999). Scope, sequence and coordination: The Iowa Project, a national reform effort in the USA. *International Journal of Science Education*, *21*(2), 169–194. DOI: 10.1080/095006999290778

Zhou, S., Han, J., Koenig, K., Raplinger, A., Pi, Y., Li, D., … (2016). Assessment of Scientific Reasoning: The Effects of Task Context, Data, and Design on Student Reasoning in Control of Variables. *Thinking skills and creativity*, *19*, 175–187. DOI: 10.1016/j.tsc.2015.11.004

IDENTIFICATION OF CHEMISTRY CONTEXTS THAT INTEREST GREEK STUDENTS

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This study explores students' interests in a variety of contexts commonly found in chemistry curriculum documents via the use of a questionnaire consisting of 50 items. The sample consisted of 314 Greek students, almost equally divided between the two genders, from two levels of secondary school: lower (14–15 years old, 160 students) and upper (16–17 years old, 154 students). Exploratory factor analysis provided evidence for five chemistry contexts that interest students: Aesthetics, Arts and Personal Care (AAPC) - Quality of life (QL) - Environmental Issues (EI) - Hazards, Forensics and Weapons (HFW) - Everyday Life (EL). Evaluation of Cronbach α's provided evidence for satisfactory internal consistency of the scores obtained for each of the five contexts. Further analyses via paired-samples t-tests led to the derivation of the specific interests' profiles of different student groups. Boys' top interest was shown to be related with the context of HFW while the AAPC was the least favorite one. Girls' exhibited the highest interest toward AAPC and the lowest toward EI. The results obtained may have significant implications for the design of chemistry curricula in order to meet the varying interests of different student groups and increase efficiency within the framework of context-based learning.

Keywords: Interest, Context-based learning, Secondary School

INTRODUCTION

Science education literature has revealed a general tendency for an increasing unwillingness of students in many parts of the world to participate in science (Bøe, Henriksen, Lyons, & Schreiner, 2011). Interest in the science subject has been among the most frequently stated factors contributing to this tendency (Osborne, 2008). The content-specific nature of interest related to a particular object, activity, and domain has been well documented (Krapp & Prenzel, 2011). Domain interest refers to students' interest in a defined body of knowledge (e.g. an interest in chemistry). Course interest refers to the interest students have for a defined course (e.g. 11th grade chemistry), which is likely to be directly influenced by how students experience specific course tasks and activities. Science and particularly chemistry courses are often considered to be irrelevant to students' everyday life (Gilbert, 2006). Therefore, many curriculum reforms have focused on the use of contexts and applications of science which may trigger students' interests. Students' prior content knowledge and personal relevance have been identified as potential factors that both trigger and maintain interest in chemistry (Nieswandt & Horowitz, 2015). Thus, studies that focus on the context in which science is taught could supply us with useful insights into disparities between students' interest in chemistry (Tytler, 2014). The aim of this study is to identify the interests associated with the context of chemistry learning in secondary school and examine their variation within specific student groups. Context-based learning and students' interests consist the theoretical frameworks of the present study.

Context-based learning

Context-based learning is one of the 'big ideas' in science education that has influenced teaching and learning science in many countries over the past decades. In 2006 and 2018 Special issues on context-based learning were published in International Journal of Science Education with the first (2006) focusing on context-based curriculum development and the second (2018) addressing the question of how a context influences the learning process.

Although context-based learning has been introduced in order to address a major problem of science classrooms, namely students' indifference and disinterest in learning science content (Fechner, Van Vorst, Kölbach, & Sumfleth, 2015), researchers have not agreed on a single, precise, technical definition of the term "context" in science education (Gilbert, Bulte, & Pilot, 2011). Duranti and Goodwin (1992) suggested that "a context is formed around some 'focal event'—an important or typical event—that draws the attention of learners while remaining imbedded in its cultural setting", while Eijkelhof (2015) defined as "context-based" a variety of science educational approaches that emphasize either the structure, the historical development, or the everyday life application of a discipline (e.g. chemistry). The effect of the context-based approaches on chemistry education has mainly been shown in the development of students' interest (King, 2012).

Students' interests

The theoretical concept of interest has attracted researchers' attention over the past few years (Hidi & Harackiewicz, 2000), and it has been proposed to be connected with intrinsic motivation to learn by educational psychologists (Koballa & Glynn, 2007). Two types of interest have been the primary focus of educational research to date: *situational* and *individual* interest (Renninger & Hidi, 2011). Individual interest can be conceptualized as a part of intrinsic motivation, which refers to a person's predisposition to attend to certain stimuli, events, and objects – including school subjects over time as well as to the immediate psychological state when this predisposition has been activated (Hidi & Renninger, 2006). Situational interest refers to focused attention and the affective reaction that is triggered in a specific time period by environmental stimuli, which may or may not last over time (Hidi & Renninger, 2006).

Person–object theory (Krapp & Prenzel, 2011) and the four-phase model of interest development (Hidi & Renninger, 2006) consider interest as an outcome of the interaction between a person and a particular object. Thus, interest is typically defined as a content and context-specific construct always related to an object, topic, subject, context, activity, or idea, and having a multicomponent structure, i.e. a cognitive and an affective component (Schiefele, 2009). Blankenburg, Höffler, and Parchmann (2016) further differentiate the analysis of interest in science based on a four-dimensional construct: (a) interest in a particular domain (e.g., chemistry); (b) interest in a particular subject matter or topic in a domain (e.g., combustion); (c) interest in a particular context, which is embedded in a topic (e.g., combustion in everyday situations such as burning a candle); (d) interest in a particular activity that is connected to the context and therefore to the topic (e.g., investigating the burning of a candle).

Silvia (2001) discussed the distinction between the terms interest and interests. He characterized interest as a basic emotion like happiness or fear, and interests as self-sustaining motives that lead people to engage in certain idiosyncratic and person-specific activities. Interests are defined as “trait-like preferences for activities, contexts in which activities occur, or outcomes associated with preferred activities” that orient individuals toward certain environments and motivate goal-oriented behaviors within environments (Rounds & Su, 2014). Such interests directly influence educational choices as people tend to be attracted to academic environments that are congruent with their interests (Su, Murdock, & Rounds, 2014). Although interests are contextualized, there exists a small number of subject-specific studies which examine interests in relation with context and, specifically, with the way context is used in chemistry courses.

Students’ interests differentiation

Brickhouse and Potter (2001) have shown that students’ interests related to science are significantly differentiated according to age and gender, as well as to socio-economic and cultural background. A number of studies have identified four interacting factors that influence student interest in school science: prior content knowledge, gender, family-cultural issues, and the quality of teaching (Nieswandt & Horowitz, 2015; Tytler, 2014). Moreover, students’ interest, as a part of intrinsic motivation, is strongly related with career motivation (Salta & Koulougliotis, 2015) and has a large impact on career choices (Lent et al., 2003; Salta, Gekos, Petsimeri, & Koulougliotis, 2012).

Some studies (e.g. ROSE) reported gender differences regarding interest in science topics, activities, and science contexts (Sjøberg & Schreiner, 2007; Blankenburg et al., 2016). Boys were found to have higher interest in the science school subject relative to the girls, with the pattern being however more differentiated upon examination of trends within specific school subjects (e.g. physics, chemistry, biology), or single topics within each subject (Murray & Reiss, 2005). There appears to be a tendency for boys to be concerned with the subject itself, whereas girls are interested in topics which may help them in their relations with themselves and other people (e.g. physics with more human-related content) (Krogh & Thomsen, 2005). Generally, girls express stronger interest in issues related with human health and well-being, whereas boys are more interested in themes related with technology and physics (Hazari, Sadler, & Tai, 2008; Jones, Howe, & Rua, 2000). The Greek ROSE study (Christidou, 2006) also revealed significant gender differences: girls were more interested in topics related to “human biology, health, and fitness”, while boys were more interested in both “science, technology, and their social dimension”, and “the threatening aspects of science and technology”.

In chemistry, the gender differences are less pronounced (Salta & Tzougraki, 2004), and research has indicated that students find chemistry topics, like molecular mass, periodic table and other intangible and microscopic entities mostly unintelligible and irrelevant for their lives (Osborne & Collins, 2001). Topics attracting interests in chemistry are "mixing chemicals", "smells and colours" and "elements of danger" (Osborne & Collins, 2001), with explosive chemicals being among the top five most interest topics for English boys (Jenkins & Nelson, 2005). German female students revealed primary interest in topics with reference to hygiene, nutrition, and health, while male students showed higher interest in industrial and technical matters. Both female and male students indicated to be strongly interested in socially relevant topics like pollution or power supply (Gräber, 2011).

Interests may also depend on other factors such as environment or culture, but the research results are diverse (Dierks, Höffler, & Parchmann, 2014; Hagay & Baram-Tsabari, 2011). In addition, students' interests could change over time (Dawson, 2000). A context that was found interesting and relevant may lose its popularity over years, or even weeks (Baram-Tsabari & Segev, 2015). Thus, the generalizability of students' interest in a specific context remains unclear and more studies that focus on the context in which science (chemistry) is taught could supply us with useful insights into disparities between students' interests (Tytler, 2014).

The present study

Since the relevance of the chemistry curriculum affects interest and learning, determining the specific students' interests in various contexts of school chemistry should provide a basis for informed discussions on how to improve curricula and enhance students' interest and engagement in chemistry. Based on the domain, activity, and context nature of interests (Fryer, Ainley, & Thompson, 2016; Renninger & Hidi, 2011), there is a large need to investigate in more detail students' opinions about chemistry and more specifically starting with the question of what students are interested in learning in chemistry courses and continuing with the one of how students' interests are differentiated within age and gender. Such an investigation, specifically concerning Greek students, could reveal chemistry contexts with thematic coherence which students are interested in learning about and possible both age (school level) and gender differentiations with respect to these contexts. Therefore, the results of the present study could contribute to the development of a more relevant and meaningful curriculum for the students.

Taking into consideration all of the above, the purpose of the present study is on one hand to identify the students' interests associated with the context of chemistry learning in secondary school and on the other to investigate the possible differentiation of the identified interests within various student groups. More specifically the specific questions that have guided this study can be summarized as follows:

- What are the chemistry contexts that Greek secondary school students' have more interest to learn?
- How are Greek students' context-related interests differentiated within each school level and gender?

METHOD

Sample

The sample consisted of 314 secondary school students (157 boys, 156 girls, and one who did not mention gender), of which 160 were in lower secondary school (14–15 years old) and 154 were in upper secondary school (16–17 years old). Intact classes drawn from 4 urban public secondary schools in four districts located in the metropolitan area of the Greek capital, Athens, participated in study. Most students in the sample were of middle socioeconomic status. The students participated voluntarily without extra credit or compensation for their participation. The students and their parents were informed about the aims of this study and provided written consent.

Instrument

The Inventory of Interests in Chemistry Contexts (ICC) is the instrument used in the present study and it is based on the theoretical assumption of the domain, activity and context specific nature of interest (Fryer et al., 2016; Renninger & Hidi, 2011). Accordingly, each item from the ICC involves two parts in the chemistry domain: an activity part (chemistry learning) and an object part of interest (chemistry context). By indicating how much they like or dislike items, respondents reveal their preferences for shared properties of domain, activities and/or objects of interest (Liao, Armstrong, & Rounds, 2008).

The ICC consists of 50 items covering a wide range of possible contexts related to learning about secondary school chemistry. The items were designed in order to assess students' interests in issues involving the interaction between chemistry and society or the everyday life of the students (relevance). The students were asked to indicate their degree of interest in various chemistry contexts in a Likert-like scale ranging between 1 and 5 (with 1= not interested at all and 5 = interested very strongly). Some exemplary items of the instrument are the following: In the chemistry course, how much interested are you in learning about …? (a) preservation of foods; (b) batteries; (c) indoor air quality.

Statistical analysis

The internal structure of interest measure was examined using Exploratory Factor Analysis (EFA). This technique groups items based on their inter-item correlations; thus, items that students answered similarly were put in the same group (Fabrigar & Wegener, 2012). For Discipline Based Education Research fields, the ideas that are grouped together in the mind of the student are communicated via their responses and can be detected by EFA (Bretz & McClary, 2015). Principal components with a Varimax rotation were chosen as the factor extraction method. The reliability of the scales, i.e. the extracted factors, were analyzed by calculating Cronbach α's. Following EFA, paired samples t-tests were employed in order to examine the size variation of the identified chemistry contexts within specific student groups.

RESULTS

The correlation matrix for the variables (items 1 to 50) was computed. The Bartlett's test of sphericity had a value of 7920.980 with a significance level <0.001, indicating that correlations between items are significantly different from zero (Field, 2013). The Kaiser–Meyer–Olkin measure of sampling adequacy was computed equal to 0.910, also indicating the appropriateness of the factor model (Field, 2013). Principal component analysis resulted in ten factors with eigenvalues >1 which in combination explained 65.92 % of the variance. After examination of the scree-plot, and the number of items per factor a solution with five of the ten factors accounting for 53.93% of the variance was chosen. An examination of the items associated with each factor allowed the identification of five chemistry contexts: "Environmental Issues (EI)" (derived from 15 items), "Aesthetics, Arts, and Personal Care (AAPC)" (derived from 12 items), "Quality of Life (QL)" (derived from 9 items), "Hazards, Forensics and Weapons (HFW)" (derived from 7 items), and "Everyday Life (EL)" (derived from 5 items). The remaining two items had loadings which were smaller than 0.4 and they were thus excluded from further consideration.

Table 1. Descriptive Statistics and Internal Consistency for Five Variables - Scale Responses Range from 0% to 100%.

	Measure	EI	AAPC	QL	HFW	EL
Lower secondary school (N=121)	Mean	60.42	68.62	69.07	72.26	73.39
	(SD)	(18.18)	(21.14)	(20.95)	(17,66)	(18.15)
	Cronbach's α	0.89	0.91	0.89	0.73	0.72
Upper secondary school (N=131)	Mean	56.87	62.63	66.02	72.63	69.31
	(SD)	(18.45)	(21.87)	(18.15)	(17.62)	(16.84)
	Cronbach's α	0.92	0.93	0.87	0.77	0.72
Boys (N=122)	Mean	59.24	50.59	65.06	73.93	68.39
	(SD)	(18.93)	(17.36)	(19.99)	(17.51)	(18.02)
	Cronbach's α	0.91	0.87	0.88	0.76	0.71
Girls (N=130)	Mean	57.95	79.51	69.76	72.07	73.97
	(SD)	(17.88)	(14.98)	(18.95)	(17.74)	(16.74)
	Cronbach's α	0.91	0.87	0.89	0.76	0.73

Descriptive statistics and internal consistency estimates (Cronbach's alpha) for the students' scores (interest levels) in these five chemistry concepts are reported in Table 1. The internal consistency analysis for each scale reveals that Cronbach's alpha (α) values are acceptable (>0.70).

Table 2. Results of paired samples t-tests administered for whole samples. (Scale pairs with non-significant differences are shown in bold characters).

	Lower secondary school			**Upper secondary school**			**Boys**			**Girls**		
	t	df	*p*	t	df	*p*	t	df	*p*	t	df	*p*
EI - AAPC	-4,956	136	,000	-3,062	141	,003	6,868	135	,000	-15,314	141	,000
EI - QL	-7,680	134	,000	-9,114	140	,000	-5,629	134	,000	-11,423	139	,000
EI - HFW	-8,377	138	,000	-12,404	143	,000	-9,868	138	,000	-10,624	142	,000
EI - EL	-8,716	142	,000	-9,893	144	,000	-6,669	141	,000	-12,422	144	,000
AAPC - QL	**-,695**	**135**	**,488**	-2,291	138	,023	-11,217	132	,000	6,796	140	,000
AAPC - HFW	**-1,851**	**140**	**,066**	-5,141	143	,000	-14,221	137	,000	5,328	145	,000
AAPC - EL	-2,380	143	,019	-4,141	146	,000	-12,333	142	,000	4,275	146	,000
QL- HFW	**-1,497**	**140**	**,137**	-5,102	140	,000	-5,360	137	,000	**-,943**	**142**	**,347**
QL - EL	**-1,955**	**141**	**,053**	**-1,889**	**141**	**,061**	**-1,320**	**139**	**,189**	-2,738	142	,007
HFW - EL	**-,466**	**148**	**,642**	3,676	146	,000	4,397	145	,000	**-1,863**	**148**	**,064**

Via application of paired samples t-test, 9 non-significant differences were found between the following scale pairs: AAPC – QL, AAPC – HFW, QL – HFW, QL – EL, and HFW - EL for lower secondary students; QL - EL for upper secondary students; QL - EL for boys; QL - HFW and HFW - EL for girls (Table 2). Moreover, the paired samples t-test was conducted in order to examine for statistically significant differences between all possible chemistry contexts pairs for boys and girls within each specific school level. Five non-significant differences were found for the following scale pairs: QL – EL, and HFW - EL for lower secondary boys; QL – EL for upper secondary boys; QL - HFW, and QL – EL for lower secondary girls (Table 3). In addition, the non-significant difference between scales HFW and EL exhibited for the whole sample of girls was not shown for either for lower or upper secondary school girls.

Table 3. Results of paired samples t-tests administered separately for each gender within specific school levels. (Scale pairs with non-significant differences are shown in bold characters).

	Lower Secondary Boys			Upper Secondary Boys			Lower Secondary Girls			Upper Secondary Girls		
	t	df	*p*	t	df	*p*	t	df	*p*	t	df	*p*
EI - AAPC	4,412	60	,000	5,314	74	,000	-11,331	75	,000	-10,443	65	,000
EI - QL	-3,584	60	,001	-4,462	73	,000	-7,466	73	,000	-8,769	65	,000
EI - HFW	-6,363	62	,000	-7,510	75	,000	-5,525	75	,000	-10,415	66	,000
EI - EL	-4,989	64	,000	-4,454	76	,000	-7,355	77	,000	-11,016	66	,000
AAPC - QL	-6,969	59	,000	-8,798	72	,000	4,895	75	,000	4,683	64	,000
AAPC - HFW	-9,811	61	,000	-10,471	75	,000	5,673	78	,000	2,167	66	,034
AAPC - EL	-8,185	63	,000	-9,183	78	,000	3,647	79	,000	2,351	66	,022
QL- HFW	-2,715	63	,009	-5,065	73	,000	**,540**	**76**	**,591**	-2,169	65	,034
QL - EL	**-1,138**	**64**	**,259**	**-,665**	**74**	**,508**	**-1,701**	**76**	**,093**	-2,213	65	,030
HFW - EL	**1,752**	**67**	**,084**	4,660	77	,000	-2,339	80	,022	-10,443	65	,000

DISCUSSION

Overall, the utilized instrument was shown to provide reliable and valid measures of students' interests in chemistry contexts over the secondary school years and, consequently, to be well suited to describe almost the entire period of chemical education in secondary schools with regard to these constructs. Data analysis allowed the identification of five main chemistry contexts related with the interests of Greek secondary school students. Paired-samples t-tests, applied within each specific school level and gender, showed that there exist statistically significant differences in the interest level between these contexts. More specifically, with respect to school level, lower secondary students were shown to exhibit the highest interest for the contexts El and HFW followed closely by AAPC and QL and subsequently by the context EI which scores the lowest. In upper secondary students, the top interest is shown to be HFW which exhibits a statistically significant difference relative to EL and QL which come in second place followed again by AAPC which is now a more distant third. The context EI displays again the lowest score.

However, the above described order of interests is significantly differentiated if the two genders are examined separately. The results are presented schematically in Figure 1. Thus, in the girls of both school levels, the context AAPC exhibits the highest interest (with the effect however being quite less pronounced for upper secondary girls) and EI the lowest (with the effect being more pronounced for upper secondary girls). On the other hand, in the boys of both school levels, the context AAPC exhibits the lowest interest, while it is the context HFW that scores in top position (with the effect being more pronounced for upper secondary boys). The girls' lowest interest (EI) is relatively low also for the boys (placed next to the boys' lowest interest). The boys' highest interest (HFW) is relatively high also for the girls (scoring next to the girls' highest score).

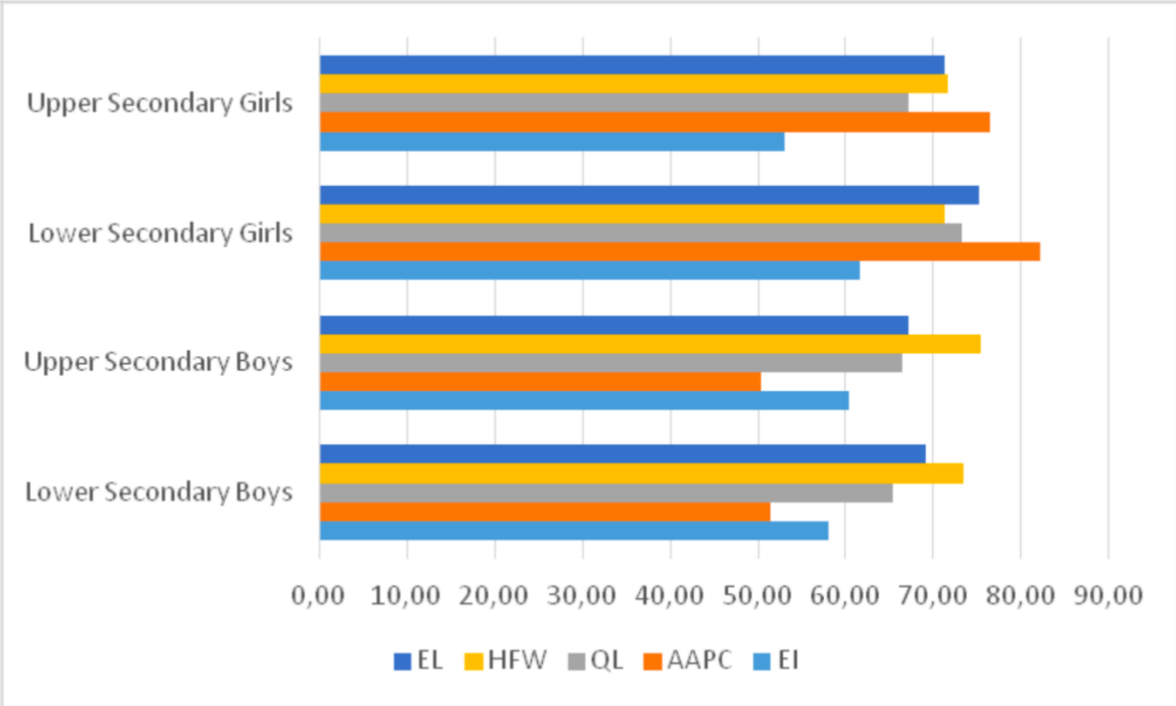

Figure 1. Mean scores of interests towards the five identified chemistry contexts exhibited within each gender for specific school levels (in a scale of 0% - 100%).

The above results may have significant implications for curriculum design in order to render school chemistry more effective in meeting students' interests. The tendency for girls and boys to be interested in different contexts cannot be overlooked. Although, relating subject matter to contemporary social issues may be especially beneficial for girls, chemistry topics in a more action-related context may be more beneficial for boys. Consequently, chemistry curricula ought to balance contexts like art and health care with others like hazards and forensics.

REFERENCES

Baram-Tsabari, A. & Segev, E. (2015). The half-life of a 'teachable moment': The case of Nobel laureates. *Public Understanding of Science*, *24*, 326–337.

Blankenburg, J. S., Höffler, T. N. & Parchmann, I. (2016). Fostering today what is needed tomorrow: Investigating students' interest in science. *Science Education*, *100*, 364-391.

Bretz, S. L. & McClary, L. M. (2015). Students' Understanding of Acid Strength: How Meaningful Is Reliability When Measuring Alternative Conceptions? *Journal of Chemical Education*, *92*, 212−219.

Brickhouse, N. W. & Potter, J. T. (2001). Young women's scientific identity formation in an urban context. *Journal of Research in Science Teaching*, *38*, 965–980.

Bøe, M. V., Henriksen, E. K., Lyons, T. & Schreiner, C. (2011). Participation in science and technology: young people's achievement-related choices in late-modern societies. *Studies in Science Education*, *47*, 37–72.

Christidou, V. (2006). Greek Students' Science-related Interests and Experiences: Gender differences and correlations. *International Journal of Science Education*, *28*, 1181–1199.

Dawson, C. (2000). Upper primary boys' and girls' interests in science: Have they changed since 1980? *International Journal of Science Education*, *22*, 557–570.

Dierks, P. O., Höffler, T. N., & Parchmann, I. (2014). Profiling interest of students in science: Learning in school and beyond. *Research in Science & Technological Education*, *32*, 97–114.

Duranti, A., & Goodwin, C. (Eds.). (1992). *Rethinking context: Language as an interactive phenomenon.* Cambridge: Cambridge University Press.

Eijkelhof H. (2015). Context-Led Science Projects. In R. Gunstone (Ed.), *Encyclopedia of Science Education* (pp. 232–235). Dordrecht: Springer.

Fabrigar, L. R. & Wegener, D. T. (2012). *Exploratory Factor Analysis*. New York: Oxford University Press.

Fechner, S., Van Vorst, H., Kölbach, E. & Sumfleth, E. (2015). It's the situation that matters: Affective involvement in context-oriented learning tasks. In M. Kahveci, & M. Orgill (Eds.), *Affective Dimensions in Chemistry Education* (pp. 159–176). Berlin: Springer.

Field, A. P. (2013). *Discovering statistics using IBM SPSS statistics.* London: Sage.

Fryer, L. K., Ainley, M. & Thompson, A. (2016). Modelling the links between students' interest in a domain, the tasks they experience and their interest in a course: Isn't interest what university is all about? *Learning and Individual Differences*, *50*, 157–165.

Gilbert, J. K. (2006). On the Nature of "Context" in Chemical Education. *International Journal of Science Education*, *28*, 957–976.

Gilbert, J. K., Bulte, A. M. & Pilot, A. (2011). Concept development and transfer in context-based science education. *International Journal of Science Education*, *33*, 817–837.

Gräber, W. (2011). German High School Students' Interest in Chemistry–A Comparison between 1990 and 2008. *Educación Química*, *22*, 134–140.

Hagay, G. & Baram-Tsabari, A. (2011). A shadow curriculum: Incorporating students' interests into the formal biology curriculum. *Research in Science Education*, *41*, 611–634.

Hazari, Z., Sadler, P. M. & Tai, R. H. (2008). Gender differences in the high school and affective experiences of introductory college physics students. *Physics Teacher*, *46*, 423–427.

Hidi, S. & Harackiewicz, J. (2000). Motivating the academically unmotivated: A critical issue for the 21st century. *Review of Educational Research*, *70*, 151–179.

Hidi, S. & Renninger, K. A. (2006). The four-phase model of interest evelopment. *Educational Psychologist*, *41*, 111–127.

Jenkins, E. & Nelson, N. W. (2005). Important but not for me: Students' attitudes toward secondary school science in England. *Research in Science & Technological Education*, *23*, 41–57.

Jones, M.G., Howe, A. & Rua, M.J. (2000). Gender differences in students' experiences, interests and attitudes toward science and scientists. *Science Education*, *84*, 180–192.

King, D. (2012). New perspectives on context-based chemistry education: Using a dialectical sociocultural approach to view teaching and learning. *Studies in Science Education*, *48*, 51–87.

Koballa T. R., Jr. & Glynn S.M. (2007). Attitudinal and motivational constructs in science education, in: S. K. Abell and N. Lederman (Eds.), *Handbook for Research in Science Education* (pp. 75–102). Mahwah, NJ: Erlbaum.

Krapp, A. & Prenzel, M. (2011). Research on interest in science: Theories, methods, and findings. *International Journal of Science Education*, *33*, 27–50.

Krogh, L. B. & Thomsen, P. V. (2005). Studying students' attitudes towards science from a cultural perspective but with a quantitative methodology: Border crossing into the physics classroom. *International Journal of Science Education*, *27*, 281–302.

Lent R. W., Brown S. D., Schmidt J., Brenner B., Lyons H. & Treistman D. (2003). Relation of contextual supports and barriers to choice behavior in engineering majors: Test of alternative social cognitive models, *Journal of Counseling Psychology*, *50*, 458–465.

Liao, H.-Y., Armstrong, P. I. & Rounds, J. (2008). Development and initial validation of public domain Basic Interest Markers. *Journal of Vocational Behavior, 73*, 159–183.

Murray, I., & Reiss, M. (2005). The student review of the science curriculum. *School Science Review*, *87*, 83–93.

Nieswandt, M. & Horowitz, G. A. I. L. (2015). Undergraduate students' interest in chemistry: The roles of task and choice. In A. Renninger, M. Nieswandt, & S. Hidi (Eds.), *Interest in mathematics and science learning* (pp. 225–242). Washington, DC: American Educational Research Association.

Osborne, J. (2008). Engaging young people with science: Does science education need a new vision? *School Science Review*, *89*, 67–74.

Osborne, J., & Collins, S. (2001). Pupils' views of the role and value of the science curriculum: a focus-group study. *International Journal of Science Education, 23*, 441–467.

Renninger, K.A., & Hidi, S. (2011). Revisiting the conceptualization, measurement, and generation of interest. *Educational Psychologist*, *46*, 168–184.

Rounds, J., & Su, R. (2014). The nature and power of interests. *Current Directions in Psychological Science*, *23*, 98–103.

Salta, K., Gekos, M., Petsimeri, I. & Koulougliotis, D. (2012). Discovering factors that influence the decision to pursue a chemistry-related career: A comparative analysis of the experiences of non scientist adults and chemistry teachers in Greece. *Chemistry Education Research and Practice*, *13*, 437–446.

Salta, K. & Koulougliotis, D. (2015). Assessing motivation to learn chemistry: adaptation and validation of Science Motivation Questionnaire II with Greek secondary school students. *Chemistry Education Research and Practice*, *16*, 237–250.

Salta K. & Tzougraki C. (2004). Attitudes toward chemistry among 11th grade students in high schools in Greece. *Science Education*, *88*, 535–547.

Schiefele, U. (2009). Situational and individual interest. In K. R. Wentzel & A. Wigfield (Eds.), *Handbook of Motivation at School* (pp. 197–222). New York: Routledge.

Silvia, P. J. (2001). Interest and interests: The psychology of constructive capriciousness. *Review of General Psychology*, *5*, 270–290.

Sjøberg, S. & Schreiner, C. (2007). Perceptions and images of science and science education. In M. Claessens (ed.) *Communicating European Research 2005* (pp. 151–158). Dordrecht: Springer.

Su, R., Murdock, C. D. & Rounds, J. (2014). "Person-environment fit," in P. Hartung, M. Savickas, and B. Walsh (Eds.), *APA Handbook of Career Intervention* (pp. 81–98). Washington, DC: American Psychological Association.

Tytler, R. (2014). Attitudes, identity, and aspirations toward science. In S. Abell & N. Lederman (Eds.), *Handbook of research on science education volume II* (pp. 82–103). New York, NY: Routledge.

THE DIFFERENT TYPOLOGIES DESCRIBING THE INTEREST IN SCIENCE

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It is essential understanding students' interests to help improving the teaching-learning process. Thus, investigations aimed at understanding how young people think and feel about Science and Technology have emerged. One of these initiatives lies on the project called Brazil Barometer, which is a 4-point Likert scale questionnaire comprising 96 questions that investigate the interest of young people in Science and Technology, among other things. The current study used data generated through the application of Brazil Barometer to 2,404 students in the age group 15 years in 2014; thus, these students were used as a representative sample of the Brazilian young population in this age group. Four (4) different typologies of Brazilian students were found based on the k-means clustering method: Reluctant, Enthusiast, Unselective Undecided, Selective Undecided. In addition, the interest of each typology was analyzed based on six different topics such as Health, Mystery, Scientific innovations, Agriculture, Science and Scientists, and Technology, which were determined based on the hierarchical clustering method. It was possible concluding that topics such as Mystery and Scientific innovations presented the greatest potential to boost students' intrinsic motivation, since they were the ones recording above average interest rates in all four typologies.

Keywords: Interest in Science; Intrinsic Motivation; Students' typology.

INTRODUCTION

Student demotivation is a common complaint among teachers, including Science teachers, who often attribute such demotivation to the mismatch between school speed and that of the digital world. This lack of interest in school contents is concerning because, as Pozo and Crespo (2009, p. 40) stated, "students are not interested in Science, they do not want to strive to study; therefore, since learning Science is an intellectual, complex and demanding task, they fail."

The motivation issue appears to be a key factor for the teaching-learning process and, sometimes, it goes unnoticed in debates about the subject. The literature points towards two motivational orientations focused on school learning: the *extrinsic* and *intrinsic* ones (Deci, Koestner & Ryan, 2001; Martinelli & Bartholomeu, 2007; Pozo & Crespo, 2009). Extrinsic motivation refers to performing tasks in response to external stimuli, i.e., students are motivated by the possibility of being rewarded (score, compliment, acknowledgement) or of avoiding punishment (failure, being grounded, humiliation). Thus, students are motivated because they aim at meeting orders given by, or the external pressure from, other people (Martinelli & Bartholomeu, 2007).

Intrinsic motivation is innate and concerns self-determination (Deci, Koestner & Ryan, 2001). Students driven by intrinsic motivation pursue challenges and novelties; thus, participating in tasks is their main reward. Consequently, prizes or external pressure are not necessary (Martinelli & Bartholomeu, 2007), since students lean because they like learning.

Although extrinsic motivation is recurrent in the classroom, studies available in the literature have reported that encouraging it can negatively affect intrinsic motivation (Deci, Koestner & Ryan, 2001). Moreover, extrinsic motivation systems depend on the maintenance of rewards and punishments, because students lose their reason for learning when rewards and punishments are withdrawn or lose meaning. According to Pozo and Crespo (2009), extrinsic motivation can generate undesirable results such as making students think that the studied content is irrelevant and show progressive lack of interest in the school subject.

There are few empirical tools and data available in the literature to help better understanding the triggers of intrinsic motivation (Martinelli & Bartholomeu, 2007). Thus, the current study adopted the hypothesis that students' interests in Science and Technology have the potential to boost their intrinsic motivation. Therefore, investigating the interests of young people would give us a tool to boost their intrinsic motivation.

In addition, there is a gap between students' interest and what is presented in Science curriculum (Amestoy, 2015; Swirski & Baram-Tsabari, 2014). The interest of young people is little, or not at all, explored at the time to plan school curricula, after all, as Ravitch (2011, p. 251) pointed out, "[...] contemporary reformers keep on searching for shortcuts and quick answers."

The aims of the current study were to elaborate Brazilian student typologies based on their interests in Science and Technology in order to generate data to be used in order to encourage students' education based on their intrinsic motivation, as well as to use students' interest to generate new interests, in a virtuous cycle of commitment to learning and knowledge.

History of studies about interest in Science

Young people's interest in Science and Technology is not a new subject of study: in 1984, the German Institute for Science Education hosted the first International Conference on Interest Research, which focused on students' interest in Science and Technology (Schreiner, 2006). The conference was so relevant that the topic to be approached in the next conference was decided right away, namely: the relation between interest and sex, which remains a recurring concern in studies conducted up to the present day.

The Science and Scientists (SAS) project was launched in 1996 based on an international partnership network generated in events such as the International Organization for Science and Technology Education Symposium (IOSTE). The study counted on the participation of 30 researchers from 21 countries and generated a questionnaire that, from 1996 to 1999, collected information from 9,350 children in the age group 13 years concerning their interest in, experiences with, and perceptions about, Science and what they learned on this field (Sjøberg, 2000).

Project ROSE (Santos-Gouw, 2013) - a new project that succeed SAS - began to be institutionally discussed in 2001. The aforementioned study was based on a questionnaire comprising 12 sections such as *My Opinions on Science and Technology*, *My Out-of-School Experiences* and *What I Want to Learn*. ROSE counted on the participation of more than 40 countries, including Brazil, whose applications were documented in the doctoral theses by Tolentino-Neto (2008) and Santos-Gouw (2013).

Some particularities about ROSE, such as the substantial number of questions and the lack of items by taking into consideration the regional context where the questionnaire was applied, were observed by researchers around the world. Hence, the project called Brazil Barometer emerged. This project is based on a 4-point Likert scale questionnaire comprising 96 questions, whose scores range from 1 - Disinterested to 4 - Very Interested; these questions approach different aspects of students' interest in, and position about, Science and Technology.

METHODOLOGY

The current study analyzed responses given to section "A" of the Barometer Brazil questionnaire, which was applied to 15-year-old students, at national representation level, in 2014. This section presents questions about students' level of interest in learning certain topics. The responses of 2,404 students were analyzed; 7 students were excluded from the sample based on pairwise comparison.

Our aim was to elaborate the typologies of Brazilian students based on the congruence of two different methodological stages, in which we made the option of using multivariate data analysis, more specifically, the cluster analysis.

The first methodological stage concerned the analysis of how the questions were grouped according to students' responses. The variables to be analyzed in this stage were the 24 questions - a sample comprising a few items to be grouped together. In this case, the literature (Hair, Black, Babin & Anderson, 2009, Ocampo & Tolentino-Neto, 2019) indicates that the hierarchical method is the most appropriate one, since it uses the nearest neighbor agglomeration algorithm and the square Euclidean distance.

The second methodological stage concerned how to group students based on their responses. The k-means was the herein adopted methodology (Hair, Black, Babin & Anderson, 2009, 2012; Ocampo & Tolentino-Neto, 2019), since it was more appropriate to analyze the massive amount of data (2,397 students) collected in the current study. Based on simulations and on our knowledge about the sample, we decided to work with the total of 4 clusters in the k-means method.

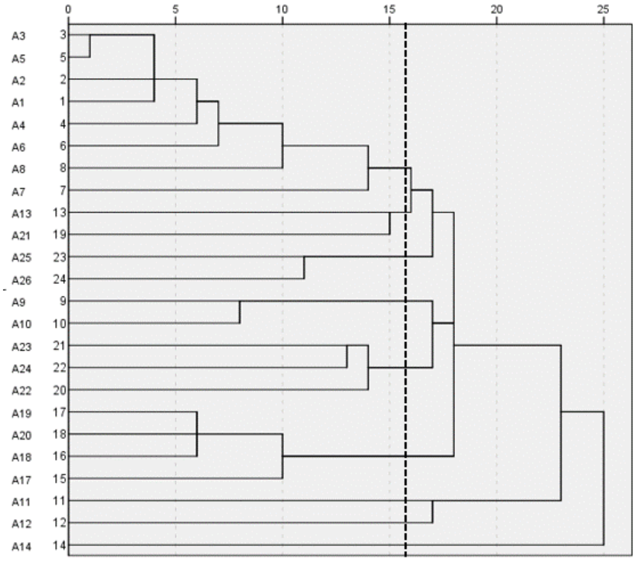
In our opinion, the combination between these two stages is what generated the students' typology. The next items of this manuscript present the results of, and the discussion about, these stages in separate and together.

CLUSTER OF QUESTIONS

The 24 Brazil Barometer questions analyzed in the current study can be empirically grouped based on topics. For example, item A2 "Cancer, what we know about it and how we treat it" can be classified as health-related topic. Thus, we hypothesized that students would respond to the questions according to their field of preference. Cluster analysis was herein adopted to find a statistical basis for this hypothesis.

The nearest-neighbor hierarchical clustering method was herein applied to generate the following dendrogram (Figure 1). We made the option for highlighting (a dotted line in the graph) clusters generated after 15 interactions, based on the good heterogeneity generated in each cluster.

Figure 1 Dendrogram depicting the clustering of questions based on the nearest-neighbor hierarchical clustering method.



Questions A11, A12 and A14 were not clustered into any other question after 15 interactions; consequently, we made the option of disregarding them in our analysis. Thus, the cluster analysis generated six clusters, which were classified based on topics (Table 1). These clusters were very similar to the ones generated by other researchers who worked with both the Barometer and ROSE projects (Schreiner, 2006; Tolentino-Neto, 2008; Chang, Yeung & Cheng, 2009; Santos-Gouw, 2013; Pinafo, 2016). Thus, the clusters generated in the current study were named by taking into consideration the legends used by these authors in their respective studies.

Table 1. Classification of the cluster of questions

Cluster	Questions
a – Health	A1,A2,A3, A4, A5, A6, A7, A8
b – Mystery	A13, A21
c – Scientific innovations	A25, A26
d – Agriculture	A9, A10
e – Science and scientists	A22, A23, A24
f – Technology	A17, A18, A19, A20

Note.Prepared by the authors of the current study, adapted from Schreiner (2006), Tolentino-Neto (2008); Chang, Yeung & Cheng (2009), Santos-Gouw (2013) and Pinafo (2016).

CLUSTER OF STUDENTS

Our first challenge in this stage lied on defining the number of clusters to be used, since the k-means method for clusters analysis requires determining the number of clusters *a priori*. Thus, we searched in the literature and found that Schreiner (2006), whose study adopted the instrument that inspired the development of the Barometer instrument, worked with five clusters of Norwegian students.

After conducting some simulations and data analyses, we noticed that two clusters always emerged: one cluster comprised students presenting above-average interest in Science and Technology, whereas the other one comprised students presenting below-average interest in the topic. Any number higher than two always generated intermediary clusters, which differed from each other based on discrepancies in one or more items, i.e., based on students' high or low interest in specific items. The number of clusters could have been increased by 2,397 so each cluster would represent a student. However, based on the herein obtained heterogeneity, we conclude that four clusters would be sufficient to enable sample segregation and definition.

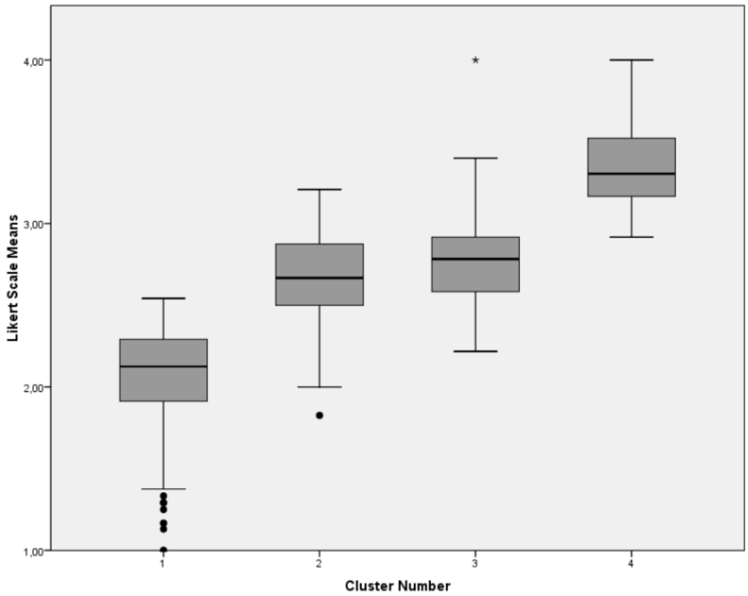
Table 2 Students' distribution per cluster

Cluster	Frequency	Percent (%)	Valid Percent (%)
1	530	22.0	22.1
2	574	23.9	23.9
3	678	28.2	28.3
4	615	25.6	25.7
Total	2,397	99.7	100.0

The number of students in each group did not differ much; there was 6.2% variation between clusters 1 and 3, which comprised the smallest and the largest number of students, respectively (Table 2). Other studies have found clusters with increased unequal distribution. Schreiner (2006) found approximately 13% variation between clusters comprising the largest and the smallest number of Norwegian students.

The clusters generated in the current study were organized according to the mean value attributed to students' responses: the first cluster encompassed students who presented the lowest interest in Science and Technology, whereas the fourth cluster comprised students who presented the highest interest in the topic (Figure 2).

Figure 2. Average and quartiles of interests per cluster



Schreiner (2006) divided Norwegian students in 5 clusters, which were differentiated based on three distinctive features. The first distinction was based on interest, which generated three typologies: *Reluctant*, *Undecided* and *Enthusiast*. The other distinction was based on the variance in students' responses, which generated two typologies: *Unselective* and *Selective*. Finally, the aforementioned researcher differed students based on what she called "Virtually sex-specific" (Schreiner, 2006, p. 128). In the end, Norwegian students were clustered as *Unselective Reluctant*, *Unselective Undecided*, *Unselective Enthusiast*, *Selective Boy* and *Selective Girl*.

Based on this study, we determined the first aspect distinguishing students' typologies: their interest in Science. We made the option of using the terms adopted by Schreiner (2006); thus, Cluster 1 was classified as Reluctant¸ Clusters 2 and 3 were classified as *Undecided*, and Cluster 4 was classified as *Enthusiast*.

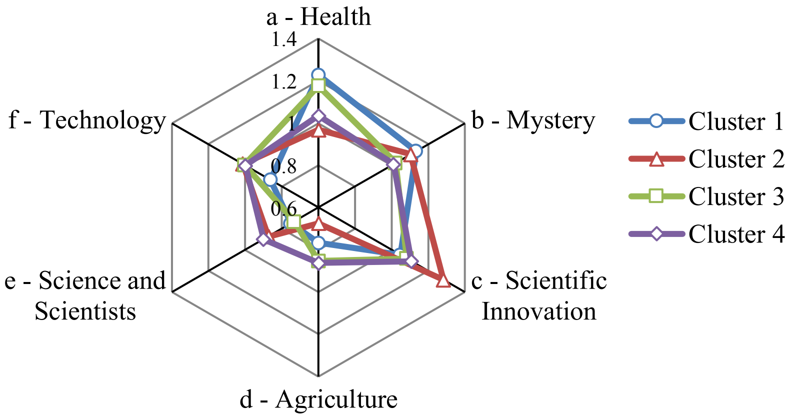
However, it is worth emphasizing that average interest alone was not enough to characterize students' typologies. It was necessary creating a second dimension to enable the elaboration of these typologies based on the fields of interest that most represented the students belonging to these clusters.

TYPOLOGY OF STUDENTS

We observed how members of each of the four clusters behaved towards the topics presented in Table 1 in order to characterize each students' typology. Thus, we herein elucidate these typologies based on students' interest in Science, as well as on the topics differentiating these clusters.

Initially, our concern was to distinguish the fields of interest of each cluster. However, since there were different average interest values, it would be difficult to effectively visualize differences between these fields. Thus, we made the option of weighing the interests in the fields based on the average interest of each cluster; this value was called $\bar{u}_p$ and it was calculated by dividing the interest of students belonging to each cluster in a certain field by the average interest of this cluster. Thus, it was possible overlapping and comparing these values, since each $\bar{u}_p > 1$ represented interest above the mean, whereas $\bar{u}_p < 1$ represented interest bellow the mean. These results are shown in Figure 3.

Figure 3. Comparison between weighted means of interest in the topics.



The center of the radar represents $\bar{u}_p$ = 0.6, whereas the extreme opposite represents $\bar{u}_p$ = 1.4. Each $\bar{u}_p > 1$ represents high interest of students belonging to this cluster in the topic.

The information that mostly stood out in Figure 3 concerned the high interest of students belonging to Cluster 2 in *Scientific innovations*. In addition, it was possible seeing that students in Clusters 2 and 4 had similar views about fields such as *Health*, *Science and scientists*, and *Technology*. Moreover, Cluster 2 stood out because its students presented the lowest interest in *Agriculture*.

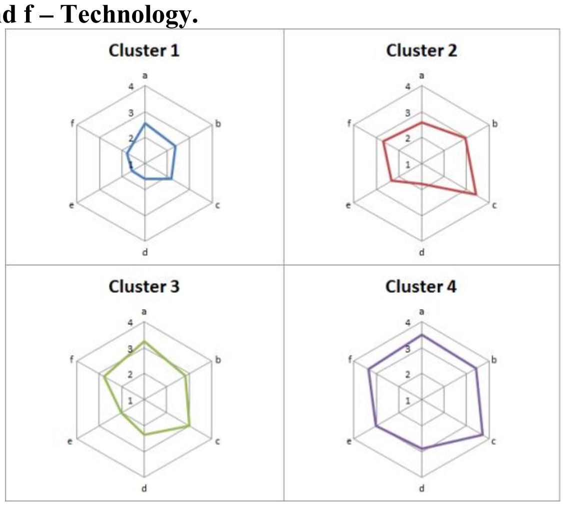
Health was the topic recording considerable interest in all clusters; only Cluster 2 presented $\bar{u}_p < 1$, although it was very close to 1. This outcome corroborates other studies such as the one conducted by Santos-Gouw (2013). However, students belonging to Clusters 1 and 3 showed more interest in the aforementioned topic than the ones belonging to Cluster 2 and 4 (Figure 3).

For illustration purposes, let us imagine a reality where most students belong to Clusters 1 and/or 3; in this case, the use of the topic *Health* in the classroom would have enormous potential, since it would sensitize students' intrinsic motivation. Similarly, if the reality in question does not count on students belonging to Cluster 1, the use of the topic *Technology* should be taken into consideration, since students belonging to the other clusters have great interest in it. Applying the questionnaire and characterizing/mapping the class is a great way for teachers to 'customize' their plans and bring examples and topics of interest to their students.

On the other hand, it is essential emphasizing that it is not the case to stop teaching topics students are not interested in. Teachers would be negligent, or irresponsible, if they failed to address - for example - photosynthesis, in case students did not express interest in botany or in environmental issues. The path to be covered is different, and we agree with Pozo and Crespo (2009, p. 43) who said that "[...] we should start from students' interests and preferences to generate new ones".

Thus, it is important identifying each cluster, which was the reason why we created typologies to name and characterize each of these groups. In order to do so, we took into consideration two aspects - the already mentioned terms based on average interest (*Reluctant*¸ *Undecided* and *Enthusiast*) and the field of greater interest of each cluster (Figure 4) - mainly to distinguish Clusters 2 and 3, which were both classified as *Undecided*. The center of the radar in Figure 4 represents value 1 (Disinterested), whereas the extreme opposite represents value 4 (Very Interested).

Figure 4. – Typologies based on fields: a - Health; b - Mystery; c - Scientific innovations; d - Agriculture; e - Science and scientists; and f – Technology.



The first typology concerned students belonging to Cluster 1. Although they had little interest in Science and Technology, the *Health* topic was attractive to them. Data indicated that the *Health* topic arouses an interest approximately 25% higher than the average. These students did not show interest in topics such as *Agriculture*, *Science and scientists*, and *Technology*. Thus, this cluster was given the *Reluctant* typology, based on the model by Schreiner (2006). *Reluctant* individuals correspond to approximately 22% of Brazilian adolescents in the age group 15 years.

On the other side of the spectrum, some students were very interested in Science. These students belonged to Cluster 4, which represents approximately 26% of the Brazilian population in the same age group. This typology was named *Enthusiast*, since, except for *Agriculture*, all other topics recorded average interest above 3 points, i.e., students belonging to this typology ranged from interested to very interested in almost all Science topics. In addition to the low interest in *Agriculture*, *Enthusiast* students showed high interest in *Scientific innovations*, the average (3.72) was very close to the maximum point. Presenting an optimistic and favorable attitude towards Science and Technology (Anderson, 2006) is characteristic of young people living in countries with low Human Development Index (HDI), which is the reality of a large number of Brazilian citizens; thus, it was not surprising that a significant number of students were given the *Enthusiast* typology.

The two aforementioned typologies comprise a large number of young individuals in Brazil. However, approximately 52% of students belong to Clusters 2 and 3, besides presenting interest close to the average in the 4-point Likert scale (2.5). These two clusters represent what

Schreiner (2006) called *Undecided* typology. Thus, we herein differentiated the two clusters based on the particularities of their interests.

Students belonging to Cluster 2 presented greater discrepancy between responses given to each Science and Technology field than the ones belonging to Cluster 3, as shown in Figure 1. There was 0.301 variance among fields in Cluster 2 and 0.197 in Cluster 3. Thus, students belonging to Cluster 2 were given the *Unselective Undecided* typology, whereas the ones belonging to Cluster 3 were given the *Selective Undecided* one, based on the criterion adopted by Schreiner (2006).

Selective Undecided individuals were very interested in *Scientific innovations* and did not appear to be interested in *Agriculture*. This information made us think about the representativeness of these young students in urban and rural schools, or even in regions presenting high or low population density. Our sample did not enable answering this question.

On the other hand, *Unselective Undecided* individuals were more interested in *Health* and less interested in *Science and scientists*. Previous studies have reported greater interest in *Health* among girls, not only in the Brazilian context (Pinafo, 2016) but also in other countries around the world such as Sweden, Finland, Spain and Ghana (Jidesjö, Oscarsson & Karlsson, 2009; Vázquez & Manassero, 2009; Anderson, 2006). Therefore, we investigated whether there was sex-related distinction in this typology: girls represented 60% of the *Unselective Undecided* students and approximately 44% of the *Selective Undecided* ones. This variation was not as significant as the one found in the aforementioned studies; thus, we did not dwell on this variable at data analysis time.

None of the typologies recorded in the current study showed as much gender discrepancy as the ones reported by Schreiner (2006), who recorded 97% boys in one cluster and 94% girls in another one. Consequently, we did not find it necessary distinguishing Brazilian students' typologies based on *Sex-Variable,* as it was done by the aforementioned researcher.

Thus, *Reluctant*, *Enthusiast*, *Unselective Undecided* and *Selective Undecided* were the typologies herein used to characterize Brazilian young students. Clearly, this is not a rule: generalizations in the education field are dangerous, mainly in significantly heterogeneous countries such as Brazil. On the other hand, these typologies can be used as guideline to develop strategies that take into consideration students' intrinsic motivation to boost Science education in Brazil.

FINAL CONSIDERATIONS

The present study aimed at generating typologies to represent Brazilian young people based on their interest in Science and Technology. Based on aspects quantified through the Brazil Barometer instrument, it was possible dividing them in four typologies named *Reluctant*, *Unselective Undecided*, *Selective Undecided* and *Enthusiast*.

It is essential understanding the existence and characteristics of these typologies in order to boost a teaching process that takes into account students' intrinsic motivations to learn Sciences. Thus, it is possible using students' interests to expand their knowledge about Science.

We concluded that individuals belonging to each of these four typologies have their own interests. *Reluctant* individuals presented greater interest in topics such as *Health*, *Mystery* and *Scientific innovations*. This outcome was similar to the one recorded for students belonging to the *Enthusiast* and *Unselective Undecided* typologies, who showed interest in *Scientific innovations* and *Health*, whereas the ones belonging to the *Selective Undecided* typology presented great interest in *Scientific innovations*.

Besides the individual interests of the herein presented typologies, it is essential investigating the fields arousing the interest of young people belonging to all typologies. Items associated with *Mystery* and *Scientific innovations* were the ones recording above-average interest in all typologies. Thus, we reiterate the potential of these two fields to boost students' intrinsic motivation to study Science, since the four herein investigated typologies shared this interest.

Acknowledgement

CAPES; PPG Educação em Ciências: química da vida e saúde.

REFERENCES

Amestoy, M, B (2015). *Articulação entre os interesses dos alunos e livros didáticos: A voz do estudante na construção curricular de ciências*. [Joints between interests of pupils and the textbooks: student voice in the construction science curriculum]. (Published master's thesis). Santa Maria: Federal University of Santa Maria, Santa Maria, Brazil.

Anderson, I. K. (2006). *The Relevance of Science Education: As seen by Pupils in Ghanaian Junior Secondary Schools*. (Doctoral doctoral dissertation, University of the Western Cape). Retrieved from http://etd.uwc.ac.za/xmlui/handle/11394/1814/

Chang, S., Yeung, Y. & Cheng, M. H. (2009). Ninth Graders' Learning Interests, Life Experiences and Attitudes Towards Science & Technology, *Journal of Science Education and Technology*, *18*(5), 447–457. http://doi.org/ 10.1007/s10956-009-9162-6

Corrar, L. J., Paulo, E. & Filho, J. M. S. (2012). *Análise Multivariada* [Multivariate analysis], São Paulo, Brazil: Atlas.

Deci, E. L., Koestner, R. & Ryan, R. M. (2001). Extrinsic Rewards and Intrinsic Motivation in Education: Reconsidered Once Again, *Review of Educational Research*, *71*(1), 1–27.

Hair, J. F., Black, W. C., Babin, B. J. & Anderson, R. E. (2010). *Multivariate Data Analysis.* (7th ed.). New York, USA: Pearson.

Jidesjö, A., Oscarsson, M. & Karlsson, K. G. (2009). Science for all or science for some: What Swedish students want to learn about in secondary science and technology and their opinions on science lessons, *NorDiNa*, *5*(2), 213–229. DOI: https://doi.org/10.5617/nordina.352

Martinelli, S. C. & Bartholomeu, D. (2007). Escala de Motivação Acadêmica: Uma Medida de Motivação Extrínseca e Intrínseca [School motivation scale: an extrinsic and intrinsic motivation measure], *Avaliação Psicológica*, *6*(1), 21–31.

Ocampo, D. M. & Tolentino-Net, L. C. B. (2019). Cluster Analysis for Data Processing in Educational Research. *Acta Scientiae, 21*(4), 34–48. DOI: http://doi.org/10.17648/acta.scientiae.v21iss4id5119

Pinafo, J. (2016). *O que os jovens têm a dizer sobre ciências e tecnologia? Opiniões, interesses e atitudes de estudantes em dois países: Brasil e Itália* [What do youngsters have to say about science and technology? Students opinions, interests and attitudes in two countries: Brazil and Italy]. (Published doctoral dissertation). São Paulo: University of São Paulo, São Paulo, Brazil.

Pozo, J. I. & Crespo, M. A. G. (2009). *A aprendizagem e o ensino de ciências: do conhecimento cotidiano ao conhecimento científico* [Science learning and teaching: from everyday knowledge to scientific knowledge]. Porto Alegre, Brazil: Artmed.

Ravitch, D. (2010). *The Death and Life of the Great American School System: How Testing and Choice Are Undermining Education*: *How Testing and Choice Are Undermining Education*. New York, USA: Basic Books

Santos-Gouw, A. M. (2013). *As opiniões, interesses e atitudes dos jovens brasileiros frente à ciência: uma avaliação em âmbito nacional* [Opinions, interests and attitudes of young Brazilian in face of science: an evaluation in nationwide]. (Published doctoral dissertation). São Paulo: University of São Paulo, São Paulo, Brazil.

Schreiner, C. (2006). *Exploring a ROSE-Garden: Noewegian youth's orientations towards science – see signs of late modern identities*. (Published doctoral dissertation). Oslo: University of Oslo, Oslo, Norway.

Sjøberg, S. (2000). Science And Scientists: The SAS-study. *Acta Didactica*, *1*/2000.

Swirski, H. & Baram-Tsabari, A. (2015). Bring the Gap between the Science Curriculum and Students' Questions: Comparing Linear vc. Hypermedia Online Learning Environments, *Interdisciplinary Journal of E-Learning and Learning Objects*, *10*(1), 153–175. DOI: http://doi.org/10.28945/2067/.

Tolentino-Neto, L. C. B. (2008). *Os interesses e posturas dos alunos frente às ciências: resultados do Projeto ROSE aplicado no Brasil* [The interests and atitudes of Young students towards Science: results of Project ROSE applied in Brazil]. (Published doctoral dissertation). São Paulo: University of São Paulo, São Paulo, Brazil.

Vázquez, Á. & Manassero, M. A. (2009). La relevância de la educación científica: actitudes y valores de los estudiantes relacionados com la ciência y la tecnología [The relevance of science education: students' values and attitudes related to science and technology]. *Enseñanza de las Ciencias*, *27*(1), 33–48.

PERFORMANCE ANALYSIS OF STUDENTS REGARDING THE COMPLEXITY AND CONTENT DIMENSIONS OF ITEMS IN LEARNING OF PROGRAMMING LOGIC

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This paper reports a study on the learning of Brazilian high school students with respect to contents of programming logic. In order to evaluate this learning two dimensions were considered: complexity dimension, which represents the difficulty of knowledge test items; and content dimension, which refers to contents related to logical reasoning and to mathematical skills. In terms of complexity, despite an increase in learning at all levels, the results indicated that the less complex questions were easier for the students, those of medium complexity were stable and those of greater complexity had an oscillating behaviour. Regarding the content dimension, the questions of pure mathematical knowledge were learned at a higher level, followed by those of programming structure. In the other hand, the hybrid questions, which combine two or more fields of knowledge, were learned the least. This corroborates the challenge of promoting interdisciplinary approaches which contemplate learning in this sense. We interpret the difficulties of achievement at hybrid domain as a process of building new knowledge and not only a direct transfer of concepts of one dimension to another.

Keywords: *Reasoning, Learning Progressions, Quantitative Methods*

INTRODUCTION

This study investigates how students learn concepts which demand logical reasoning in higher abstraction levels such as the scientific ones. The participants are students from an IT (Information Technology) Technical course of a Federal Technical School in northern Brazil. Programming logic is a discipline offered every first term in IT courses of technical and undergraduate levels. One of the main goals in this discipline is in promoting the ability of students to solve ordinary problems using logically structured instructions of computer programming languages. (Pereira Juúnior & Rapkiewicz, 2004). Some studies of learning disabilities in programming logic found difficulties of the students in understanding the problem to be solved, i. e., the understanding of what is asked to do, even before the difficulty of interpreting some kind of representation (Falkembach et al, 2003). Other studies found difficulties in: solving problems (Martins & Correia, 2003); in building the algorithm (Campos, 2009), in applying the algorithm control structures (Gomes, 2008); and in assimilating the abstractions involved in the teaching-learning process of programming fundamentals (Rodrigues, 2002). As IT courses usually have high rates of repetition and dropouts, we noted the importance of investigating issues related to the learning of abstract concepts. The present study focuses on learning from the perspective of cognitive development associated with hierarchical complexity of elements or attributes, which change in time (Fischer, 1980, Commons, 2008, Case, 1992, 1996). Cognitive development is explained by a series of skill structures called levels together with a set of transformation rules that relate these levels to each other. The levels designate skills of gradually increasing complexity, with a specific skill at one level built directly from specific skills at the preceding level (Fischer, 1980). In this way, learning is considered from the evolution of latent traits.

METHODS AND RESULTS

The learning of 71 students was evaluated over a school year. This evaluation was done through class observation by the researcher and the application of 9 exams. These exams were knowledge tests (measurement waves) created from a qualitative analysis of the material given by the IT course teachers (Regebe & Amantes, 2013, 2015). The tests were designed to evaluate the understanding of different contents related to mathematics and logical reasoning. Based on the categorical system TCH - Taxonomy of complexity of skills (Regebe & Amantes, 2013), the test items were intended to comply with the hierarchical complexity perspective (Fischer, 1980). All used material went through peer and sampled validation (Regebe & Amantes, 2015).

The analysis was performed from two perspectives: item complexity level which is related to the difficulty of the items; and content type which can be related to mathematical knowledge, logical reasoning or hybrid knowledge (the latter comprehend both types: mathematical content and logical reasoning). For the analysis of the complexity dimension, we measured the difficulty of the item in the Rasch scale (1960). This measure was provided by estimates considering the number of persons who answered the items correctly and the proficiency of these students. The items ended up being divided into 3 levels of complexity after the construction and analysis of the psychometric models where several types of tests were applied, such as exploratory analysis, confirmatory analysis and ANOVA (Regebe & Amantes, 2017).

Results suggested that learning rises at all levels, that is, as the difficulty index of the item decreases, the learning level increases. The Figure 2 shows that the level of complexity 1 had a downward trend as it became easier for students; the level of complexity 2 had a more or less stable trajectory; and the level of complexity 3 had a very oscillating behaviour, which is expected from more complex questions (Coelho, 2011).

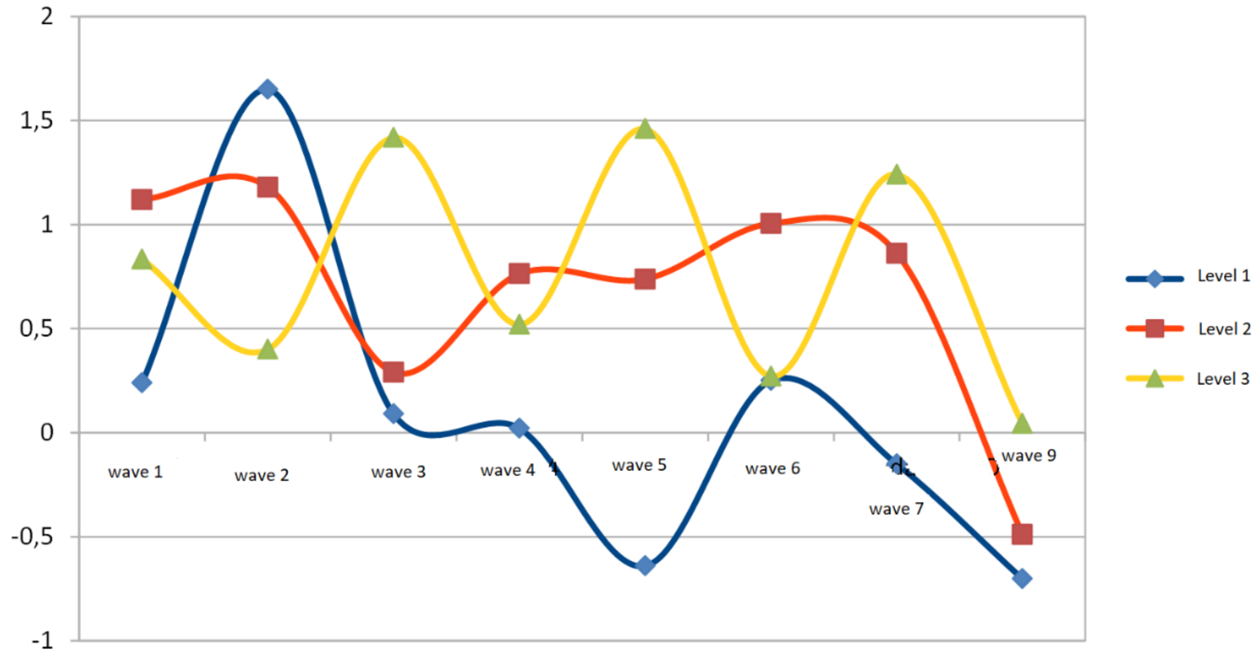

Figure 2. Trajectory of the difficulty index of the items, regarding complexity

We interpret that, according to the trajectory of the difficulty indexes in terms of levels of complexity, students learn more at the less complex level (blue line, complexity level 1). For the highest level of complexity (yellow line, complexity level 3), they end up not learning as much as the line does not follow a downward trend. For the intermediate level of complexity (red line, complexity level 2), the trajectory was more or less stable between waves 4 and 7, having a huge fall after wave 7. However, all levels of complexity presented a drop after wave 7, which may indicate some contextual aspect that has not been analysed yet.

For the content dimension analysis, we used the difficulty levels of items in the dimensions MK (mathematical knowledge), PS (programming structures) and HB (hybrid questions) during the measurement waves. We also used the item maps which show the difficulty indexes of the items and the proficiencies of the students on the same logit scale (Figure 3). This item map represents the result of 7th test applied to students. The item map also allows us to verify the evolution of student proficiency during the school year, through the relationship between increased proficiency and decreased difficulty level of items in their macro and micro contents. On the left side of the graph are estimates of the proficiency parameters of students who have completed the knowledge tests (mathematical content skills, programming logic, and hybrid content). Item estimates (item difficulty index) are represented on the right side of the graph. In this item map, the mathematical knowledge (MK) items are in blue, the programming structure items (PS) are in red, and hybrids (HB) are in green. Hybrid items are divided into three levels: N1, N2, and N3. Level N1 consists of recognizing and identifying the input, processing and output variables of the program, i. e., if the student has only been able to correctly identify and declare the input, processing and output variables, he or she only achieves the item of level heading N1 of the question of hierarchical level IV of our categorical system. Level N2 means that the student understood the problem, that is, if we can see a formula or outline of their understanding, the student achieves the N1 and N2 items. And finally, the

N3 level means that he was able to overcome the problem to the algorithmic language with all its nuances. If the student achieves this, he or she scores the N1, N2, and N3 level items, as this is a Guttman's partial score scale (Guttman, 1944).

Figure 3 - Items Map (Wave 7)

Results showed that students had less difficulty in items with MK content in almost all waves. The PS items were more difficult for the students than the former. In the other hand, the most difficult items were the hybrids (HB) which demands the implementation of an algorithm to solve a mathematical problem (Figure 4), that is, these are questions which request skills that combine different areas of knowledge to solve a problematic situation.

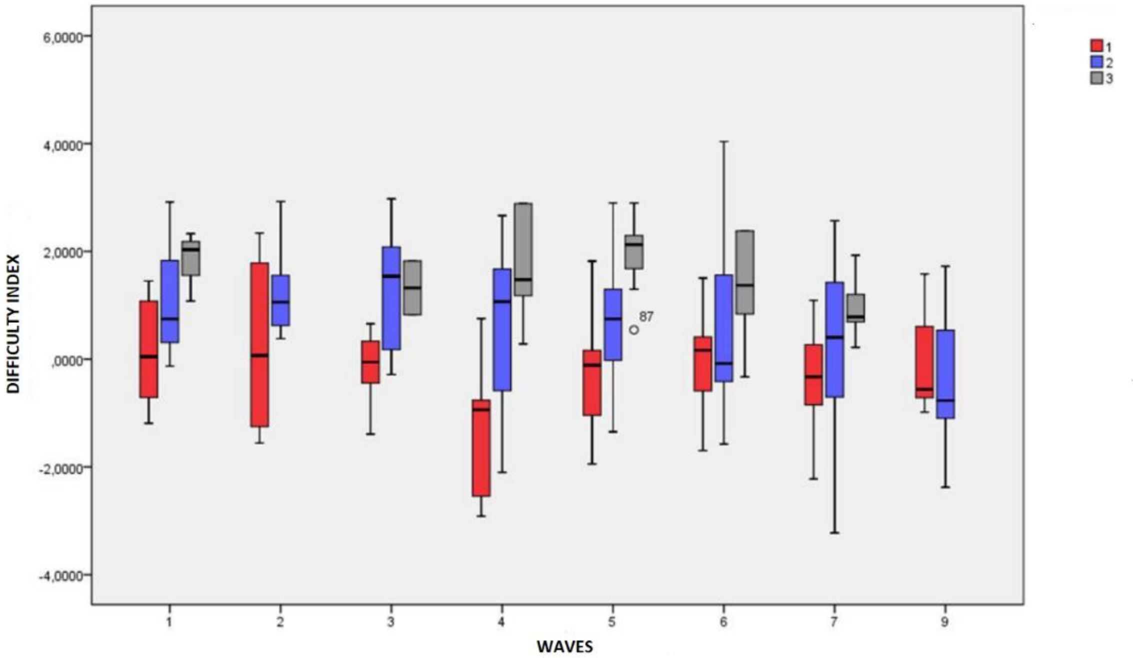

Figure 4. Medians in content dimension

In this way, it can be noted that, despite the items involving pure mathematical knowledge (MK) were considered easier by students, the same questions became much more difficult when requesting the implementation of algorithms. This finding corroborates with the results obtained by Amantes (2009) when investigating how technological and scientific knowledge is used to solve problems. In this present study, there is no direct transfer of knowledge from one area to another in order to develop algorithms, but rather a construction of new knowledge based on the specificities of the two domains (Fensham, 1994). Our findings pointed a difficulty to achieve higher complexity levels, indicating that there is necessary improvement to teaching strategies in order to provide a better way to develop students' abstract thinking. To accomplish this goal, it is also important to develop teaching approaches for improving students formal reasoning, once the hybrid questions were considered the most difficult ones. We also consider it is important to develop techniques for solving complex problems, such as the process of breaking a problem down into the smaller pieces necessary to solve it: "divide to conquer", but often the difficulties lie in understanding the problem as a whole and identifying its pieces. Understanding the mathematical problem and how to split it into easier ones to solve is a preceding step and without it the students cannot transpose the problem to an algorithm.

DISCUSSION

The analysis of student learning points to the increase in all levels of complexity and content, even though less complex questions have become easier for students, indicating that teaching strategies for the development of abstract thinking are necessary. In order to encourage the development of abstract and complex knowledge, it may be necessary to adopt approaches that strengthen students' formal reasoning. With regards to content, the hybrid questions were considered the most difficult. As an educational implication, this result draws particular attention to teaching strategies of programming logic subject. The algorithmic problems included in the hybrid questions required reasoning skills to transpose the problem, that is, that the students had enough proficiency in several mathematical contents, as raised by Gomes and Mendes (2006). Theses authors correlated the difficulties experienced by students to their background in mathematical knowledge. Therefore, the difficulty is more likely to be in transposing mathematical contents to build algorithms and in transferring knowledge from one area to another, that is, students may have trouble in in building new knowledge from the specificities of the two domains (Fensham, 1994). These finding calls attention to the difficulty in developing interdisciplinary approaches which could effectively enable the achievement of generalized knowledge.

Through our research we evaluated that an adoption of strategies that promote abstract thinking, logical/mathematical reasoning, interpretation and division of mathematical problems in the curriculum of mathematics discipline itself would be a great help to improve this situation. This would not only benefit the students' performance in the programming logic discipline, but throughout all the courses related to computer programming, programming skills is a prerequisite for many other subjects. The student's difficulties or success in the programming logic discipline extend throughout the course, leading to failures and dropouts. Focusing in these strategies would greatly increase the number of technology learners, while contributing to the generation of qualified jobs and country development.

REFERENCES

Amantes, A. (2009). *Contextualização no Ensino de Física: Efeitos sobre a evolução do entendimento dos estudantes*. UFMG.

Campos, R. L. B. L. (2009). Lógica de Programação: Há como melhorar o aprendizado fugindo dos padrões estabelecidos nos livros didáticos e adotados pela maioria dos docentes ?. In: *XXXV Latin American Informatics Conference – XXXV CLEI, 2009, Pelotas, RS, Brazil. Iberian-American Conference on High Education in Computer Science – XVII CIESC*. Pelotas, RS, Brazil: Universidade Federal de Pelotas.

Case, R. (1992). Neo-Piagetian theories of intellectual development. In H. Beilin, H. & P. B. Pufall (Eds.), *Piaget's Theory*. Hillsdale, NJ: Erlbaum.

Case, R. (1996). Changing views of knowledge and their impact on educational research and practice. In Olson, D. R. & Torrance, N. (Eds.), *The Handbook of Education and Human Development: New models of learning, teaching and schooling*. Cambridge, MA: Blackwell.

Coelho, G. R. (2011). *A evolução do entendimento dos estudantes em eletricidade: um estudo longitudinal*. UFMG.

Commons, M. L. (2008). Introduction to the model of hierarchical complexity and its relationship to postformal action. *World Futures*, *64*(5–7), 305–320.

Falkembach, G. A. M., Amoretti, M. S. M., Tarouco, L. R. & Viero, F. (2003). *Aprendizagem de Algoritmos: Uso da Estratégia Ascendente de Resolução de Problemas*. 8º Taller Internacional de Software Educativo. Santiago, Chile.

Fensham, P., Gunstone, R. & White, R. (1994). *The Content of Science: A Constructivism Approach to its Teaching and Learning*. Hong Kong: The Falmer Press.

Fischer, K. W. (1980). A theory of cognitive development: The control and construction of hierarchies of skills. *Psychological Review*, *87*, 477–531.

Gomes, A., Carmo, L., Bigotte, E. & Mendes, A. J. (2006). "Mathematics and programming problem solving", *Proceedings of 3rd E-Learning Conference –Computer Science Education*. Coimbra: Portugal.

Gomes, A, Henriques, J. & Mendes, A. J (2008). Uma proposta para ajudar alunos com dificuldades na aprendizagem inicial de programação de computadores. *Educação, Formação & Tecnologias*, *1* (1), Maio 2008.

Guttman, L. (1944). A basis for scaling qualitative data. *American Sociological Review*, *9*, 139–150, 1944.

Martins, S. W. & Correia, L. H. de A. (2003). *O Logo como Ferramenta Auxiliar Desenvolvimento do Raciocínio Lógico – um Estudo de Caso*. International Conference on Engineering and Computer Education – ICECE 2003, Santos.

Pereira Junior, J. C. R. & Rapkiewicz, C. E. (2004). O Processo de Ensino-Aprendizagem de Fundamentos de Programação: Uma visão crítica da pesquisa no Brasi. In: *I Workshop de Educação em Computação RJ/ES*, 2004, Vitória, ES. I Workshop de Educação em Computação RJ/ES, 2004. v. 1.

Regebe, F. & Amantes, A. (2013). Habilidades X Entendimento de Conceitos Abstratos relacionados ao raciocínio lógico: uma análise preliminar. In: *IX Encontro Nacional de Pesquisa em Ensino de Ciências, 2013*. Águas de Lindóia: ENPEC.

Regebe, F. & Amantes, A. (2015). Accessing complexity levels about abstract content skills: taxonomy and tests validation. In: *ESERA, 2015*. Helsinki: ESERA.

Regebe, F. & Amantes, A. (2017). Evaluation of a model to access logical reasoning. In: *ESERA, 2017*. Dublin: ESERA.

Rodrigues, M. C. (2002). *"Como Ensinar Programação?"*. Informática – Boletim Informativo Ano I n° 01, ULBRA. Canoas, RS, Brasil.

DEVELOPMENT AND VALIDATION OF THE NEGATIVE APPRAISALS OF STUDYING SCHOOL SCIENCE (NASSS) SCALE

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Based on recent conceptualization of the cost construct from the expectancy-value model of achievement motivation, this study reports on the development of the Negative Appraisals for Studying School Science (NASSS) scale and initial psychometric evidences performed with elementary school students (N = 442) from the Spanish educational system. Results revealed a two-factor structure consistent with theoretical expectations and with strong internal consistency reliability and face, content and construct validity evidences. These findings provide sound theoretical and empirical evidence to consider NASSS as a valid and reliable instrument for the Spanish context.

Keywords: loss of valued alternatives, task effort, exploratory factor analysis.

INTRODUCTION

Despite the many curricula reforms, the leaky pipeline in science education seems to persist worldwide. More specifically, Spain has experienced a steady decline in students interested in studying science during secondary and tertiary education (MECD, 2016). On the other hand, persistence has been linked to achievement motivations and cost-related variables (Andersen & Ward, 2014). Since career aspirations and interest in science seem to be already established at 13 years old (Lindahl, 2007), and given that the promotion of positive attitudes towards science from early years is paramount for science education worldwide, it is crucial to advance the understanding of the variables affecting late elementary students interest for scientific studies and disciplines. Thus, the present study aims at developing and validating a short scale for the measurement of negative factors that hinders further participation in science education among Spanish-speaking elementary students, called the Negative Appraisals of Studying School Science (NASSS) scale. The availability of a valid and reliable instrument would enable future research on this important aspect, which may shed some light on this pattern of generalized disinterest in science. In turn, an increase in understanding of the negative aspects related to studying science may contribute to the effectiveness of educational interventions aimed at fostering scientific vocations.

BACKGROUND

Several studies highlighted concerns about the methodological quality of the attitudinal instruments published in science education research (i.e. Blalock et al, 2008; Gardner, 1975), revealing that many science attitudes instruments lack conceptual clarity and validity and reliability psychometric evidence. More recently, Toma (in press) performed a systematic review of 15 science attitude instruments published between 2004 and 2016, concluding that, overall, the quality of most recently published instruments remains a matter of concern; the author pointed that science attitude instruments were not rooted in any existing theoretical framework and that there as a deficient or inadequate analysis of the psychometric properties of the proposed instruments.

These findings question the validity and reliability of existing instruments and highlight the need to adopt more rigorous methodological designs for the development of instruments in science education research.

THEORETICAL UNDERPINNINGS

The expectancy-value theory of achievement motivation postulates that motivation, choice and persistence in a given activity or task are influenced by expectancies and task-values variables (Eccles, Wigfield, Harold, & Blumenfeld, 1993). While the expectancy construct refers to individual's beliefs about its own ability to successfully perform a specific activity, the task-value construct relates to the assessment that an individual attributes to that particular task or activity in terms of (a) intrinsic value (level of enjoyment related to a task), (b) attainment value (the importance of doing well on a given task that relates to own identity), (c) utility value (usefulness of a given task for future goals and plans), and (c) cost (negative factors related to a given task).

Recently, new studies further reported that cost dimension is better conceptualized as a separate construct from task-values and that the cost construct may be formed by others underlying factors, such as task effort cost, outside effort cost, loss of valued alternatives, and emotional cost (Flake, Barron, Hulleman, McCoach, & Welsh, 2015). Therefore, the NASSS scale is rooted in the understudied cost-construct from the EVT theory that may serve as a theoretical framework for understanding the factors influencing the development of students' interest and engagement in science courses.

An important caution needs to be raised. It is important to note that cost is different than self-efficacy and should not be confounded or treated as similar traits. While Bandura (1993) conceived self-efficacy as the beliefs that individuals have about their own ability to be successful at a given task (e.g. being able to understand science lessons), the cost construct includes internal beliefs about the salient negative aspects derived from the participation in a given task or activity, regardless of the ability to perform that task (i.e. having to study for long hours to understand science lessons).

For example, a student may be highly interested in the science subject and have high self-efficacy in the learning of the school science content. However, he/she may perceive that being successful in science requires for him/her too much effort (i.e. many hours of studying), the abandon of other activities to devote more time to study science, and the high changes of failing may be causing a lot of stress and anxiety. Despite the interest and ability to be successful in science, these perceived adverse factors related to science education could ultimately act like a barrier and affect his/her decision to engage in future science subjects and to pursue a science related career. Therefore, if the cost of studying school science is too high, or in other words, if students perceived too many adverse factors related to studying school science, students may be willing to abandon science studies.

METHODS

Sample

A total of 442 students (M_{age} = 10.3, *SD* = 1.18) enrolled in 3rd to 6th elementary school grades constituted the sample for this study. Participants were drawn from 21 elementary schools from the province of Burgos (Spain) by means of convenience sampling.

Procedure

The NASSS scale was developed using a three-stage procedure consistent with recent recommendations (AERA, APA, & NCME, 2014). In the first stage, an initial item pool was created by selecting items from existing cost scales. Items were translated from English to Spanish following cross-cultural adaptation procedures, which include translation into spanish and back-translation into the original language by two bilingual professors. In the second stage, selected items were subjected to theoretical analysis for content and face validity through a panel of experts composed of two university professors and six elementary school teachers, and through cognitive interviewing protocol with elementary students (*n* = 16) to assess item interpretation. In the last stage, large scale administration and psychometric analyses were performed. Construct validity was examined by subjecting items to exploratory factor analysis (EFA) using Principal Component Analysis (PCA) extraction with oblique-Promax rotation because factors were hypothesized to be related. Factors were retained following parallel analysis criteria and were further examined for convergent and discriminant validity using Pearson correlation within and between items included in each factor. Finally, internal consistency reliability was examined through Cronbach α, item-total correlation, and split-half reliability. Each one of these psychometric properties is defined in the next subsection.

Psychometric properties examined

Validity refers to the degree to which an instrument ""(…) measures the construct(s) it purports to measure" (Mokkink et al. 2010, p.743). One of the main validity indices is content and face validity, which examines if the content of a instrument adequately measures the construct of interest. More specifically, face validity examines what the test appears to be measuring based on subjective evaluations related to whether the test looks as thought to be measuring the target construct. Similarly, content validity evaluates the "(…) adequacy of content coverage and relevance for multi-item measures of a construct" (Polit, 2015, p.1750), but following a much more rigorous and systematic procedure.

Once the content and face validity are established, the instrument should be submitted to construct validity procedures to examine if the scores of the new instruments "(…) supports the inference that the construct has been appropriately represented" (Polit, 2015, p. 1750). Thus, construct validity is usually examined through factor analysis that reveal whether the proposed instrument captures the theoretically expected dimensionality. Likewise, it should be examined whether items of one construct are related to items with which conceptual convergence is expected (convergent validity), are not related to items with which conceptual convergence is not expected (discriminant validity).

Finally, the reliability of the extracted constructs should be examined. Reliability is defined as whether "(…) scores for people who have not changed are the same for repeated measurements, under several situations" (Polit & Yang, 2016, p. 25). One of the most common types of reliability is internal consistency, which examines if the items on a scale are part of the same underlying construct.

RESULTS

From the initial list of 19 items, the panel of experts reached agreement (above 75%) in including a total of 10 items measuring task effort, valued alternatives, and emotional negative appraisals. The cognitive interviews indicated that the emotional items were problematic, with most students showing difficulties in understanding some words included in these items. After eliminating emotional items including difficult words such as exhausting, frustrating, or anxious or stressful, six items remained for the large-scale administration.

Kaiser–Meyer–Olkin measure of sampling adequacy (KMO) was .795 and Bartlett's test of sphericity reached statistical significance ($p < .001$), which supports sampling adequacy for factor analysis. PCA with Promax rotation revealed a simple structure of two factors explaining a total of 65.16% of the variance, with items strongly loading on only one component and with no cross loadings between components above .40 (Table 1). The decision to retain two factors was further supported by parallel analysis which showed only two factors with actual eigenvalues exceeding the eigenvalues from a random generated sample of the same size (6 variables, 442 subjects). Thus, the first factor, named *Loss of valued alternatives*, measures the extent that students perceive that studying school science subject requires them to give up other valued activities, and the second factor, named *Task effort*, measures the effort students feel they must perform in order to be successful in school science.

Pearson correlation coefficient revealed medium to large-positive significant correlations ranging from .405 to .519 between items included the *Loss of valued alternatives* factor, and .345 to .519 for the *Task effort* factor items, which indicate convergent validity. The component correlation matrix revealed a medium-positive correlation between both factors (r = .457), which supports discriminant validity between factors.

Table 1. Pattern matrix of principal component analysis (PCA) with Promax rotation

Items	Factors extracted		
	1	2	h^2
6. I have to sacrifice a lot of free time to be good at science	**.937**	-.220	.739

3. I have to give up too much to do well in my science class	**.788**	.068	.674
4. I have to invest a lot of time to get good grades in science	**.557**	.299	.552
2. I am unable to put in the time needed to do well in my science class	-.282	**.887**	.638
5. Science class required too much effort	.190	**.713**	.668
1. My science classwork requires too much time	.189	**.696**	.640
% variance explained	47.9	17.29	3.91 (65.19)

Factor 1: Loss of valued alternatives; Factor 2: Task effort
h^2 refers to items communalities

Cronbach α for the entire scale was .778 (Factor 1 α = .715; Factor 2 α = .701). Split-half reliability was .724 for the *Loss of valued alternatives* factor and .743 for the *Task effort* factor, as reported by Spearman-Brown Coefficient. Finally, corrected item-total correlations ranged between .403 and .590. These indices suggest acceptable reliability for both factors.

CONCLUSIONS

The goal of this study was to develop and provide initial validation evidences for an instrument aimed at examining negative appraisals of studying school in Spanish elementary education students. Using a multistage translation approach and multiple psychometric evaluations, the NASSS scale reported strong validity (face, content, construct) and reliability evidences. Both constructs of the NASSS scale were consistent with recent conceptualization and existing cost instruments developed in the literature (Flake et al., 2015).

During the development and validation of the NASSS scale, it was intended to overcome the criticisms raised in science education research literature in relation to poorly validated instruments (see Blalock et al., 2008). Therefore, the NASSS was rooted in recent conceptualization of the cost construct from the EVT framework and the procedure used for selecting, adapting and assessing the items was robust and systematic, including back-translation, the use of both experts and students for examining the content and face validity, and the use of many more psychometric tests than most existing instruments in the literature to establish the validity and reliability of the proposed instrument. Consequently, the NASSS scale can be considered as a promising first step in the measurement of negative appraisals factors related to the study of school science in the Spanish context, which can allow future research about cost as an important factor in the development of student's interest toward school science and scientific-related disciplines.

ACKNOWLEDGEMENTS

Funded by 2017 – 2021 Ph.D. research fellowship (UBU) and MINECO-AEI EDU 2017-89405-R research project.

REFERENCES

AERA, APA & NCME. (2014). *Standards for educational and psychological testing*. Washington, DC: American Educational Research Association.

Andersen, L. & Ward, T. J. (2014). Expectancy-value models for the STEM persistence plans of ninth-grade, high-ability students: A comparison between black, hispanic, and white students. *Science Education*, *98*(2), 216–242.

Bandura, A. (1993). Perceived self-efficacy in cognitive development and functioning. *Educational Psychologist, 28*(2), 117–148.

Blalock, C. L., Lichtenstein, M. J., Owen, S., Pruski, L., Marshall, C. & Toepperwein, M. A. (2008). In pursuit of validity: A comprehensive review of science attitude instruments 1935 – 2005. *International Journal of Science Education*, *30*(7), 961–977.

Eccles, J. S., Wigfield, A., Harold, R. B. & Blumenfeld, P. B. (1993). Age and gender differences in children's self- and task perceptions during elementary school. *Child Development*, *64*, 830–847.

Flake, J. K., Barron, K. E., Hulleman, C., McCoach, B. D. & Welsh, M. E. (2015). Measuring cost: The forgotten component of expectancy-value theory. *Contemporary Educational Psychology*, *41*, 232–244.

Gardner, P. L. (1975). Attitudes to science: A review. *Studies in Science Education, 2*, 1–41.

Lindahl, B. (2007). Longitudinal study of students' attitudes towards science and choice of career. In *Paper presented at the 80th session of the International Conference of the National Association for Research in Science Teaching*. New Orleans.

MECD. (2016). *Datos y cifras del sistema universitario español. Curso 2015/2016*. Secretaría General Técnica.

Mokkink, L. B., Terwee, C. B., Patrick, D. L., Alonso, J., Stratford, P. W., Knol, D. L., … de Vet, H. C. W. (2010). The COSMIN study reached international consensus on taxonomy, terminology, and definitions of measurement properties for health-related patient-reported outcomes. *Journal of Clinical Epidemiology, 63(*7), 737–745.

Polit, D. F. (2015). Assessing measurement in health: Beyond reliability and validity. *International Journal of Nursing Studies, 52*(11), 1746–1753.

Polit, D. F. & Yang, F. (2016). *Measurement and the measurement of Change: A primer for health professionals.* Philadelphia: Lippincott Williams & Wilkins.

Toma, R. B. (in press). Revisión sistemática de instrumentos de actitudes hacia la ciencia (2004-2016) [Systematic review of attitude toward science instruments (2004-2016)]. *Enseñanza de las Ciencias*.

EVALUATION OF LEARNING PROGRESSIONS ON CHEMICAL CONCEPTS IN SECONDARY SCHOOLS

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Chemistry is characterized by a logical and hierarchical structure. The acquisition of new content knowledge is highly dependent on students' previous knowledge and how it is connected. If this knowledge is available, the new (hierarchically higher) knowledge can be integrated into existing knowledge in terms of cumulative learning (Duschl, Schweingruber & Shouse, 2007; Fischer, Glemnitz, Kauertz & Sumfleth, 2007). However, international (e.g. PISA, TIMSS) and national (IQB) studies report that students fall behind the desired knowledge developments. One possible assumption is that these students lose track in instruction and fail to catch up due to the deficits they acquired early on. Therefore, this study tries to map this hierarchical structure via a strand map and to empirically evaluate this map. The strand map considers the three chemical core concepts Structure of Matter, Chemical Reaction and Energy for the first two learning years (MSW NRW, 2011). Performance tests were developed and administered in a quasi-longitudinal and a true-longitudinal study to analyze the validity of the presupposed interdependencies of the core ideas. Different methods like the McNemar test for the single interdependencies and the Bayesian networks for the whole map were used for evaluation purposes. The results of this study contribute to the development of more precise diagnosis instruments for learning difficulties.

Keywords: Learning Progression, Conceptual Understanding, Secondary School

THEORETICAL FRAMEWORK

The results of international assessment studies such as PISA, in which German pupils' performance in the natural sciences fell short of expectations (Baumert et al., 2001), lead to discussions on initiating educational standards for science subjects. These were consequently introduced into the school system as general standards that define the middle performance level an average student is expected to reach (competence level III) (Klieme et al., 2007). The IQB national assessment study 2012 showed that many German students, especially in North Rhine-Westphalia, do not reach the educational standards for content knowledge in chemistry (Pant et al., 2013). About 69.7 % of the pupils who took part in this survey did not reach the first two competence levels and thus missed the minimum standards. Only 27.6 % reach competence level III and thus the standard, and only 2.7 % of pupils reach the last two higher competence levels (Pant et al., 2013, p. 216). The second IQB national assessment study of 2018 confirms the results for the competence area of content knowledge once again (Stanat, Schipolowski, Mahler, Weirich & Henschel, 2019). A possible reason for the students' lack of proficiency could be the cumulative structure of the subject chemistry (Fischer, Glemnitz, Kauertz, & Sumfleth, 2007). Early content knowledge deficits may hinder students to build a logical and hierarchical network where core ideas are cross-linked. In consequence, they cannot not catch up during further chemistry instruction but even increase their deficiencies, because low-achieving students cannot integrate new knowledge into existing knowledge structures. One approach to support them is to make the underlying structure of content knowledge explicit to them and to make sure, that "lower" ideas have been understood before "higher" ideas can be addressed. For this purpose, learning progressions are used to structure the content knowledge in strand maps – analogous to the "project 2061" of the *American Association for the Advancement of Science* (AAAS, 2007). Learning progressions are descriptions of possible pathways for the development of competences over time (e.g. Corcoran, Mosher, & Rogat, 2009; Duncan, & Hmelo-Silver, 2009). In preceding studies smaller learning progressions have already been described and evaluated, e.g. for different science subjects in the US (e.g. Alonzo, & Steedle, 2009; Stevens, Delgado, & Krajcik, 2010) or specifically the core concept of energy in physics (Neumann, Viering, Boone, & Fischer, 2013) as well as in the concept of chemical reactions in chemistry in the German context (Weber, 2018). Taking this into account, this study aims at mapping out a complete strand map for the first two years of chemistry education in Germany, and describing interdependencies between the core concepts *Structure of Matter*, *Chemical Reaction* and *Energy*. They can be assigned a structuring function with which chemical contents can be networked and systematically ordered (Demuth, Ralle & Parchmann, 2005).

RESEARCH QUESTION

In this study the following research question is investigated:

Are the presupposed interdependencies between the chemical core ideas valid?

PROCEDURE AND STUDY DESIGN

In a first step, a group of experts (school teachers and researchers) have developed a preliminary strand map which describes assumed links between the individual core ideas (Figure 1). Each core idea is supported by clarifications specifying knowledge students are expected to have about the targeted idea and boundaries describing knowledge students are not expected to have. In total, 57 core ideas were identified for the first two learning years and arranged in a logical and hierarchical strand map.

For the evaluation of these hypothetical interdependencies it was necessary to develop a test, which assesses students' knowledge about the core ideas. For this reason, in a second step, at least five items per core idea were developed in a multiple-choice single-select format. The items were administered to students from secondary schools (comprehensive schools and grammar schools in Germany) in a multi-matrix-design using an *unbalanced incomplete block design* (Giesbrecht & Gumbertz, 2004). The test items were arranged in test booklets in such a way that all items that belong to a core idea were administered together with the items of the core ideas that are directly related. The different test booklets were linked at least by the test items of two core ideas. However, some core ideas were cross-linked more frequently than others, which means that the tasks relating to these core ideas appear more often in the test booklets.

After the removal of items with construction errors a total of 326 items was administered to 787 students from the first two learning years in a quasi-longitudinal study. In addition, students from the third learning year were tested for increasing the variance. Data from this assessment (pilot study) was used to evaluate the test instrument.

In a last step, within the context of the main study the reworked test instrument (with 348 items) was administered to another sample of students at two measurement points to evaluate the proposed interdependencies between the core ideas. Here, a quasi-longitudinal study was chosen. Students from the first two learning years were tested two times in an interval of five months for a true longitudinal design. As control variables a cognitive ability test with a verbal and a non-verbal scale (Heller, & Perleth, 2000) was administered. The sample size for the main study was N = 1232 students for the first and N = 1187 students for the second measurement point.

RESULTS

All analyses regarding test quality were conducted using ConQuest® software, while group comparisons were calculated in SPSS. Due to a design error, 9 out of 348 items were excluded from the calculation, so the calculations were performed with 339 items. The fit statistics for the main study show that the item reliability (.919 and .929) and the EAP/PV reliability (.836 and .829) are satisfying (see Table 1).

Table 1. Results of the test quality.

Measurement point	Number of items	Item reliability	EAP/PV reliability	wMNSQ	t
1	339	.919	.836	.78 – 1.35	-3.5 – 3
2	339	.929	.829	.72 – 1.29	-3.9 – 2.8

The mean item difficulty for three chemical concepts C*hemical Reaction* ($t(69) = 11.271$, $p \leq .001$, $d = 1.355$), *Energy* ($t(67) = 11.809$, $p \leq .001$, $d = 1.436$) and *Structure of Matter* ($t(200) = 18.448$, $p \leq .001$, $d = 1.3$) for the first measurement point is significantly higher than for the second measurement point. This difference was expected and can be retraced to the fact that some of the content has been learned by the students in the meantime. Hence, the test is able to measure learning progress. There are no significant differences between the three chemical core concepts within each measurement point ($F(2,336) = 1.428$, $p = .241$, $\eta^2 = .008$; $F(2, 336) = 1.584$, $p = .207$, $\eta^2 = .009$) which means that the items for the three concepts are equally difficult.

Since there is no uniform procedure for testing the hypothetical dependencies between core ideas, two different methods with different focuses are combined here: The McNemar test and the Bayesian nets. The investigated dependencies are shown exemplarily for the section shown in Figure 1. The arrows drawn in mean that the core idea from which the arrow departs is the prerequisite for the acquisition of the core idea to which the arrow leads.

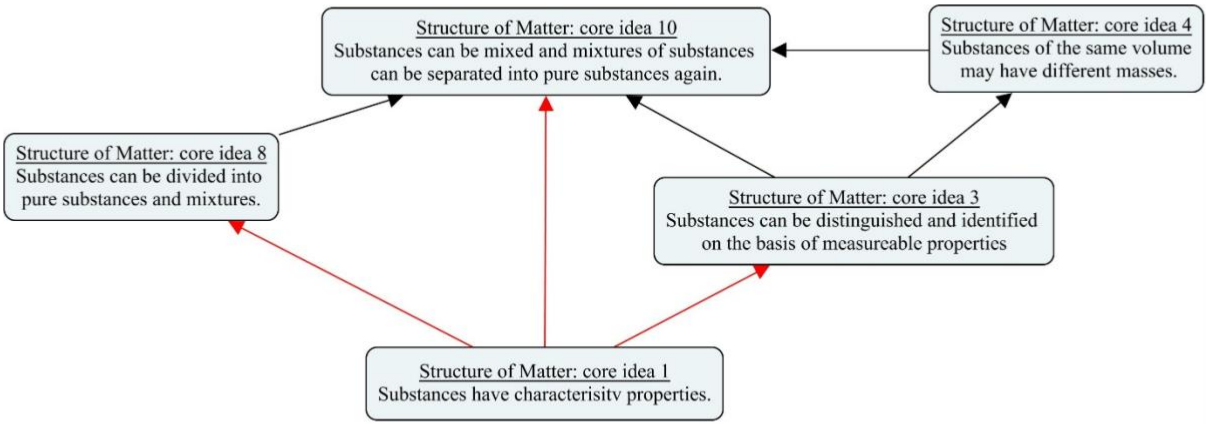

Figure 1. Excerpt from the strand map for the basic concept Structure of Matter of the first learning year.

Until now, the interdependencies have only been calculated for single core ideas. For the calculation of the McNemar test it was necessary to determine a cut off threshold to label a core idea as understood. Therefore, a binomial test was calculated to determine the guessing probability for a group of five items. Resulting from this, it has been decided that a minimum of four out of five items has to be answered correctly to make sure an idea is sufficiently understood (Bühl, 2016). The following example illustrates the calculation procedure for the McNemar test for one interdependency: For the assumption that core idea 3 is dependent on core idea 1 (Figure 1) the McNemar test (Field, 2013; Wirtz & Caspar, 2002) shows the consistency in the answers across both core ideas. For this test the three cases 0/0, 1/0 and 1/1 are expected, while the case 0/1 is unexpected (Table 2). For this test the last case (0/1) must have the lowest frequency to support the hypotheses that core idea 1 is the requirement of core idea 3. Over time decreasing numbers in the cell 0/0 are expected, while increasing numbers are expected for 1/0 and 1/1. In the example at hand, a marginal movement in this direction is noticeable. Here, the occupation of the cell 0/0 decreases while the cell 1/0 increases. For both measurement points the frequencies for the bold printed (expected) are higher than for the 0/1 cell (Table 2). However, the highest frequencies are in the 0/0 cell, which means that a lot of students have not acquired sufficient knowledge concerning both of the core ideas. For the dependencies marked in red in the figure, significant dependencies could be determined in each case. The black arrows, on the other hand, indicate that there is no significant dependency after the McNemar test. A total of 101 relationships were displayed with arrows in the strand map. Of these 38 relations are significantly dependent. Since there are only a few case numbers (N < 50) for some items of individual core ideas, the significance may be influenced. A minimum of 18 and a maximum of 243 case numbers are available for the core ideas.

Table 2. Cross table for the first (left) and second (right) measurement point.

		core idea 3		
		0	1	total
core idea 1	0	**68**	3	71
	1	**13**	**11**	24
total		81	14	95

		core idea 3		
		0	1	total
core idea 1	0	**63**	7	70
	1	**12**	**12**	24
total		75	19	94

0 = answered wrong   1 = answered correctly

The McNemar test was calculated not only for the analysis of the response behavior of two different core ideas within one measurement time (1 and 2), but also between two measurement times for the same core idea (Table 3). A similar pattern can be seen here in the results. Most pupils do not master the core ideas, despite the teaching that took place between the first and second point of measurement. Only a small proportion answered (partially) correctly the test items for the core ideas at both measurement points and consequently understood the core idea. While there these results confirm of the IQB national assessment study (Pant et al., 2013; Stanat et al. 2019), the low proficiency level is adverse for our analysis.

Table 3. Cross table for the core idea 1 (left) and core idea 3 (right) between two measurement points (mp).

		core idea 1 mp 2		
		0	1	total
core idea 1 mp 1	0	**64**	8	72
	1	**3**	**9**	12
total		67	17	84

		core idea 3 mp 2		
		0	1	total
core idea 3 mp 1	0	**63**	9	72
	1	**3**	**9**	12
total		66	18	84

The dependencies of larger sections of the strand map are checked with the Bayesian networks. The analyses were carried out with the Netica® software. This software calculates the conditional probabilities for the examined core ideas in a Conditional Probability Table (CPT) (Wei, 2014), which can be used to make statements about which core idea might have a greater influence on the understanding of another core idea. A CPT (Figure 4) was issued for the section shown in Figure 1, more precisely for core idea 10. The table on the right shows the percentages of students who master (state 1) or do not master (state 0) the core idea 10, depending on the other core ideas associated with the core idea 10. Here it becomes clear that core idea 1 has the greatest influence on core idea 10, because about 66.7 % of the pupils who understood core idea 10 also understood core idea 1, while about 33.3 % of these pupils did not understand this core idea. This finding is consistent with the McNemar test, which found that there is a dependency at least between core idea 1 and 10.

Table 4. Conditional Probability Table for core idea 10 (created with Netica®).

SDM7_K1	SDM7_K3	SDM7_K4	SDM7_K8	state0	state1
state0	state0	state0	state0	86.667	13.333
state0	state0	state0	state1	50	50
state0	state0	state1	state0	50	50
state0	state0	state1	state1	50	50
state0	state1	state0	state0	75	25
state0	state1	state0	state1	50	50
state0	state1	state1	state0	50	50
state0	state1	state1	state1	50	50
state1	state0	state0	state0	33.333	66.667
state1	state0	state0	state1	66.667	33.333
state1	state0	state1	state0	50	50
state1	state0	state1	state1	50	50
state1	state1	state0	state0	50	50
state1	state1	state0	state1	66.667	33.333
state1	state1	state1	state0	66.667	33.333
state1	state1	state1	state1	33.333	66.667

CONCLUSION AND OUTLOOK

Learning progressions offer the possibility to organize the core ideas in a strand map hypothetically and to empirically analyse the presented learning pathways. The investigated dependencies in the strand map could partly be confirmed, whereby there is a share that does not seem to be significantly dependent. From a content point of view, this is quite plausible in some places. For example, the separation of materials is dealt with in some lessons without any further elementary concepts being linked to these. The determination of the threshold value for the binomial test is set too strictly against the background of the test values found that - as international and national studies have shown - many pupils do not achieve the required competences and presumably leads to an underestimation of the actual dependencies or to no statements being made about many assumed relationships. For the discussion of the strand map with the teachers, the limit of the binomial test was therefore reduced (to three out of five items) and converted into a "traffic light system" that takes both analyses into account: If at least four items were solved, there is an empirically proven dependency between two core ideas whose relationship is marked green. If it is orange, there is probably a dependency (at least three correct answers). If less than three items were solved, no dependency is assumed, so that this dependency is shown in red.

These results should be interpreted with caution. Due to the study design, not all students were able to answer the same questions. Therefore, there are not many student responses to the items of some core ideas, so this may affect the analysis of dependencies.

ACKNOWLEDGEMENT

At this point I would like to thank all teachers involved in the project for the good cooperation. A further thank you goes to the schools, especially to all the pupils who took part in the project.

REFERENCES

Alonzo, A. C., & Steedle, J. T. (2009). Developing and assessing a force and motion learning progression. *Science Education*, *93*(3), 389–421.

American Association for the Advancement of Science (AAAS) (2007). *Atlas of Science Literacy. Volume 2.* Washington, DC: AAAS.

Baumert, J., Klieme, E., Neubrand, M., Prenzel, N., Schiefele, U., Schneider, W. & Weiss, M. (Eds.). (2001). *PISA 2000: Basiskompetenzen von Schülerinnen und Schülern im internationalen Vergleich*. [PISA 2000: Basic competences of pupils in an international comparison]. Opladen: Leske + Budrich.

Bühl, A. (2016). SPSS 23. *Einführung in die moderne Datenanalyse*. [SPSS 23. Introduction to modern data analysis]. Hallbergmoos: Pearson.

Corcoran, T., Mosher, F. A., & Rogat, A. (Eds.) (2009). *Learning Progressions in Science. An Evidence-based Approach to Reform*. Philadelphia, PA: CPRE.

Demuth, R, Ralle, B. & Parchmann, I. (2005). Basiskonzepte – eine Herausforderung an den Chemieunterricht. [Basic concepts - a challenge for chemistry lessons]. *CHEMKON, 12*(2), 55–60.

Duncan, R. G., & Hmelo-Silver, C. (2009). Editorial – Learning Progressions: Aligning Curriculum, Instruction, and Assessment. *Journal of Research in Science Teaching, 46*(6), 606–609.

Duschl, R. A., Schweingruber, H. A., & Shouse, A. W. (Hrsg.) (2007). *Taking Science to School: Learning and Teaching Science in Grades K-8*. Washington, DC: The National Academies Press.

Field, A. (2013). Discovering statistics using IBM SPSS statistics. Los Angeles, London, New Delhi, Singapore, Washington DC: Sage Publications.

Fischer, H. E., Glemnitz, I., Kauertz, A. & Sumfleth, E. (2007). Auf Wissen aufbauen – kumulatives Lernen in Chemie und Physik. [Building on knowledge - cumulative learning in chemistry and physics.] In E. Kircher, R. Girwidz & P. Häußler (Eds.), *Physikdidaktik. Theorie und Praxis* (pp. 657–678). Berlin, Heidelberg: Springer.

Giesbrecht, F. G. & Gumpertz, M. L. (2004). *Planning, Construction, and Statistical Analysis of Comparative Experiments*. Hoboken, New Jersey: John Wiley & SonS, Inc.

Heller, K. A., & Perleth, C. (2000). *Kognitiver Fähigkeitstest für 4. bis 12. Klassen, Revision.* [Cognitive ability test for grades 4 to 12]. Göttingen: Beltz Test GmbH.

Klieme, E., Avenarius, H., Blum, W., Döbrich, P., Gruber, H., Prenzel, M., Reiss, K., Ricquarts, K., Rost, J., Tenorth, H.-E. & Vollmer, H. J. (2007). *Zur Entwicklung nationaler Bildungsstandards - Expertise.* [On the development of national educational standards - Expertise.] Bonn, Berlin: BMBF.

Kultusministerkonferenz (KMK), Sekretariat der Ständigen Konferenz der Kultusminister der Länder in der Bundesrepublik Deutschland (Eds.) (2005). *Bildungsstandards für das Fach Chemie für den Mittleren Schulabschluss* [Educational standards for the chemical standards for middle school]. München: Luchterhand.

Ministerium Für Schule und Weiterbildung NRW (MSW NRW) (2011). *Kernlehrplan für die Gesamtschule – Sekundarstufe I in Nordrhein-Westfalen. Naturwissenschaften. Biologie, Chemie, Physik* [Core curriculum for the comprehensive school - Middle school in North Rhine-Westphalia. Sciences. Biology, Chemistry, Physics]. Frechen: Ritterbach Verlag.

Neumann, K., Viering, T., Boone, W., & Fischer, H. E. (2013). Towards a Learning Progression of Energy. *Journal of Research in Science Teaching*, *50*(2), 162–188.

Norsys Software Corp. (2016). *Netica Application for Windows*. Vancouver, BC.

Pant, H. A., Stanat, P., Schroeders, U., Roppelt, A., Siegle, T. & Pöhlmann, C. (Eds.) (2013). *The IQB National Assessment Study 2012. Competencies in Mathematics and the Sciences at the End of Secondary Level I*. Münster, New York, München, Berlin: Waxmann.

Stanat, P., Schipolowski, S., Mahler, N., Weirich, S. & Henschel, S. (2019). *IQB-Bildungstrend 2018. Mathematische und naturwissenschaftliche Kompetenzen am Ende der Sekundarstufe I im zweiten Ländervergleich.* [IQB educational trend 2018. Mathematical and scientific literacy at the end of lower secondary level in the second country comparison]. Münster, New York: Waxmann.

Stevens, S. Y., Delgado, C. & Krajcik, J. S. (2010). Developing a Hypothetical Learning Progression for the Nature of Matter. *Journal of Research in Science Teaching*, *47*(6), 687–715.

Weber, K. (2018). *Entwicklung und Validierung einer Learning Progression für das Konzept der chemischen Reaktion in der Sekundarstufe I.* [Development and Validation of a Learning Progression for the concept of Chemical Reaction for the lower secondary level]. Berlin: Logos.

Wei, H. (2014). *Bayesian Networks for Skill Diagnosis and Model Validation*. Annual Meeting of the National Council on Measurement in Education, Philadelphia, PA. Available under: https://pdfs.semanticscholar.org/7a6e/522e4f308d761074ae9d5566e106bb859817.pdf [27.05.2019].

Wirtz, M. & Caspar, F. (2002). *Beurteilerübereinstimmung und Beurteilerreliabilität*. [Assessor agreement and assessor reliability]. Göttingen, Bern, Toronto, Seattle: Hogrefe.

Wu, M. L., Adams, R. J. & Wilson, M. R. (2007). *ACER ConQuest version 2.0: Generalized Item Response Modeling Software*. Camberwell, Victoria: ACER Press.

PROPOSAL OF THE USE OF SCIENTIFIC LITERACY INDICATORS TO ANALYSE A WRITTEN EVALUATION

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Scientific Literacy is a process in which the students' learning occurs by experiencing the scientific culture. Furthermore, this is currently one of the science education goals. Through this method, students can acquire a critical awareness to make conscious decisions about life and society problems. To do so, we use an alternative didactic approach known as inquiry-based teaching. The inquiry performed during the classes must be evaluated in consistent ways, thus we propose the use of the Scientific Literacy Indicators to analyse written evaluations. It will reveal skills related to the scientific competencies that should be found within the Scientific Literacy process. These indicators are divided into 1) working with data obtained in the investigation, 2) structuring thought through logical and proportional reasoning and, 3) understanding the analysed situation and searching for connections in a given context. This study aimed to analyse a written evaluation applied in a didactic sequence about public health using Scientific Literacy Indicators. As a result, although there were found three questions containing most of the indicators, the other ones had a low variety of them. In conclusion, the Scientific Literacy Indicators were a good instrument to analyse the quality of written evaluations. Therefore, teachers must invest more time elaborating tests to achieve a greater amount of students with Scientific Literacy skills.

Keywords: Initial teacher education, evaluation, scientific competences.

INTRODUCTION

One of the goals of science education is the Scientific Literacy (SL). SL is an educational process that seeks to promote competencies and skills in students to understand science and its applications to social experiences (Bybee, 2012). It can insert students in scientific culture, making them capable of reading, understand and discuss science. Activities and classes that deliberatively seeks to promote SL in students can be guided by its axes: basic understanding of scientific terms, knowledge, and concepts; understanding the nature of science and its ethical and political factors surrounding the scientific practice; and, understanding the relationships between science, technology, society and environment (Sasseron & Carvalho, 2008). The same authors propose indicators that must be present in the DS to reveal scientific competencies through the process of SL. The indicators are divided based on scientific competencies: work with data obtained in an investigation, structuring and organization of thought, understanding of the analysed situation and searching for relation with scientific knowledge.

Health education is a subject that can include SL bringing a critical view about it during the classes. It can be defined as "a broad and varied set of strategies to influence both individuals and their social environments, to improve health behaviour and enhance health and quality of life" (Glanz, Rimer & Viswanath, 2008, p.10). William Griffiths (1972) stresses that health education is a concern of individuals, families, and institutions, such as the schools. He also says that this kind of education should give individuals some abilities. As a result, they begin to look at their environment paying attention to its real conditions which involve social conditions that hind them or facilitate optimal health. Similarly, Hurd (1998) emphasizes that the school curriculum should have practical activities in which students can solve problems, make investigations and develop field projects. Those activities show how science impacts our culture and citizenship and, as so, health issues must be included. Undoubtedly, school is a particularly relevant place where health education can be settled, and many educational approaches can be used to achieve this aim, such as inquiry-based learning.

Inquiry-based learning is an alternative teaching-learning approach that allows students to feel involved in their development and to recognize that they can use what they learn (Hurd, 1998). We can work these practices in didactic sequences (DS) that is a group of activities designed and organized for educational propose to reach a learning objective, additionally, it can also be a tool for data collection (Motokane, 2015). Furthermore, educational strategies such as we cited must have a consistent evaluation that upsurge elements previously acquired at the DS. This should be pointed out because the practice of evaluation is directly related to education democracy, in other words, the permanency of students in school is strongly and directly influenced by this practice (Luckesi, 2011). Black & William (1998) highlight essential characteristics of evaluation for it to be considered formative, and, consequently, democratic: it must be focused on the education of students to promote learning, in the process of decision-making of students, share of responsibility among professor and student, lastly, it must be focused on the form of transmission and in the moment of intervention and interaction.

Following these theoretical references, we formulated a DS about Public Health, Diseases, and Biotechnology which was applied in seventh-grade classes (12 and 13 years old) by scholarship recipients of a government program that promotes the insertion of undergraduate students in teaching initiation. The use of external contexts such as public health is a way to insert situations of student's daily life. In this study, we will use SL Indicators as an instrument to analyse a written evaluation applied during the DS and make a critical review of the professor's evaluative practice.

METHODS

The location and the participants of the study

The study was accomplished in a public elementary school located in a small town in the interior of the country. The DS and the written evaluation were applied to seventh-grade students from 12 to 13 years old. The DS was applied in two classrooms, and 45 students took the written evaluation.

The Didactic Sequence

The DS about Public Health, Diseases and Biotechnology was structured following the presupposes of inquiry-based teaching (Carvalho, 2013). Firstly, we surveyed to investigate students' prior knowledge. Secondly, the sequence had a contextualized problem that introduced the theme for students. Thirdly, support material and were used to systematize knowledge. In the DS the approached topics were: diseases caused by viruses, bacteria, worm and protozoan; endemic, epidemic, and pandemic diseases; and biotechnology (vaccine and fermentation). A brief description of each class follows:

Protozoan diseases

The DS was executed in 150 minutes, distributed in three classes of 50 minutes each. The class began with a conversation with the students about the topics: What is parasitism? What is a disease? What are public policies? This moment was important to raise the prior knowledge of students about these topics. The theme of protozoan diseases was approached using as a pedagogical resource the characters of the cartoon "The Powerpuff Girls". In this animation, one of the villains present in Townsville is the Amoeba Trio and they intend to contaminate the whole city. From these characters, several questions were asked of the students, based on a line of reasoning already pre-established, but which did not exclude the possibility of students questioning the subject matter. The questions involved the understanding of the life cycles, symptoms, form of contamination and prophylaxis of amoebas and another protozoan, focusing on the social and environmental characteristics related to the contamination by this group of organisms. At the end of this activity, students developed solutions to eliminate the Amoeba Trio from Townsville and help the Powerpuff Girls using arguments based on the knowledge worked in the class.

Diseases caused by a parasitic worm

The DS was executed in 150 minutes, distributed in three classes of 50 minutes each. The class began with the resumption of the topics covered in previous classes through a conceptual map formulated with the help of the students. Next, specimen of *Ascaris lumbricoides* and specimen of *Taenia solium* were shown. Students were able to see and ask about the morphological adaptations of worms to endoparasite life, always questioning the students about what they were observing. After observing the worms, an activity was proposed to the students to be performed in groups, based on the precepts theorized by Vygotsky, which approached the efficiency of the work done in this way. The students were organized into groups. For each group was given a story related to a disease caused by a parasitic worm and a drawing kit with a life cycle of the worm. Each group had a story about a disease that affected the population of a neighbourhood. After, each group made a poster with information about the disease, the life cycle of the worm and put the poster in the school's walls as an awareness. Many of the information needed to make the posters were already present in the story, except for prophylaxis. This should be proposed and justified by the students through the interpretation of history, it also was necessary to propose political measures to improve neighbourhood's wellbeing. This class was important to understand the consequences of political and social negligence related to health. The teachers acted as proposed by Carvalho (2013): a teacher-guide. After that, each group presented their work to the classroom and it was possible to discuss the information presented by each group, highlighting important information and reviewing misconceptions.

The epidemic, endemic and pandemic diseases

The DS was executed in 150 minutes, distributed in three classes of 50 minutes each. It had the objective to work the following concepts: endemic, epidemic and pandemic diseases, natural selection and adaptation. For this it was used a computer game named “Pandemic II”, free available on the internet, in which the player can control characteristics of a disease caused by a virus, a bacterium or parasite to kill all humankind. The students were instigated to think about strategies to contaminate the world, who was seeking a cure for the disease at the same time. Over the discussion, the students also remembered concepts previously worked in the classes, like diseases caused by viruses, bacteria and its characteristics including how it propagates, and prophylactic measures. It was possible to train scientific abilities like hypothesis testing and assessment, prediction, justification, explanation, logical and proportional reasoning, and information organization. The teacher was acting like a mediator between the knowledge of the content and the students in an epistemic way to rise and complement conceptions previously worked in class.

Biotechnology and microbiology

The DS was executed in 200 minutes, distributed in four classes of 50 minutes each. The objective of this sequence was students have contact with the scientific method, show benefits of microorganisms and talk about the work of a scientist. Initially, the students visited a bakery where they could see the process of making bread and the teacher complete the explanation bringing the concepts of fermentation and its uses by humankind. In the next class, they were able to familiarize themselves with the scientific method to learn how to make observations, elaborate questions, and hypotheses in a more systematized way. It was focused on methodologies to observe microorganisms and, for this, the students were initially instigated to ask questions about the existence and permanence of these beings in the classroom. Afterward, the students formulated hypotheses and saw the need to carry out experiments to validate them. The teacher presented instruments used in scientific research and how it was used most specifically in the field of microbiology, such as Petri dishes, pipettes, nutrient agar. The idea was to use those instruments to grow microorganisms and, therefore, to examine some hypotheses previously formulated. Petri dishes containing nutrient agar were opened in the courtyard and classroom for two minutes and they added in the middle of each plate a filter paper soaked with different substances that could or could not prevent the growth of microorganisms, such as mouthwash, sanitary water, water, and a control. After the experiment, we discussed the deficiencies and limitations of the used method and explained the existence of better and more accurate technological tools for the study of microorganisms. In this class, it was possible to find the following indicators of scientific literacy: hypothesis testing and assessment, prediction, explanation, logical and proportional reasoning, and information organization.

The evaluation

At the end of the DS, we applied an evaluation with three questions approaching the main themes. The first question was about the contamination and prevention of diseases, the second was about the vaccine and the third was about fermentation. Knowing that didactic innovations must be associated with innovative evaluation proposes, we use scientific literacy indicators to analyse this written evaluation to see if the applied evaluation were consistent with the investigative work done during the DS. The indicators are divided into three categories: 1) working with the data obtained through the serialization, organization, and classification of information, 2) structuring of thought through logical and proportional reasoning, and 3) understanding the analysed situation and searching for connections in a given context through the survey of hypotheses, hypothesis testing, justification, prediction and explanation (Sasseron & Carvalho, 2008). The written evaluations were digitalized and the responses of each student were analysed according to the scientific literacy indicator, separating the answers in categories.

RESULTS

The Investigative Didactic Sequence

By providing a context and a problem for the activities in the DS, it was possible to observe that most of the Scientific Literacy Indicators proposed by Sasseron (2008) appear in the classes. Table 1 resumes the scientific competencies observed in given classes.

Table 1. Scientific Literacy indicators in each class of the DS about Public Health, Diseases and Biotechnology. S: seriation of information; O: organization of information; C: classification of information; LR: logical reasoning; PR: proportional reasoning; HS: hypothesis survey; HT: hypothesis test; J: justification; P: prediction; E: explanation.

Topic	Indicators									
	Working with data			Structuring and organization of thought		Understanding the analysed situation				
	S	O	C	LR	PR	HS	HT	J	P	E
Viruses										
Worms										
Epidemic										
Microbiology										

The evaluation

We analysed 45 written evaluations seeking for the scientific literacy indicators. Table 2 systematizes the results found in this research, showing how many indicators were found in each question. The evaluation had three main questions and each question was divided in smaller questions, so in the table, we can see in the columns that the question 1 has, inside, questions A and B. The same happens in the questions 2 (A, B, C, D, and E) and 3 (B, C, and D).

Table 2. Scientific literacy indicators (lines) in each question (column) of the written evaluation.

	1A	1B	2A	2B	2C	2D	2E	3A	3B	3C	3D
Seriation of information	38	39	31	7	30	32	32	38	37	36	38
Organization of information	34	39	29	9	30	32	27	14	12	29	3
Classification of information	4	23	2	0	0	0	0	0	0	1	0
Logical reasoning	8	1	0	0	0	0	0	0	0	6	0
Proportional reasoning	0	2	0	0	0	0	0	0	0	1	0
Hypothesis survey	13	2	0	0	0	0	0	0	0	1	0
Hypothesis test	1	0	0	0	0	0	0	0	0	0	0
Justification	8	2	2	4	3	0	0	0	2	4	0
Prediction	10	9	0	0	4	0	0	2	4	23	0
Explanation	33	13	10	35	28	4	0	7	10	30	4

From the result presented in Table 1, it can be observed that the indicators "seriation of information" and "organization of information" (Sasseron & Carvalho, 2008) are present in all classes. On most of the evaluation questions, we can also see those indicators (Table 2). We can also see that questions 1A, 1B and 3C cover almost all SL indicators. However, eight of the eleven questions present a low variety of indicators in the analysed answers, being limited mostly by the serialization and organization of information. Figures 1 and 2 illustrate the difference between questions 1A and 2D, comparing the scientific literacy indicators found.

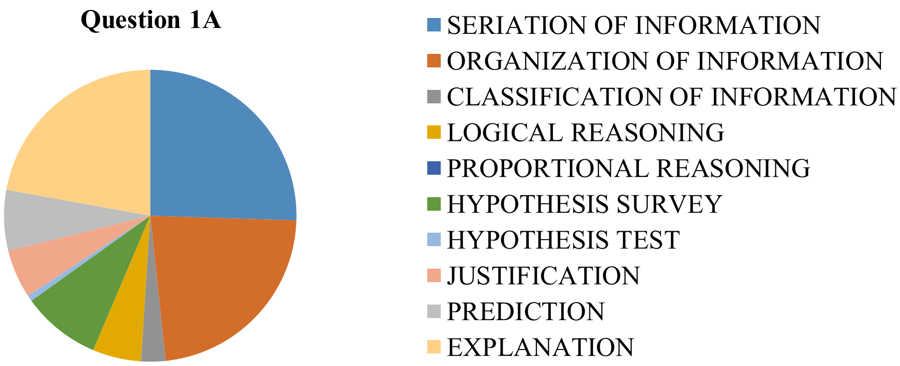

Figure 5. Indicators present in student's answers to question 1A.

Question 2D

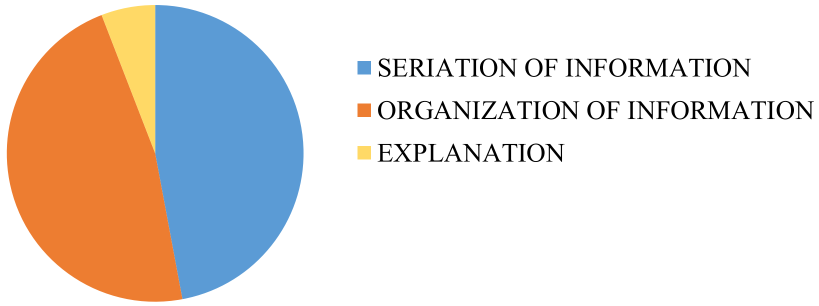

Figure 6. Indicators present in student's answers to the question 2D.

DISCUSSION AND CONCLUSION

The analysis of the written evaluations evidences a link between the type of question formulated by the teacher and the indicators of SL developed by the students in each question. Indeed, the type of question asked by the teacher in the written evaluation can influence the appearance or not of the SL indicators and, therefore, the questions is an important instrument that can unleash fundamental skills for SL. According to Machado & Sasseron (2012), the questions formulated by the teacher in classes should contain clear intentions and retake the purposes established in class planning. However, it was not possible to observe this in the applied evaluation. The questions were contextualized, but eight of the eleven questions did not present an investigative character, having a more traditional and memorization examination character. Those eight questions began with "what" or "which" and even though a few indicators appeared (serialization and organization of information), the majority of data used by students raised from the question itself and were content review and memorization of information. Only three questions had a bigger range of SL indicators. Those questions initiate with "how" and "why" and allowed students to structure data by having logical and proportional reasoning, as well as to explore the context of the proposed situation by formulating and testing hypotheses, justifying, predicting and explaining. Thus, we can see that in the applied written evaluation the questions did not stimulate students to reason and expose their point of view. Also, it does not bring the investigative character worked among the entire DS about Public Health, Diseases and Biotechnology and does not explore the problem in which the questions were inserted.

In fact, the evaluation can increase the quality of the learning (Luckesi, 2011), however, the present work brought examples of an inconsistent evaluation applied at the end of an DS potentially democratic. Over the DS the teachers possibly could improve cognitive and metacognitive resources in the students, but it couldn't be contemplated in the evaluation for its traditional character. Because of all the years spent in a traditional school with traditional curriculum, assessment and evaluations make the exit from this traditionalism very difficult to happen, since it is deep-seated in the students from the beginning of their school life (Nascimento, 2018). As a result, despite attempts to diversify didactic strategies, the evaluation followed the same traditional characteristic that teachers so much wanted to avoid.

From this work, we can see evidence of an alienating and uncritical educational system so efficient that even when teachers try to accomplish different actions they can fail. As a result, it is imperative that newly graduated teachers, and even older teachers, know theories of teaching-learning and evaluation within a democratic, dialogic and formative perspective. Also, it is substantial to emphasize the importance of the teacher as a researcher within the classroom, sensitive to feedback from students to always improve their pedagogical practice (Black & Wiliam, 1998). Indeed, the evaluation cannot be by memorization and aim to classifying students. On the contrary, the teacher as a reflective practitioner (Schön, 1987) always has to ask himself about the purpose of their evaluation: is it improving student's learning? Is it helping to overcome student's difficulties?

Thus, using the indicators of Scientific Literacy to analyse the final written evaluation, it is concluded that the questions do not stimulate the students to reason and to expose their point of view, not promoting the Scientific Literacy itself. Besides, this evaluation does not expose the investigative character worked during the entire Didactic Sequence on Public Health, Diseases and Biotechnology and does not explore the problem in which the questions are inserted. In fact, the evaluation is an important tool to achieve the knowledge constructed by the students in the DS. Therefore, a set of instructional practices that aim to subsidize the construction of successful learning is needed, using the evaluation in service of student learning and growth, like the formative evaluation. So teachers must invest more in the elaboration of questions and evaluation if they want to detect the skills and competencies internalized by students in the DS.

The SL indicators provided us a good tool to analyse the quality of written evaluations and the teacher's work. In conclusion, we see that the investment of teachers in the elaboration of questions that leads the students to think is very important. As a result, students can develop the skills necessary to promote Scientific Literacy.

ACKNOWLEDGEMENT

We thank CAPES for financing the project. This study would not be possible without the other fellows from the Pibid who assisted in the elaboration and application of DS on Public Health, Diseases and Biotechnology. We also thank the supervisor Gabriela Zanarotti for the confidence inside and outside the classroom and the coordinator of the project Marcelo Motokane for assistance and support.

REFERENCES

Black, P. & Wiliam, D. (1998). Assessment and classroom learning. *Assessment in Education: principles, policy & practice*, *5*(1), 7–74.

Bybee, R. W. (2012). Scientific literacy in environmental and health education. In: A. Zeyer & R. Kyburz-Graber (Eds.), *Science | Environment | Health. Towards a renewed pedagogy for science education*. Dordrecht: Springer.

Carvalho, A. M. P. de (2013). O ensino de ciências e a proposição de sequências de ensino investigativas. In *Ensino de Ciências por Investigação: condições para implementação na sala de aula*. São Paulo: Cengage Learning.

Glanz, K., Rimer, B. K. & Viswanath, K. (Eds.). (2008). *Health behaviour and health education: theory, research, and practice*. John Wiley & Sons.

Griffiths, W. (1972). Health Education Definitions, Problems, and Philosophies. *Health Education Monographs*, *1*(31), 7–11. DOI: https://doi.org/10.1177/109019817200103103

Hurd, P. D. (1998). Scientific Literacy: New Minds for a Changing World. *Science Education*, *82*(3), 407–416.

Luckesi, C. C. (2011). *Avaliação da aprendizagem escolar*.

Machado, V. F. & Sasseron, L. H. (2012). As perguntas em aulas investigativas de Ciências: a construção teórica de categorias. *Revista Brasileira de Pesquisa em Educação em Ciências*, *12*(2), 29–44.

Motokane, M. T. (2015). Sequências Didáticas Investigativas E Argumentação No Ensino De Ecologia. *Revista Ensaio*, *17*, 115–137.

Nascimento, L. A. D. (2018). *Avaliação Formativa: análise da orientação específica de codificação de bolsistas do pibid*. Universidade de São Paulo.

Sasseron, L. H. & Carvalho, A. M. P. (2008). Almejando a alfabetização científica no ensino fundamental: a proposição e a procura de indicadores do processo. *Investigações Em Ensino de Ciências*, *13*(3), 333–352.

Schön, D. A. (1987). *Educating the reflective practitioner: Toward a new design for teaching and learning in the professions*.

EVALUATING DIVERGENT THINKING AMONG PARTICIPANTS OF A GERMAN SCIENCE COMPETITION

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Creativity plays an important role in society, for it is needed for societal development. Discovering students' creative potential enables them to develop new technologies and ideas in the future. Sciences, especially chemistry, are pointing the way in many areas. Identifying a problem and finding its solution is part of the creative process and also closely related to divergent thinking. However, this has been poorly explored so far. In a study presented here, the divergent thinking abilities of students taking part in a German Student Science Competition called "Jugend forscht" have been tested using a validated test. First results regarding different performance depending on gender, parental academic background and previous participation in a competition among the participants in divergent thinking and problem discovery will be presented here.

Keywords: informal learning, problem solving, cognitive development

Introduction

Creativity plays an important role in many areas these days. This meaning not only comes into play in the creative subjects such as music and art, but also in science and technology; areas that advance a society in an increasingly complex world and are more important to our society today than ever before (Runco, 2004). Creativity refers to the ability to develop new ideas and solutions. Expressing them in a unique way (Abraham, 2016). Creative skills such as problem awareness and problem solving are needed to find solutions to political, economic, and social challenges, as well as to remain flexible in the development of new technologies.

The natural sciences and chemistry are pointing the way in many fields. However, creativity is rarely used or fostered in science education. Classical chemistry lessons, in which teachers set strict framework conditions for all phases of teaching and thus in particular for the path of knowledge, inhibit creative and innovative processes (Gärtner & Scharf, 2001). Kind and Kind (2007) assumed that elements of frontal teaching like "recipe" work is a teaching method that usually does not promote creativity, whereas it is still the method that is preferred by most teachers (Semmler & Pietzner, 2017). In doing so, the students are often already given a stringent solution by the teacher, which has to be worked on during the experimentation phase. The result is that for experiments, an important pillar of chemistry lessons, are carried out in a recipe-like way. This does not give young people the freedom to follow creatively their own ideas in the classroom (Starko, 2010). Free work phases, in which the students themselves can develop problems can also rarely be found in chemistry classes. Which means that an important aspect of problem solving cannot be addressed at all. Student-oriented school lessons, where students work independently on open-ended tasks, promote creative skills by giving the students the opportunity to develop, test and revise their own ideas therefore enhancing science learning (Kind & Kind, 2007; Semmler & Pietzner, 2017).

Unlike the formal school as a place of learning, non-formal learning environments such as Science Competitions make it possible for students to work on their projects in their afternoon hours with support, but still independently. The solution to the problem students' work on is not predetermined and can be designed by the participants themselves. Often there is not just one solution, but several. It has to be thought of in breadth, divergent. This divergent thinking is an important aspect of creativity that involves special significance and creative application in the natural sciences and leads to an improved life quality and scientific innovation (Achieng'Rabari et al., 2011). Finding a problem and its possible solutions is closely related with divergent thinking, which is a cognitive ability of a creative person (Runco & Okuda, 1988; Guilford, 1967). Problem solving skills as well as creative thinking skills are emphasised by after school programs (Wirt, 2011). Mund (2007) investigated the differences between participants in two different federal competitions; in science and music, and a comparison group of High School students regarding graphic creativity using a figural test. Here, the students taking part in *Jugend forscht* showed higher abilities. However, divergent thinking has not been evaluated. The aim of the study presented here is to close this gap and to investigate the divergent thinking abilities of students taking part in a German Student Science Competition called *Jugend forscht.* They were tested using a validated test. Initial results show gender differences among the participants in their aptitude for divergent thinking and problem discovery.

THEORETICAL BACKGROUND

Creativity is omnipresent, but in the search for a uniformly understood concept one searches in vain. Instead, one finds many different definitions and theoretical explanatory approaches (Urban, 2004). Since the beginning of modern creativity research which was initiated in the 1950s by psychologist J.P. Guilford. At the beginning of the 1970s, this trend spilled over to Europe. As a result, not only Guilford but also creativity researchers like Torrance, Wallach and Kogan or Urban tried to make creativity measurable (Urban, 2004). He defined creativity as an "*ability to create a new, unusual, and surprising product as the solution to a sensitively perceived or given problem whose implications are sensitively perceived*." (Urban, 2004, p.34). In so doing, Urban's Definition of Creativity not only encompasses the creative thinking process, but about the entire interaction process. He describes this interaction process in his "4P-E interaction" model. The four P's stand for Problem, Person, Process and Product; the E for environment. According to Urban (2004) divergent thinking and problem discovery are two out of six components of a creative person. In 1959, Guilford first defined divergent and convergent thinking: "*In divergent thinking operations we think in different directions, sometimes searching, sometimes seeking variety*." and "*in convergent thinking the information leads to one right answer or to a recognized best or conventional answer*." (Guilford, 1959, both p.470). Divergent thinking is one of the most important skills for creative thinking (Guilford & Hoepfner, 1976).

Runco and Okuda conclude that consequently "divergent thinking tests can be used to investigate problem finding, and they support the theory of problem discovery" (Runco & Okuda, 1988, p.219). Only if tasks were given, where the problem has to be discovered independently does "*the problem itself becomes a goal, necessitate problem finding*" (Starko, 2018, p.38). For Wakefield (1985), the pre-requisite for creative performance is the freedom to discover and solve problems. According to Urban (2004), divergent thinking is essential for the creative process and a prerequisite for fluent, flexible thinking, as well as a broad knowledge base and the ability to focus on the task. Urban (1995) further describes that divergent thinking does not lead to creative excellence alone but requires a special field mastery.

For decades, attempts have been made throughout Europe to increase the interest of students in natural sciences (Janštová et al., 2015). As a result, non-formal learning has emerged in education (Council of Europe, 2003). "*Science centres and non-formal student laboratories have emerged to provide additional value to school science education.*" (Affeldt et al., 2017, p.13). In these previously described non-formal learning settings, students have the opportunity to instigate and prepare their own projects for science competitions.

In Germany, in 1965 the most famous and still expanding Science Competition *Jugend forscht* was initiated to promote young scientists. It is promoted by the German Federal Government, as well as the German president, chancellor, and many large companies. In 2018, over 110 competitions took place per round on the three competition levels (Stiftung Jugend forscht e.V., 2019).There is a total of seven subject areas - biology, chemistry, geography and spatial sciences, mathematics/computer science, physics, technology and working world in which students can develop and present their project. Participants from age 10 to 14 belong to the junior category *Schüler experimentieren*, and the older ones from the age of 15 to 21 belong to the category *Jugend forscht*. After having successfully worked on their research project, mostly in non-formal learning places, students apply for the regional competition. The winners of this level take part in the federal contest (second level) and this is where the competition for the younger students ends. The winners of the senior federal level move on to take part in the national competition (third level).

When working on an own project, it is common to works not only on a stringent or convergent solution, but rather to think divergently. Whether this assumption holds true and how developed the participants' divergent thinking skills are has been little studied so far. This research gap could be closed with the help of two questions:

1.) How does divergent thinking of students taking part in a German Science Competition differ with respect to their gender, previous participation and academic background of the parents?
2.) How does divergent thinking and problem discovery differ with respect to the different competition levels (national and federal competition)?

Method

For collecting data, the divergent thinking questionnaire of Wallach and Kogan (1965) as well as the problem finding questionnaire of Wakefield (1985) were used, according to Runco and Okuda (1988). The divergent thinking questionnaire contains three standards, so called "presented-problem" items: *instances*, *alternate uses* and *similarities*. In the following, all the tasks of the present problems from the divergent thinking test are listed.

Instances: "Name all the round things you can think of."; "Name all the things you can think of that will make a noise."; "Name all the things you can think of that move on wheels."

Alternate uses: "Tell me all the different ways you could use a knife."; "Tell me all the different ways you could use a chair."

Similarities: "Tell me all the ways in which a potato and a carrot are alike."; "Tell me all the ways in which a cat and a mouse are alike."; "Tell me all the ways in which a radio and a telephone are alike."

Discovered problems were adapted from Wakefield (1985) for each of these items. The participants then had to define a problem and provide solutions for it, e.g. "Choose two objects that are alike, and then list your ideas of how the objects are similar."

The results were evaluated using the three criteria of fluency (scored number of distinct ideas as described in Runco (1986)), flexibility (the number of categories from which the ideas originated) and originality (Runco & Albert, 1985). All answers were categorised according to Torrance (1966), although for the evaluation of flexibility the Torrance list (1966) needed additional categories to aid analysis. This was validated by several group discussions with four experts.

The questionnaire was incorporated into a free App called Actionbound, which is supported by the German Federal Agency for Civic Education. This App collects data anonymously with a mobile phone with internet access. Depending on the type of task, data can either be entered in writing using the keyboard, or the multiple-choice task can be selected by clicking on it. This digital collection method enables fast data transfer. Due to the different procedure, a pilot study was performed in January and February 2018 at a comprehensive school. 29 students of different age participated in the study during their chemistry lesson (16 female, 12 males, 1 N/A). The results show that also with the different procedure compared to the original literature, valid results can be obtained.

In co-operation with the organisers and for the purposes of data collection a declaration of consent form for the underage participants was sent to the parents in advance. The procedure for the survey was in a leaflet and mentioned that the Actionbound app was required and therefore installed onto the participants' smartphone. During the competition the participants have been contacted directly, and the main author was always available to answer questions during the procedure. Based on Runco & Albert (1985), the participants were not given any time limits in this study, which resulted in some examinees completing the survey within 10 minutes, others after one hour. The latter were particularly ambitious and saving that after a few seconds another new answer came to mind, so they did not want to click on "Continue" in the online questionnaire and thus needed more time.

From the results of each task an average was formed representing the category result and used for evaluation. To assess the originality of an answer, all items named by students were listed according to Runco and Albert (1985). Every item that only occurred once received three points. Items which occurred less than 2,5 % had two points. Items which occurred between

2,51 % and 4,99 % were given one point, and all others received no points. An exception was made for the group from the national competition, where only 23 participants were interviewed. Here the point system was changed due to the low number of participants. Consequently, an item that occurred twice received two points, an item that occurred three times got one point, and all others got no points. Then the number of points for each student was calculated. For evaluating the discovered problems, only the creativity characteristics of the fluency and flexibility were applied. Originality was, according to Runco (1985), only evaluated in the presented it is not due to the individual discovered problems. The Whitney-Mann-U-test was used to investigate the differences between the gender, academic background and previous participation and presented and discovered problems were investigated. These were then compared to the presented and discovered problems that had also been investigated. The U-Test examines whether the central tendencies of two independent samples are different and is used if the requirements for an independent sample t-test are not met (Schwarz, 2019). If the sample sizes are less than 30, the exact significance is used, and since the number of participants in the study for the national competition was only 23 it was applied (Schwarz, 2019), providing valid results even for these small samples. All results were presented with an effect strength, which follows the division of Cohen (1992), so that a weak effect is represented by $r = 0.10$, a medium effect by $r = 0.30$ and a strong effect by $r = 0.50$.

Data was collected in the federal and national competitions ($n = 67$); for the federal competitions was collected between January and April 2018 in Hamburg, North Rhine-Westphalia, Lower Saxony and Schleswig-Holstein, for the national competition in Darmstadt on May 23, 2018.

DESCRIPTION OF THE SAMPLE

The participants in the study were students aged 15 - 21 years competing in the Science Competition *Jugend forscht*. In this survey, 44 students (12 female, 29 male and 3 N/A) took part in the federal competition and 23 students taking part in the national level of *Jugend forscht* (6 female and 17 male) participated, a total of 64 students. From the 42 participants in the federal competition, 26 have parents with an academic background: 16 do not. Of 23 participants in the national competition, 18 had parents with an academic background, whilst five sets of parents.

Results

Regarding the academic background and a possible previous participation in *Jugend forscht*, no differences have been found in the sample. Participants of the national competition show a higher performance in all criteria of both tests than participants of federal competition (see Table 1).

Whether the divergent thinking of girls in federal and national competition differ, should be examined hereinafter. Girls in the national competition outperform better in all criteria of both tests compared to girls of the federal with a strong effect (see Table 2). Also, differences between boys in federal and national competition are visible. Boys in national competition outperform better in originality (Mean Federal = 4.30, Mean National = 10.46, U = 76.000, Z = -3.881, p = 0.00, r = 0.572) and fluency (Mean Federal = 5.77, Mean National = 7.00, U = 142.500, Z = 2.368, 0.018, r = 0.439) of divergent thinking test compared to boys in federal competition. No differences are visible in problem discovery test.

Table 1: Differences between the participants of federal and national level.

Test	Criterion	Mean Federal Competition	Mean National Competition	Z	p	r
Divergent thinking (DT)	Originality	4.25	12.41	-4.986	< 0.0009	0.515
	Fluency	5.61	8.14	-2.991	0.003	0.365
	Flexibility	3.71	5.47	-3.606	< 0.0009	0.440
Problem discovery (PD)	Fluency	3.61	6.01	-2.148	0.032	0.262
	Flexibility	2.53	4.17	-2.620	0.009	0.320

Table 2: Differences among girls between federal and national competition

Test	Criterion	Mean Federal Competition	Mean National Competition	Z	p	r
DT	Originality	3.55	17.92	-3.278	< 0.0009	0.773
	Fluency	5.20	11.40	-3.092	0.001	0.729
	Flexibility	3.52	6.86	-3.097	0.001	0.730
PD	Fluency	3.08	7.50	-2.675	0.005	0.631
	Flexibility	2.22	4.89	-2.817	0.003	0.664

Regarding gender differences in on the federal and national level of *Jugend forscht,* girls in national competition show a higher performance in all criteria of divergent thinking test than boys with a strong effect (see Table 3). The results of the problem discovery test did not identify any significant gender differences in fluency and flexibility.

Table 3: Gender differences in national competition

Test	Criterion	Mean Value Girls	Mean Value Boys	Z	p	r
DT	Originality	17.92	10.46	-2.521	0.010	0.526
	Fluency	11.40	7.00	-2.591	0.008	0.540
	Flexibility	6.86	4.98	-2.031	0.044	0.424

In the federal competition, no significant differences between boys and girls in divergent thinking and problem discovery test could be measured.

Discussion and conclusion

This study has shown that a general difference between the competition levels regarding divergent thinking/problem discovery does exist. The participants showed a higher originality, fluency and flexibility in national competition compared to the results of the federal competition. The data contains some gender-dependent results; since no gender difference was found by Runco and Okuda (1988) among older participants (age 15 years and 11 months to 17 years and 7 months) and Wakefield (1985) among younger participants (age 10 years and 5 months to 11 years and 6 months), the question arises as to the background of this difference. Comparing the same gender in both levels of *Jugend forscht*, girls have greater divergent thinking in all three criteria compared to boys at national competition. Additionally, they also performed better in the problem discovery test than girls in federal competition. Boys show stronger divergent thinking in the national competition than boys in lower competition level. Unlike the girls, no connection between problem discoveries is measurable. It is noteworthy that girls with a pronounced skill for problem discovery reach the next competition level, while boys get ahead without a pronounced problem discovery sense which leads to further research questions like who chose the students taking part in a science competition and what are their selection criteria, as well as which priority has divergent thinking in this process.

The observed gender may have its origin in school, as often students were asked by their teachers if they would like to take part in *Jugend forscht*. The teachers' attribution of competences and ability of female students in science education and the question of whether girls in the classroom may need to be standing out with special achievements or special problem discovery skills to be supported by a teacher should be investigated. Since the beginning of their school career, science is perceived by girls as a male domain (Kennedy and Parks, 2000). Teachers influence students' interest the scientific interest of Chemistry and Physics Olympiad participants. Parents, regardless their profession, often have a positive impact on girls' interest in biology and often initiate it (Janštová et al., 2016). This may explain why most girls participated in biology in the national competition level of *Jugend forscht*, followed by chemistry and physics. It is an open question as to why teachers do not seem to have a more positive influence regarding the image of the other science subjects.

Further examination of whether teachers attribute the personal characteristics of a creative person to male stereotypes. According to Kämmerer (2000), characteristics of a creative person such as independence and belief in one's own abilities/positive self-assessment are ascribed to boys. A Portuguese study of national science competitions (NSC) showed that teachers pre-selected their best students to participate as they see a connection between performance in school and the results in the competitions (Descalço & Olivereira, 2018). However, good grades and a good relationship to the teacher is no guarantee of effective divergent thinking ability. These qualities of creative boys are at odds with the educational styles and socialisation of girls. In the process, girls are taught to be a good girl, otherwise they are "*considered bossy and worse*" (Wirt, 2011, p.59). It could be that girls are perceived by teachers more as "*troublemakers*" than as "*creative persons*". As Westby and Dawson (1995) found, the character traits of creative students' determination, independence and individualism are not consistent with the teacher's goals in traditional classroom.

A thesis that still needs to be reviewed posits is creative girls find their ways to *Jugend forscht* via out-of-school learning venues such as student laboratories. Here they can work freely on science projects in the afternoons without pre-conceived gender traits being at the forefront, as at school. These extra-curricular activities are encouraged and supported by the families. Whether families, especially those with an academic background, have more creative children was examined in this study. No connection between the *Jugend forscht* participants at either federal or national competition and the academic background of their parents could be measured.

Unexpectedly, and unlike originally thought, divergent thinking and problem discovery skills did not change during the problem-solving process of their projects changing; no difference could be measured between the participants who had previously taken part in the competition and those who took part the first time.

If the participants are influenced too much by a mentor with a knowledge advantage, the path to the product is convergent and the participation motivation is "extrinsic-reward", which is linked with extrinsic motivation. Rewards leads to obligation motivation that only compulsory tasks are solved, but that the person does not completely settle in a task and have an inner interest in solving the problem (Cooper & Jayatilaka, 2006). As a result, the actual spirit of research is satisfied, but the work and intrinsic motivation can be low. Extrinsic "motivation reduces individuals' freedom in that their behaviours tend to be confined to actions instrumental in gaining the rewards" and "typically reduces individual's creativity" (Cooper & Jayatilaka, 2006). Even though intrinsic motivation is a key factor for creativity, which is a "recognizable level of creativity to be produced" and is associated with best academic outcomes (Amabile, 1983, p. 367; Orvis et al., 2018). "As a result, individuals may be distracted from creativity-relevant aspects of the task and/or may exhibit functional fixedness or other forms of cognitive rigidity, with their efforts narrowly focused on the task as originally defined and on common algorithms that have worked well in the past" according to Cooper and Jayatilaka (2006, p. 153). Therefore, further studies should examine more closely the motivation of the participants taking part in a competition and where students are preparing. Additionally, other important questions would be what the supervisors influence on the students' work is, do the participants have the opportunity to playfully open and investigate the problem, or does the teacher/supervisor present a topic for the students work out.

In principle, it should be examined if participants had divergent thinking skills before their attendance at a *Jugend forscht e.V.* competition and to what extent the competition initiates divergent thinking. The latter question will be answered in a second study which examines non-formal learning places and out-of-school activities, where students are allowed to work freely on projects and partly prepare for *Jugend forscht*.

ACKNOWLEDGEMENT

We would like to thank Jugend forscht e.V. for the opportunity to carry out the study on their competitions.

REFERENCES

Abraham, A. (2016). Gender and creativity: An overview of psychological and neuroscientific literature. *Brain Imaging and Behavior*, *10*(2), 609-618. doi: 10.1007/s11682-015-9410-8.

Achieng'Rabari, J., Indoshi, F. C. & Omusonga, T. O. (2011). Differences in Divergent Thinking among Secondary School Physics Students. *Journal of Emerging Trends in Educational Research and Policy Studies*, *2*(4), 216–227.

Affeldt, F., Tolppanen, S., Aksela, M & Eilks, I. (2017). The potential of the non-formal educational sector for supporting chemistry learning and sustainability education for all students – a joint perspective from two cases in Finland and Germany. *Chem. Educ. Res. Pract.*, *18*, 13–25. DOI: 10.1039/c6rp00212a.

Amabile, T. M. (1983). Social psychology of creativity: A componential conceptualization. *Journal of Personality and Social Psychology*, *45*(*2*), 357–377.

Cohen, J. (1992). A power primer. *Psychological Bulletin, 122*(1), 155–159.

Cooper, R. B. & Jayatilaka, B. (2006). Group creativity: The Effects of Extrinsic, Intrinsic and Obligation Motivations. *Creativity Research Journal*, *18*(6), 153–172.

Council of Europe (2003). *Non-formal education*. Retrieved from: https://rm.coe.int/2012-compendium-non-formal-education/168077c10b.

Descalço, L. & Oliveira, P. (2018). *Science Competitions: Do they foster learning?* Conference Paper. doi: 10.21125/edulearn.2018.0440

Gärtner, H-J. & Scharf, V. (2001). *Chemische "Egg Races" in Theorie und Praxis*. [Chemical "Egg Races" in theory and practice]. Retrieved from http://www.chemie-biologie.uni-siegen.de/chemiedidaktik/dokumente/service/fundgrube/chemrace.pdf

Guilford, J. P. (1959). Three faces of intellect. *American Psychologist*, *14*(8), 469–479.

Guilford, J. P. (1967). *The nature of human intelligence*. New York, NY, US: McGraw-Hill.

Guilford, J. P. & Hoepfner, R. (1976). *Analyse der Intelligenz* [Analysis of intelligence]. Weinheim und Basel: Beltz Verlag.

Janštová, V., Jáč, M. & Dvořáková, R. (2016). Identifying the factors that motivate pupils toward science competitions. In J. Lavonen, K. Juuti, J. Lampiselkä, A. Uitto & K. Hahl (Ed.), *Electronic Proceedings of the ESERA 2015 Conference. Science education research: Engaging learners for a sustainable future, Part 2* (pp. 332–338). Helsinki, Finland: University of Helsinki.

Kämmerer, A. (2000). Kreativität und Geschlecht [Creativity and Gender]. In: R.M. Holm-Hadulla (Eds.), *Heidelberger Jahrbücher: Vol. 44. Kreativität* (pp. 301–328). Heidelberg: Springer Verlag.

Kennedy, H. L. & Parks, J. (2000). Society cannot continue to exclude women from the fields of science and mathematics. *Education*, *120*(3), 529.

Kind, V. & Kind, P. M. (2007). Creativity in science education: Perspectives and Challenges for Developing School Science. *Studies in Science Education*, *43*, 1–37. DOI: 10.1080/03057260708560225.

Mund, W. (2007). *Jugend forscht und Jugend musiziert: Kognitive Fähigkeiten und Persönlichkeitsmerkmale erfolgreicher Teilnehmer*. ["Jugend forscht" and "Jugend musiziert": cognitive abilities and personality traits of successful participants] (Doctoral dissertation). Retrieved from: http://archiv.ub.uni-marburg.de/diss/z2008/0750/pdf/dwm.pdf

Orvis, J., Landge, S. & Sturges, S. (2018). A culture of Extrinsically Motivated Students: Chemistry. *Journal of the Scholarship of Teaching and Learning*, *18*(1), 43–57. DOI: 10.14434/josotl.v18i1.21427.

Runco, M. A. (1986). Divergent thinking and creative performance in gifted and nongifted children. *Educational Psychological Measurement*, *46*(2), 375–384. DOI: 10.1177/001316448604600211.

Runco, M. A. (2004). Creativity. *Annual Review of Psychology*, *55*(1), 657–687. DOI: 0.1146/annurev.psych.55.090902.141502.

Runco, M. A. & Albert, R. (1985). The reliability and validity of ideational originality in the divergent thinking of academically gifted and nongifted children. *Educational and Psychological Measurement*, *45*, 483–501. DOI: 10.1177/001316448504500306.

Runco, M. A. & Okuda, S. M. (1988). Problem Discovery, Divergent Thinking, and the Creative Process. *Journal of Youth and Adolescence*, *17*(3), 211–220. DOI: 10.1007/BF01538162

Schwarz, J. (2019) *Mann-Whitney-U-Test*. Methodenberatung Universität Zürich. Retrieved from: https://www.methodenberatung.uzh.ch/de/datenanalyse_spss/unterschiede/zentral/mann.html (25.11.2019)

Semmler, L. & Pietzner, V. (2017). Creativity in chemistry class and in general – German student teachers' view. *Chemistry Education and Research and Practice*, *18*(2), 310–328. DOI: 10.1039/c6rp00230g

Starko, A. J. (2010). *Creativity in the Classroom. Schools of Curious Delight. Fourth Edition*. New York: Routledge, Taylor & Francis.

Starko, A. J. (2018). *Creativity in the Classroom. Schools of Curious Delight. Sixth Edition*. New York: Routledge, Taylor & Francis.

Stiftung Jugend forscht e.V. (2019) *Historie* [History]. Retrieved from https://www.jugend-forscht.de/stiftung-jugend-forscht-e-v/historie.html.

Torrance, E. P. (1966). *Torrance tests of creative thinking: norms-technical manual: verbal tests, forms A and B: figural tests, forms A and B. Torrance tests of creative thinking*. Princeton, New Jersey: Personal Press.

Urban, K. K. (1995). Different Models in Describing, Exploring, Explaining and Nurturing Creativity in Society, *European Journal of High Ability*, *6*(2), 143–159. DOI: 10.1080/0937445940060243

Urban, K. K. (2004). *Kreativität. Herausforderung für Schule, Wissenschaft und Gesellschaft*. [Creativity. Challenge for school, science and society]. Münster: LIT-Verlag.

Wakefield, J. F. (1985). Towards creativity: Problem finding in a divergent-thinking exercise. *Child Study Journal, 15*(4), 265–270.

Wallach, M. A. & Kogan, N. (1965). *Modes of Thinking in Young Children*. New York: Holt, Rinehart, & Winston.

Westby, E. L. & Dawson, V. L. (1995). Creativity: Asset or Burden in the Classroom? *Creativity Research Journal*, *8*(1), 1–10. DOI: 10.1207/s15326934crj0801_1.

Wirt, J. L. (2011). *An Analysis of Science Olympiad Participants' Perceptions Regarding Their Experience with the Science and Engineering Academic Competition* (Doctoral dissertation). Retrieved from https://scholarship.shu.edu/dissertations/26/

AN EMPIRICAL STUDY ON LEARNING PROCESSES AND ACTIONS OF STUDENTS WHILE INTERACTING WITH EXHIBITS AT A SCIENCE CENTRE

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Studies about informal learning environments like science centre show that pupils' interests in scientific topics can be aroused. However, current research only provides few indications on how pupils can develop subject-specific knowledge and competencies through self-directed interactions with exhibits. The aim of the presented study is to clarify how characteristics of the exhibits and the explanatory media lead to an understanding of the represented phenomena or hinder it. It is also of importance to take into consideration that although the learning processes are individual, the teachers as well as the staff of the science centre can affect these processes. Therefore, in cooperation with a Science Centre firstly the intentions of the centres' pedagogical leaders are empirically investigated. Secondly, certain exhibits are subjected to a subject-specific educational potential analysis. And thirdly, accompanying interviews and questionnaires are used to investigate pupils' processes of decoding and to interpret to what extent the exhibits induce subject-specific learning. Also, the perspective of teachers on pupil learning is examined. The preliminary results of the study will be presented.

Keywords: Informal learning, Non-formal Learning Environments, Primary School

INTRODUCTION

Studies about informal learning environments like science centres show that pupils' interests in scientific topics can be aroused at these environments (Scharfenberg & Bogner, 2014). However current research provides few indications on how pupils can develop subject-specific knowledge and competencies through self-directed interactions with exhibits. For example, previous studies have shown that common learning processes that are possible to occur during the interaction with exhibits are: a) remembering previous knowledge built on personal experience, b) establishing and recognising correlations between exhibits, c) asking questions and explaining (for example the function of the exhibit) (Hein, 1998; Falk & Dierking, 2000; Kelly, 2007). There were also proposals to operationalize the link between exhibition features and visitor activities. The four stages of Achiams praxeology (2013) that show the level of an users interaction with an exhibit are the following: (1) Task: The user is able to perceive the task provided by the exhibit. (2) Technique: The user can carry out or use a procedure in a given situation to solve the task. (3) Technology: The user can justify his action. He can also explain what and why is happening while interacting with the exhibit. (4) Theory: The user is able to justify himself with abstract concepts. However, to what extent the learning goals are achieved, in what way they differ from those at school, and how they can be described as inquiry-based learning remains to be further investigated.

Therefore, this presented study is aiming to investigate pupils' learning processes during their interactions with exhibits and to clarify how characteristics of the exhibits and the explanatory media lead to an understanding of the represented phenomena or hinder it. In order to get a deeper insights into the pupils' learning we took into consideration not only the pupils interactions with the exhibits but also what role teachers as well as the intentions the science centres' pedagogical leaders play in the learning process of the individuals during the visit at the science centre. It is of importance to take them into consideration, because although learning is individual for each pupil, the teachers as well as the staff of the science centre affect the learning process of the pupils (Griffin, 2012; Falk & Dierking, 2000).

Research questions

The study addresses the following questions:

(1) To what extend does learning of scientific content and what actions occur while interacting with the exhibits at a science centre visit?

(2) To what extent do the intentions of the science centres' leaders fit to the learning processes of the pupils?

(3) What are the teachers' views of their pupils' learning outcomes and the effective features of the exhibits?

RESEARCH DESIGN AND METHOD

The study is based on the Model of Educational Reconstruction (MER) (Duit, Gropengießer, Kattmann, Komorek & Parchmann, 2012). The aim of the model is to take equally into consideration science subject matter issues and learning needs and capabilities to improve the quality of teaching and learning. However, MER considers the general goals of science education to be 'given' by the curriculum. The situation in a out of school environment such a science center differs as the informal learning environment has no constraints imposed by a curriculum. MER must be, also, specified with an interpretation of visitors' interactions with the exhibits and the aim of the visit (Laherto,2013).

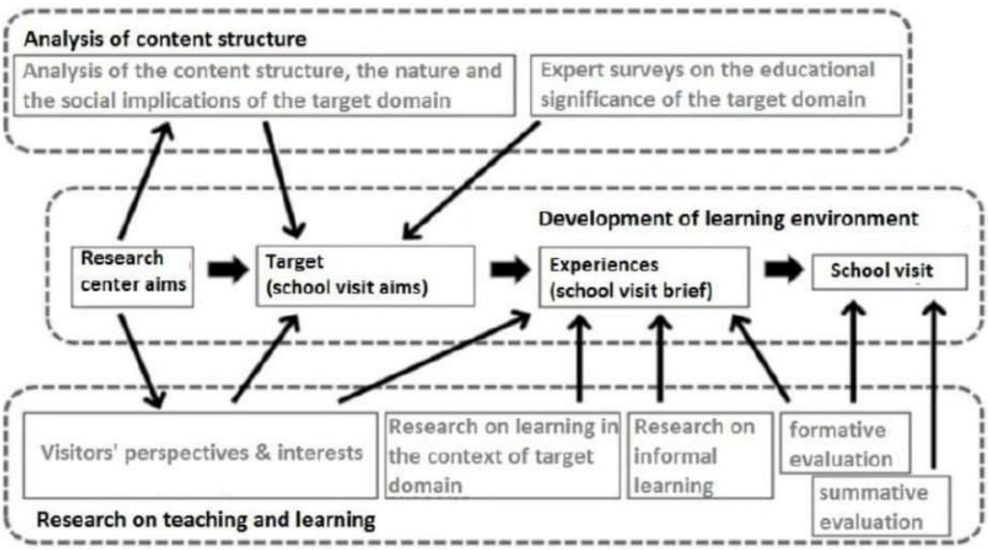

Figure 1: The suggested procedure for developing visits to non-formal learning environments based on MER (Laherto,2013)

Therefore, we apply the model to the situation where learning takes place by interacting with exhibits in a science centre: The exhibits have a scientific and an educational structure that need to be analysed. The results of these analyses have to be systematically related to the empirical results on the learning processes and the influences of the teachers and supervisors.

Research Context and Design

The empirical study is taking place in a science centre where 80 hands-on exhibits are provided to the public. Based on our educational analysis, we came to the conclusion that those exhibits provide different levels of interaction to the visitor. For example, some of them give the opportunity to change multiple variables to affect the phenomenon, while others only display the phenomenon at the push of a button. The exhibits are educationally analyzed to determine which actions and which learning processes are possible while interacting with them based on the "Praxeology" of Achiam, which scientific content of the exhibits could be conveyed to the pupils by interaction with them and what interaction they offer. We selected four exhibits (camera obscura, visible light, Bernoulli Effect, pulley system) with different offer of interaction to find out about the pupils' learning paths while interacting with them.

The views of the centres' pedagogical leaders were recorded during a structured guideline interviews in order to find out their views on what the four exhibits are aiming for and what kind of pupils' learning processes they expected. Examples: "What is the main goal of this particular exhibit?", "To what extend do you think that pupils will reach that goal?" Following, pupil visits at the science were attended and a random sample of pupils was participatory observed and interviewed in groups of two during their interactions with the hands-on exhibits, in order to investigate their actions and their learning paths. The aim is to interpret to what extent the exhibits induces subject-specific learning. Furthermore, questionnaires with open ended and multiple choice questions were administered before and after the school visit to pupils in order to find out which pupils' ideas emerge on the phenomenon of the selected exhibits and which the pupils' expectations of the visit to the science centre are. There were also teacher questionnaires with open and multiple-choice questions before and after the visit, based on categories by Cox-Peterson, Marsh, Kisiel & Melber (2003) and Griffin & Symington (1997). They are about the teachers' views on the learning outcomes they expect from the pupils' visits, and how the visit to the science centre could be integrated into the school curriculum (preparation, expected learning outcomes to be achieved by the visit, etc.). In this study–a random sample of 10 fourth grade pupils, were participatory observed and audio-recorded in groups of two. Additionally, 34 fourth grade pupils of two schools, 6 teachers and the supervisor of the science centre participated in the study.

RESULTS

In order to determine the actions and learning paths that occur while interacting with the exhibits we evaluated the empirically obtained data using qualitative content analysis (Mayring, 2015), and related the data to each other systematically through data triangulation (Flick, 2004). This is outlined in the following case study of the fourth-grade pupil Stefan. The pupil was interviewed and observed during his interaction with the “Visible Light” exhibit. At this exhibit there is the possibility to fold three colour filters (red, green, blue) and a prism one by one or simultaneously in front of a light source. The written task at the exhibit was: "Look at the spectrum of visible light with the prism, and the filters will only pass through a certain area." Stefan recognises all objects (lamp, button, colour filter, etc.) at the exhibit. He retrieves his prior knowledge of the exhibit and can justify and explain his actions. However, one also recognises his difficulty in distinguishing between the relevant and irrelevant variables of the exhibit. Although he placed the red and blue filters in front of the light source at the same time and could see that the light was largely absorbed by the filters, he remained in his initial opinion of his first questionnaire "the light should turn purple". His explanation for the phenomenon observed on the exhibit was that the filters are "too thick for any light to pass through". Therefore, he also replied at the questionnaire after the visit, that "the light is purple, if it goes first through a red and then through a blue filter". So Stefan stays with his initial opinion, that the phenomenon shown at this exhibit is colour addition instead of the actual phenomenon shown, that is colour subtraction.

This example is also reflected in the questionnaires of the pupils, where only 26% of the pupils answered before and after their interaction with the exhibit that little or no light goes through a blue and red filter (Figure 2).

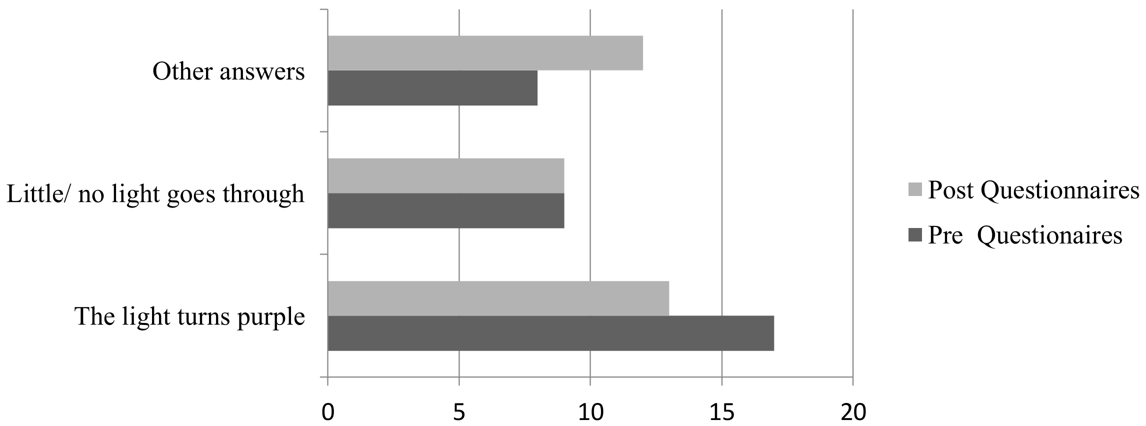

Figure 2: Answers to the question: "Describe what happens with the white light when it first goes through a red and then through a blue filter." (n=34)

The analysis of the pupils’ interviews during their interaction with the visible light exhibit with the Praxeology (Table 1), revealed that all pupils are able to perceive all the objects (filter, light source, etc.) and the task provided by the exhibit (Task). The pupils were also able to carry out the task in the science centres’ leaders intended way (Technique). However, they found some difficulty to explain what and why is happening while interacting with the exhibit and to justify themselves with abstract concepts (Technology, Theory).

For example, although eight out of ten pupils noticed that the white light was almost completely absorbed when it went through the red and blue filter of the exhibit, they remained to their prior idea that the light should turn purple. This happens because two of the pupils can’t give any explanations about the phenomenon they just observed, while six of them base their explanation on the fact that the light won't go through the filters because of the thickness of the exhibits' filters or because of the "larger distance the light has to go to reach both filters". Only one group of two pupils could explain that what happened at exhibit (Technology) but without the use of scientific terms.

Praxeology	□	~	X
(1) Task	5	0	0
(2) Technique	5	0	0
(3) Technology	1	3	1
(4) Theory	0	0	5

Table 1: Number of groups (2 pupils per group) and degree of accomplishment of Praxeology stages in the "visible light" exhibit. (n_{groups} = 5)
□ : fully accomplished ~: deficient accomplished X : unable to accomplish

As one can conclude from this example the intentions of the science centres' leaders do not fit one by one to the learning processes of the pupils. The data also showed that five of six teachers expected that their pupils had learned something new from the visit, although four of six noticed their pupils' difficulty to understand the different phenomena through the interaction with the exhibits, because of the lack of further guidance and explanations. Nevertheless, four of six teachers answered that there would not be any follow-up discussions about the visit in the classroom.

DISCUSSION

Responding to the first research question about the extent to which science content occurs when students interact with exhibits at a science centre, we conclude that interactive exhibits that at the centre appear to be unable to influence most pupils' perceptions without appropriate support. The results of this study show that when pupils visit the science centre, they are able to recognise the tasks and to carry out work procedures (Technique). They can also give explanations (technology) to their actions on the exhibits. These do not always agree with the desired explanations of the exhibition supervisor (Achiam, 2013). In addition, pupils have difficulties in justifying themselves with abstract concepts (Theory). This study also confirmed previous studies that the pupils, the teachers, and the centres leaders' views are not aligned (Griffin, 2012). Therefore, we suggest that further research is needed in order to bridge the gaps between the science centres' leaders intended use and learning processes of the exhibits from the pupils, the teachers views on their pupils learning during a school visit and the actual use and learning processes of the pupils while interacting with the exhibits.

ACKNOWLEDGEMENTS

This research is being carried out at the University of Oldenburg in Germany within the framework of the graduate program GINT (Geography, Informatics, Natural Sciences and Technology in non-formal learning areas) funded by the Land of Lower Saxony in Germany.

This research is also being part of the research project «Bridging the gap between school and out of school learning environments» within the framework of the IKYDA 2018-2020 (an exchange and cooperation program between the University of Crete and the Carl von Ossietzky University of Oldenburg, supported by the State Scholarships Foundation (IKY) and the German Academic Exchange Service (DAAD)).

REFERENCES

Achiam , M. F. (2013) A Content-oriented Model for Science Exhibit Engineering, *International Journal of Science Education*, Part B: Communication and Public Engagement, 3:3, 214-232.

Cox-Peterson, A. M., Marsh, D. D. , Kisiel, J. & Melber L. M. (2003). Investigation of Guided School Tours, Student Learning, and Science Reform Recommendations at a Museum of Natural History. *Journal of Research in Science Teaching,* 40 (2), 200–218.

Falk, J. H., & Dierking, L. D. (2000). *Learning from museums: Visitor experiences and the making of meaning*. Walnut Creek, CA: AltaMira

Flick, U, Kardoff, E, Steinke,I., (2004) A Companion to Qualitative Research,Sage, Publications Ltd

Duit, R., Gropengießer, H., Kattmann, U., Komorek, M., & Parchmann, I. (2012). The model of educational reconstruction. In D. Jorde & J. Dillon (Eds.), The world handbook of science education – Handbook of research in Europe (pp. 13–37). Rotterdam, Taipei: Sense Publishers.

Griffin, J. (2012) *Exploring and Scaffolding Learning Interactions Between Teachers,Students and Museum Educators*. In: Davidsson E., Jakobsson A. (eds) Understanding Interactions at Science Centers and Museums. SensePublishers

Griffin, J., & Symington, D. (1997). Moving from Task- Oriented to Learning- Oriented Strategies on School Excursions to Museums. *Science Education* 81, 763-779.

Hein, G.E. (1998). Learning in the Museum. New York: Routledge.

Kelly, L. (2007). The Interrelationships between adult museum visitors' learning identities and their museum experiences. Sydney: University of Technology

Laherto, A. (2013) Informing the Development of Science Exhibitions Through Educational Research, International Journal of Science Education, Part B: Communication and Public Engagement, 3:2, 121-143.

Mayring, P. (2015). Qualitative Content Analysis: Theoretical Background and Procedures. In *Approaches to Qualitative Research in Mathematics Education* (pp. 365-380). Springer Netherlands

Scharfenberg, F., & Bogner,F (2014), Outreach Science Education: Evidence-Based Studies in a Gene Technology Lab. *Eurasia Journal of Mathematics, Science & Technology Education*, 10(4), 329-341.

PART 12: STRAND 12

Cultural, Social and Gender Issues in Science and Technology Education

Co-editors: *Lucy Avraamidou & Marisa Hernandez*

CONTENTS

STRAND 12: INTRODUCTION

CULTURAL, SOCIAL AND GENDER ISSUES IN SCIENCE AND TECHNOLOGY EDUCATION

Strand 12 examines cultural, social and gender issues in science and technology education. The seven papers included in the proceedings examine unique issues, as follows: a) Students' positioning and career aspirations in STEM professions; b) Students' gendered identities and views about science; c) Teachers' identities, practices and teacher education; and, d) Linguistic diversity in science classroom.

In the first paper with title Career orientation in the field of food chemistry for secondary school students, Alberding and Pietzner report on the findings of a study related to the preparation of German students for their post school life regarding their professional careers. For the purpose of their study, learning tasks for vocational orientation in the context of food chemistry were developed and evaluated. Important parameters for checking the quality of the learning tasks, which were tested in a specially developed student laboratory, are aspects of motivational and interest research, professional self-efficacy expectations and the motivational learning climate.

The second and third paper touch upon issues related to gender in science. Ampatzidis and Armeni examine gender gap in some science related occupations in areas such as physics and technology. In their paper titled "Gender and science: men and women in Greek Gymnasium science textbooks" the researchers examined the ways in gender is portrayed in science textbooks since it is argued that they may contribute to the sex role socialization of students; gender bias in science textbooks may influence the development of a view that science is a subject addressed more to boys than girls. Rodrigues, Roque and Signori report on the findings of a study that aimed to tackle the disparity of gender in science and research fields related to STEM. In order to verify students' conceptions of scientists, they used a pre- and post-evaluation with the use of the Draw-A-Scientist Test (DAST) with 50 middle-school girls who attended an extracurricular science course designed to support them in developing understandings about women in science.

The next three papers explore issues related to teacher identities with the use of different kinds of methodologies in different contexts. Sievert and LaFrance examine the underrepresentation of American Indian people in STEM and STEM education college degree programs and professions in the United States. In their paper titled "Identifying elements of effective programs for preparing American Indian secondary STEM teachers" they present a qualitative study designed to identify essential elements for effectively preparing American Indian secondary STEM teachers as a strategy for improving STEM outcomes for American Indian students. The research data for the study were collected through interviews with a range of education stakeholders.

Romero-Ariza and Quesada present results from a European project promoting context-based and inquiry-based learning approaches in their paper titled "Making use of contexts and inquiry to engage all students in STEM learning". Their study examined how teachers make use of contexts and inquiry to engage all students in their mathematics and science classrooms. Results from multiple case studies provide evidence of teachers from different schools and backgrounds articulating their beliefs, values and experiences to enact their teaching and to adapt to their particular group of students.

Kotwica and Pietzner examined "Chemistry teachers' knowledge about chemistry professions" in Germany. To do that, the researchers investigates how chemistry classes may contribute to career aspirations and career choices, focusing on getting information about chemistry teachers' regarding chemistry professions and how career education is implemented in their teaching and at their respective schools.

Greses Pérez-Jöhnk's work with title "Translanguaging in the science classroom: Learning engineering in multilingual contexts" is situated in California. Through event mapping of participants' video data, the study provides evidence of how students negotiate languages in science and engineering and their perceptions around notions of language boundaries in schools.

Lucy Avraamidou & Marisa Hernández

CAREER ORIENTATION IN THE FIELD OF FOOD CHEMISTRY FOR SECONDARY SCHOOL STUDENTS

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One essential task for school in Germany is the preparation of its students for their post school life regarding their professional careers. Chemistry education on a secondary school level has the goal to empower students to infer scientific phenomena while keeping an eye on learners' achievements and development opportunities. Research on vocational orientation shows that chemical education did not succeed in opening a career orientation for young people, for the time being. This is the starting point of this study. Within this study learning tasks for vocational orientation in the context of food chemistry were developed and evaluated. Important parameters for checking the quality of the learning tasks, which were tested in a specially developed student laboratory, are aspects of motivational and interest research, professional self-efficacy expectations and the motivational learning climate. This article presents a first state and focuses on the motivational learning climate and the professional self-efficacy expectations of the students.

Keywords: Science Education, Self-Efficacy, Vocational Education

INTRODUCTION

The transition from school to working life represents a great challenge for young people, which starts well before graduation. The process of career choice is determined by many factors. Fundamentals of motivational and interest research as well as career research are among the most important areas of observation to clarify questions about career orientation. There are a variety of theories that describe the career orientation of people from various perspectives. A central theory is the RIASEC model of Holland (1997). The background to this basic idea is the clarification of the endogenous and exogenous characteristics of professional development, from orientation to professional implementation. First, according to Holland, six personality types can be mapped: realistic, investigative, artistic, social, enterprising and conventional. In these attributes, the personal abilities and skills can be incorporated. Depending on this, occupational groups that contain similar attributes are considered interesting perspectives. Holland thus describes an interaction between people and the environment that influences the career choice. It is important that a high fit between their personal and the environmental characteristics is achieved. The strongest three attributes are summarized to the so-called Holland code (Eder & Bergmann, 2015). By means of this typological approach, intersections between occupations and personalities can be identified and applied for career orientation. However, in order to broaden this aspect for scientific orientation, the IKON project completed the perspective of the natural sciences on the other attributes (Wentorf, Löffler, Parchmann, 2015). In addition, the extended model can be used to convey ideas about scientific fields of activity and the persons employed in it. It becomes clear that activities of chemistry-related occupations include not only analytical traits but also creative or social aspects. An integration of this characteristic can thus be realized for teaching, for example through learning tasks (Dierks et al., 2014).

In the centre of the process of vocational orientation is the adolescent individuum. The process can also be described as finding its professional identity. Based on the developmental psychology approach of Erikson and Super and the transition theoretic approach according to Bußhoff, Egloff developed the cooperation model (Egloff, 1998). In addition to the theories of the before mentioned authors Egloff considers the core idea that young people can and do find support from different persons to deal with the question of their professional career. These cooperation partners should accompany the transition of young people to vocational training, into working life or into a secondary school and support them in a role-specific manner. They represent the persons who co-develop the identity in the course of adolescence and persons as well as institutions who serve as competent contact persons in vocational training.

Further attention in career orientation is based on the importance of the self-efficacy that can be described as subjective conviction to self-manage a situation and achieve certain goals, which in turn affect the further life-course (Bandura, 1994). The objective of a successful career choice can only be achieved if there is a match between the action-outcome expectation and one’s self-efficacy (Wirth, 2019).

Career education in chemistry lessons

The educational decisions of the political decision-makers at state and federal level emphasize the importance of school-based vocational orientation as a school-related as well as subject-specific task (Kultusministerkonferenz [KMK], 2019). The ROSE study shows that teaching chemistry fails in opening interesting career prospects for learners (Krause et al., 2014). Science education therefore must contribute to career orientation and to show the students corresponding occupational areas (Parchmann et al., 2014). This raises the question for many teachers how to integrate vocational orientation in subject-specific education. According to Parchmann et al. (2014) many teachers combine this demand with excursions or elective lessons. Beyond these temporal limited insights into career orientation, chemistry education is rather based on teaching strictly chemical content. This procedure is based on the perception that career orientation is an additional task that has to be done alongside the curricular given content; as a consequence, this additional task is often dropped (Parchmann et al.,2014). However, several examples exist that career orientation in fact can be integrated (Parchmann & Lühken, 2014). In order to give the students as many vocational orientations as possible, it is necessary to talk and teach about (also non-academic) occupations of scientific industry in chemistry lessons. In this context, it is important to not only point out theoretical content of these occupational fields, but also in practical or informative learning approaches (Bertels, 2015). One way of practical orientation is to link learning tasks with professional focus, but appropriate materials are lacking. Therefore, learning tasks need to be developed that enable the teachers to include career orientation in multiple ways. Learning tasks with a job-oriented focus should, in addition to the acquisition of knowledge as well as specialised and social competences, primarily address the educational needs of the students. These needs must be professional and adapted to the students (Sokolowski & Pietzner, 2015).

The school lab on food chemistry professions

Foods are used for human nutrition and are derived from plant or animal organisms. Major components are proteins, carbohydrates and fats, which play a key role in the functionality of the organisms. All these substances can be viewed from a chemical perspective, for example digestion, the supply of energy in the cells or the conversion to water and carbon dioxide. Within food many chemical reactions take place that can lead to spoilage. On the other hand, chemical processes are used to produce foods such as making bread, wine, beer and cheese. The third area is food control, where chemical reactions are used to maintain food safety and, for example, uncover food fraud. For many people the terms "food" and "chemistry" have little or no relationship. All in all, the school lab has the objective of integrating existing experiments as they in part are done in school already with knowledge about food chemistry professions, so that the students also gain specialist knowledge. The materials developed in the school laboratory should create a first step to enable young people to better link these two terms. In addition, food chemistry is of great societal relevance, which can help to make students aware of the societal relevance of chemistry in general.

The chemical processes related to food described here are used or monitored by various professions. However, studies show that many of these occupations are unknown among adolescents (Haase, 2017). In order to convey the relevance of professions in food chemistry in chemistry classes, five different professions were selected and used in a school lab. All of the chosen professions can be learned within a vocational training that requires a graduation from lower secondary school after grade ten. The five professions are chemical lab assistant, distiller, chemical technical assistant, food technical assistant, and dairy industry lab assistant. Table 1 gives an overview how the different experiments intersect with the professions. The assigned tasks have been derived from the training requirements of the respective professions and the school curricula applicable to the state of Lower Saxony.

Table 1: Assignment of experiments to the respective occupations; CLA: chemical lab assistant, DIST: distiller, CTA: chemical technical assistant, FTA: food technical assistant, DILA: dairy industry las assistant; X: regular connection, (X): extended connection

Experiment	CLA	DIST	CTA	FTA	DILA
Analysis of raw milk	(x)		x	(x)	
Examine of dairy products on lactose	(x)		x	(x)	
Acidity of milk	(x)		x	(x)	
Maturity of apples		x			
Density of spirits	(x)	x		(x)	(x)
Content of salmiac in liquorice	(x)			(x)	x
Sensory food analysis		(x)	(x)	x	(x)
Food analysis of honey		(x)		(x)	x
TLC of vanillin/ethylvanillin	x		(x)	(x)	(x)
Qualitative analysis of vanillin sugar	(x)			x	
Determination of nitrate in lettuce	x			(x)	(x)

Learning tasks in the school lab

The school lab is scheduled to run for about five hours. Before and after the lab work, a seminar phase will be held to welcome the students, to discuss topics, to provide general information about experimentation and safety, and to accompany observations and phenomena in a professional manner. The students receive a lab journal containing information about the professions presented in the lab, worksheets for the experiments as well as general information on career orientation. The students experiment in groups of two or three at the workplaces prepared for them.

Students select experiments that are of interest to the individual small groups. Each experiment is connected to a professional context in which the experiment reflects a typical task. However, these activities are not just for just one profession, but can also be linked to other occupations. The students should immerse themselves into the course of action of the professions presented. For this, the tasks are designed to be action oriented. They note their observation and work on the subtasks of the experiments, which always require an interpretation (and explanation) of the observations. For example, decisions drawn from the experimental outcome must be formulated; e.g. if the milk tested is still suitable for making cheese. After the experimental phase, the results of the groups are discussed in the seminar. There students present their observations and which conclusion they derive from them. The also may describe how they came to this conclusion.

The lab script that every student gets for the work begins with a general job-oriented information section. Here, essential information on career orientation is deposited, including QR codes that refer to the internet pages of "http://www.berufe.net" as well as the Federal Employment Agency. In addition, the chemical background of the experiments is presented. Since enzymatic reactions often play a role in the context of food, but also is very difficult to understand for students of grade 7 to 10, this topic has been made as tangible as possible, because a complete waiver of biochemical processes would not have met the intention of the lab. Wherever it appears necessary and sensible for the students, the specialist knowledge is simplified, and the context of professional orientation is increasingly brought to the fore.

Each of the professions then is presented by means of an overview. In this overview, a variety of information such as educational content, training duration or activities are conveyed. The core elements of the lab script are the test protocols with the instructions. For each analysis, a page is provided where students can write down their observations. After noting their observation, the students can evaluate them with the help of a given analysis instruction and then give a recommendation regarding the examined food, food quality or characteristic. The students hereby get into the role of one of the chosen food chemistry professions and give a professional recommendation based on their own findings. An important reflection task of the following seminar is that there are recurring tasks in chemical analysis. Thus, an arc is to be closed that shows the young people that the knowledge they acquire in class is not useless knowledge, but rather serves as the basis for a professional work in many professions.

To investigate the success of the school lab, we focused on the professional self-efficacy, the students' assessment of various affective aspects of teaching as well as gender differences. Here, the results regarding the learning climate as well as selected results regarding gender differences will be presented.

METHOD

In this study, the data is collected via a fully standardized questionnaire that was developed, piloted and then used in a pre/post/follow-up design. Whilst the pre and post-test were admitted right before and after the school laboratory, the follow-up test was filled out by the students four to five months after the visit. The questionnaire comprises questions regarding the students' status of their personal career aspirations, their professional self-efficacy (Abele et al., 2000), the scientific interest (Engeln, 2004; Pawek, 2009), the self-assessment of the academic interests (Pawek, 2009) and finally questions regarding the motivational climate (Bolte, 2004). The learning climate questionnaire consists of 7 dimensions: satisfaction, comprehensibility, chemical relevance of the topic, societal relevance of the topic, participation opportunities, participation of the class and own participation. The focus of the learning climate is to present the societal significance of chemistry to students because vocational orientation can also show the societal relevance of chemistry. Therefore, investigating the learning climate of general chemistry lessons in the pre-test and of the school lab in the post and follow-up test provide information to what extend the school lab meets the goal of pointing out the societal relevance of chemistry. Most of the questions were scaled in a five-level Likert scale, the ones about the already experienced career orientation have been open questions. In total, 3 classes with 67 students took part in validating both the questionnaire as well as the materials used in the school lab. Afterwards, questionnaire and materials have been revised. To ensure the reliability of the research instrument, a group discussion was held with lecturers, PhD students and a professor about the method, the data collected and their analysis (Steinke, 2004). With the follow up test admitted four to five months after the school lab the medium-term effects have been evaluated. Data was analysed using SPSS 25. Besides the frequency distribution, the Wilcoxon sign-rank test and the Friedman test were used for evaluation. To evaluate the significance of the results, the effect size according to Cohen is calculated (Schwarz & Bruderer Enzler, 2019). As a valid level of significance for the evaluation, $\alpha = 0.05$ is chosen.

RESULTS

So far, a total of 498 students filled out the questionnaires. The students have been between 12 and 16 years old and attend grades seven to ten of the middle level of various German school types (see Table 2).

Before the lab visit, many of the students have no or only rudimentary knowledge and ideas about food chemistry professions, and less than five percent of the students would choose a chemical profession. This value increases slightly to just under 12 percent directly after the lab visit but drops to seven percent at the time of follow-up. Based on the task profiles, less than ten percent of the students recognise the five professions presented here as a food chemistry profession. After visiting the school lab, the value rises to over 71 percent and remains at 64 percent in the follow up. Therefore, a gain in knowledge can be seen.

Table 2: Student sample that participated in the school lab and already filled out all three questionnaires

Age	Male	Female	∑
12	18	18	36
13	53	73	126
14	17	15	32
15	50	80	130
16	91	83	174
∑	**229**	**269**	**498**

In order to assess the development of the motivational learning climate, the three paired samples were evaluated with the Friedman test. As can be seen in table 3, there are differences in all seven dimensions. The satisfaction increases significantly and then decreases significantly. Subjectively, the students are less satisfied in the general lessons than in the school lab. However, the school lab receives less approval in the reflection after five months. However, the rating is still significantly higher compared with the general lessons. In addition to satisfaction, the results in terms of the comprehensibility are of a similar structure, but the students do not rate the lab as more comprehensible in the follow-up test compared to the pre-test.

Table 3: Median rank of the learning climate dimensions; significant differences are marked with an *, highly significant results with an **

Dimension	Pre	Post	Follow Up
Satisfaction	1.52 Post**/Follow Up**	2.35 Pre**/Follow Up**	2.13 Pre**/Post**
Comprehensibility	1.83 Post*/Follow Up	2.22 Pre*/Follow Up*	1.95 Pre/Post*
Chemical relevance	2.53 Post**/Follow Up**	1.78 Pre**/Follow Up	1.69 Pre**/Post
Societal relevance	1.72 Post**/Follow Up**	2.36 Pre**/Follow Up**	1.92 Pre**/Post**
Participation opportunities	1.72 Post**/Follow Up**	2.10 Pre**/Follow Up	2.16 Pre**/Post

Participation of the class	1.42 Post**/Follow Up**	2.48 Pre**/Follow Up**	2.10 Pre**/Post**
Own participation	1.98 Post**/Follow Up*	2.24 Pre**/Follow Up**	1.79 Pre*/Post**

The chemical relevance of the school lab is rated significantly lower than of the general chemistry lessons. For the students, chemistry is a world of formulas and equations. The school lab shows the students that other factors such as application-related problem solving also play an important role in chemistry. This effect is also visible in the follow-up test. The food chemistry context also changed the recognition of societal relevance, so that the students evaluate this dimension significantly higher in both post and follow-up test. Regarding the three dimensions dealing with participation, there was significant growth in all of them. Working and experimenting in the laboratory differs significantly from the general chemistry class. The school lab is characterized by a high level of initiative; the students have no time pressure and experience that doing experiments is a casual way to acquire information about the presented professions.

Looking at differences between girls and boys the girls rate the comprehensibility of general chemistry lessons significantly lower than boys ($U = 24990,00$; $z = -1,994$; $p = 0,046$). No further differences between the two groups can be detected.

Further analysis was done to investigate the different ratings of the learning climate between general chemistry lessons (see Table 4). Both groups rate the learning environment in the school laboratory as more satisfied than the regular lessons in school. The median values in the post-test of the girls are higher, therefore it can be assumed that the girls were more interested in the learning tasks than the boys. The dimension of comprehensibility also shows a higher growth for girls than for boys.

Table 4: Gender-specific median rank results of learning climate dimensions 1-4

Dimension		Pre	Post	Follow Up
Satisfaction	male	1.61 Post**/Follow Up**	2.35 Pre**/Follow Up	2.14 Pre**/Post
	female	1.44 Post**/Follow Up**	2.44 Pre**/Follow Up**	2.12 Pre**/Post**
Comprehen-sibility	male	1.93 Post/Follow Up	2.15 Pre/Follow Up	1.92 Pre/Post
	female	1.73 Post**/Follow Up*	2.28 Pre**/Follow Up*	1.99 Pre*/Post*
Chemical relevance	male	2.53 Post**/Follow Up**	1.74 Pre**/Follow Up	1.72 Pre*/Post
	female	2.52 Post**/Follow Up**	1.82 Pre**/Follow Up	1.66 Pre*/Post

Societal relevance	male	1.78 Post**/Follow Up	2.25 Pre**/Follow Up**	1.97 Pre/Post**
	female	1.68 Post**/Follow Up	2.44 Pre**/Follow Up**	1.88 Pre/Post**

The rating of the chemical relevance decreases significantly in both groups, and this effect is also visible in the follow up-test. Looking at the societal relevance, the results are vice versa. The girls were also better able to leave the chemical relevance behind and saw the social aspect more clearly than the boys. However, the follow-up test shows no significant difference to the per-test. Therefore, the positive effect of the school lab regarding the societal relevance cannot be maintained.

Overall, the students rated the general lessons much more subject-specific, whereas the school lab was able to point out the societal aspects of chemistry. Both groups also report that the school lab is more motivating than general chemistry lessons. However, Table 4 also shows that the positive effects cannot be maintained in all dimensions. The values of the follow-up test for social relevance in both groups as well as the intelligibility among the boys approximate those of the pre-test again.

Conclusions

In addition to teaching knowledge, schools also have the task of promoting students' personal development, their abilities and their skillset. For this, complex school and extra-curricular offers for personal development should be offered. These are important aspects for career orientation and at long last a successful career choice. Chemistry education, as part of the overall school concept, should take up this development. This study supports the problem identified by Haase (2017) that adolescents have little or no ideas about chemical training occupations. School does not succeed in providing sufficient information about STEM professions. This study thus reflects the results of Krause, Stuckey, & Eilks, (2014). One method to change this problem is the conception of job-oriented learning tasks in chemical teaching. With learning tasks that provide both chemistry knowledge and professional orientation in class, students not only succeed in realizing the relevance of chemistry, but also are able to see the link between chemistry and the social world they live in.

Learning tasks are developed and tested as part of the presented student laboratory on professions related to food. Initial results show that the school lab has brought about a change in the self-perception of the participating students. However, clarity is not yet recognizable to the current state of research. The learning climate shows clearly differences between the three evaluation tests. The students rate the learning environment as well as the learning tasks more positively in comparison with their experience in general chemistry lessons. At the same time, the recognition of societal relevance increases with the learning tasks in the school lab. Results from Sokolowski & Pietzner (2015) also show the significantly higher assessment of social relevance for tasks relating chemistry and career orientation. These changes cannot be kept completely over time. This leads to the conclusion that action and process-oriented learning tasks dealing with food chemistry professions can positively influence the learning climate in chemistry education. However, these special learning tasks need to be used frequently in chemistry class, otherwise the positive effects cannot be maintained. This shows that the tasks have the potential to combine subject-specific and professional information in the classroom.

The primary purpose of the learning tasks is to show the students the importance of chemistry in social perception to support their career choices. With the newly designed tasks the students experience a change of perspective. Both the boys and the girls support these statements on the quality of the learning tasks. Furthermore, the students' horizon is broadened by their work in the school laboratory at the university. This data will be further analysed regarding professional self-efficacy as well as motivational and interest-oriented values. Currently there are hardly any data that allow a statement as to the extent to which occupational teaching tasks in chemistry lessons can promote the motivational learning climate and interests in food chemistry professions. This shows the exploratory nature of this study. Furthermore, the motivation and interest of students in the use of professional learning tasks in science teaching is examined. So that a better statement of the change of perspective can take place in the context of food chemistry.

REFERENCES

Abele, A. E., Stief, M., & Andrä, M. S. (2000). Zur ökonomischen Erfassung beruflicher Selbstwirksamkeitserwartungen - Neukonstruktion einer BSW-Skala. [For the economic assessment of professional self-efficacy expectations - new construction of a BSW scale]. *Zeitschrift für Arbeits- und Organisationspsychologie A&O*, *44* (3), 145–151. doi: 10.1026//0932-4089.44.3.145

Bandura, A. (1994). Self-efficacy. In V. S. Ramachandran (Ed.), *Encyclopedia of human behavior.* (pp. 71–81). New York, Academic Press.

Bertels, N. (2015). Unterrichtsrelevante Einflussfaktoren auf chemiebezogene Berufswahlabsichten im Meinungsbild von Jugendlichen. [Teaching-relevant factors influencing chemistry-related career choices Intentions in the opinion of young people]. (Doctoral dissertation, Freie University Berlin, Germany) Retrieved from https://refubium.fu-berlin.de/bitstream/handle/fub188/3485/DissxNinaxBertels.pdf?sequence=1&isAllowed=y

Bolte, C. (2004). Motivationales Lernklima im Chemieunterricht an Realschulen und Gymnasien. [Motivational learning environment in chemistry classes at secondary schools and high schools]. *Praxis der Naturwissenschaften - Chemie in der Schule*, *53* (7), 33–37.

Dierks, P. O., Höffler, T., & Parchmann, I. (2014). Interesse von Jugendlichen an Naturwissenschaften. [Interest of young people in science]. *CHEMKON*, *21* (3), 111–116. doi: 10.1002/ckon.201410215

Eder, F., & Bergmann, C. (2015). Das Person-Umwelt-Modell von J. L. Holland: Grundlagen - Konzepte - Anwendungen. [The person-environment model by J. L. Holland: basics - concepts - applications]. In C. Tarnai (Ed.), Berufliche Interessen: Beiträge zur Theorie von J. L. Holland. (pp. 11–30). Münster, Waxmann.

Egloff, E. (1998). Das Kooperationsmodell der Berufswahlvorbereitung. [The cooperation model of career preparation]. In R. Zihlmann (Ed.), Berufswahl in Theorie und Praxis: Konzepte zur Berufswahlvorbereitung und Beratung unter veränderten wirtschaftlichen und gesellschaftlichen Bedingungen. (pp. 87–102). Zürich, Sabe.

Engeln, K. (2004). *Schülerlabors: Authentische, Aktivierende Lernumgebungen Als Moglichkeit, Interesse an Naturwissenschaften Und Technik Zu Wecken. Studien zum Physik- und Chemielernen. [Student laboratories: authentic, activating learning environments as a possibility to awaken interest in natural sciences and technology]*. Berlin, Logos.

Haase, L. (2017). Kenntnisse, Einstellungen und Bewertungen von Jugendlichen bezüglich chemischer Berufe: Ergebnisse einer Fragebogenstudie in der Sekundarstufe I an allgemeinbildenden Schulen. [Knowledge, attitudes and evaluations of young people regarding chemical professions: Results of a questionnaire study in the secondary level I in general education schools] (Doctoral dissertation, University of Oldenburg, Germany). Retrieved from http://oops.uni-oldenburg.de/3222/1/haaken17.pdf

Holland, J. L. (1997). *Making vocational choices: A theory of vocational personalities and work environments*. Odessa, Psychological Assessment Resources.

Krause, M., Stuckey, M., & Eilks, I. (2014). Chemie im Beruf: Spielend und multimedial über Berufe mit Chemiebezug lernen. [Chemistry at work: Learn about professions related to chemistry in a fun and multimedia way]. *Naturwissenschaften im Unterricht. Chemie*, *25* (140), 13–17.

Kultusministerkonferenz (Ed.). (2019). Dokumentation zur Beruflichen Orientierung an allgemeinbildenden Schulen. [Documentation for professional orientation in general education schools]. https://www.kmk.org/fileadmin/Dateien/veroeffentlichungen_beschluesse/2017/2017_12_07-Dokumentation-Berufliche-Orientierung-an-Schulen.pdf

Parchmann, I., & Lühken, A. (2014). Einleitung. [Introduction]. *Naturwissenschaften im Unterricht. Chemie, 25* (140), 1.

Parchmann, I., Lühken, A., Haucke, K., & Pietzner, V. (2014). Chemie als Beruf - Chemie in Berufen!: Vielfalt chemischer Perspektiven zur Berufsorientierung. [Chemistry as a profession - chemistry in professions!: Diverse chemical perspectives for career orientation]. *Naturwissenschaften im Unterricht. Chemie, 25* (140), 2–6.

Pawek, C. (2009). Schülerlabore als interessefördernde außerschulische Lernumgebungen für Schülerinnen und Schüler aus der Mittel- und Oberstufe. [School laboratories as an out-of-school learning environment that promotes interest for middle and high school students.] (Doctoral dissertation, Universität Kiel, Germany). Retrieved from https://macau.uni-kiel.de/servlets/MCRFileNodeServlet/dissertation_derivate_00002763/diss_cpawek.pdf

Schwarz, J., & Bruderer Enzler, H. (2019). Methodenberatung: Mann-Whitney-U-Test. [Methodological advice: Mann-Whitney-U-Test]. Universität Zürich. https://www.methodenberatung.uzh.ch/de/datenanalyse_spss/ unterschiede/zentral/mann.html

Sokolowski, S., & Pietzner, V. (2015). Berufsorientierende Lernaufgaben. [Vocational learning tasks]. In S. Bernholt (Ed.), Gesellschaft für Didaktik der Chemie und Physik: Vol. 35. Heterogenität und Diversität - Vielfalt der Voraussetzungen im naturwissenschaftlichen Unterricht: Gesellschaft für Didaktik der Chemie und Physik, Jahrestagung in Bremen 2014 (pp. 244–246). Berlin, Lit.

Steinke, I. (2004). Quality Criteria in Qualitative Research. In U. Flick, E. v. Kardoff, & I. Steinke (Eds.), A companion to qualitative research (pp. 184–190). London, Thousand Oaks, New Delhi, Sage Publications.

Wentorf, W., Höffler, T. N., & Parchmann, I. (2015). Schülerkonzepte über das Tätigkeitsspektrum von Naturwissenschaftlerinnen und Naturwissenschaftlern: Vorstellungen, korrespondierende Interessen und Selbstwirksamkeitserwartungen. [Student concepts about the range of activities of natural scientists: ideas, corresponding interests and self-efficacy expectations]. *Zeitschrift für Didaktik der Naturwissenschaften*, *21* (1), 207–222. doi: 10.1007/s40573-015-0035-7

Wirth, R. (2019). Berufsorientierung im außerschulischen Lernort mit chemiebezogenen Berufen im Umweltschutz: Ergebnisse einer Fragebogenstudie mit Schülerinnen und Schülern der Sekundarstufe I. [Vocational orientation in the extracurricular learning location with chemical-related professions in environmental protection: results of a questionnaire study with pupils of the secondary level I.] (Doctoral dissertation, University of Oldenburg, Germany). Retrieved from http://oops.uni-oldenburg.de/4050/1/wirber19.pdf

GENDER AND SCIENCE: MEN AND WOMEN IN GREEK GYMNASIUM SCIENCE TEXTBOOKS

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Although the gender gap in science related occupations has been considerably reduced during the last 40 years, women still seem to be underrepresented in areas such as physics and technology. Several reasons have been suggested to explain the lack of interest of female students for science classes such as (a) the formation of sex-segregated groups of students especially in early school years, (b) parental attitudes and behaviour and (c) textbooks. Focusing on the latter, it has been argued that the way gender is portrayed in science textbooks may contribute to the sex role socialization of students; gender bias in science textbooks may influence the development of a view that science is a subject addressed more to boys than girls. This article focuses on the frequency of appearance of men/women and male scientists/female scientists in the illustrations of science textbooks of the Greek Gymnasium (students aged 12-15 years old). The analysis of 7 science textbooks shows that men and male scientists appear more frequently than women and female scientists respectively in the illustrations of physics, biology and chemistry textbooks. Relevant limitations and possible implications are discussed.

Keywords: Gender Issues, Curriculum, Science Education

INTRODUCTION

Although the gender gap in science related occupation has been considerably reduced during the last 40 years – for example, the number of women employed in science fields in US has increased significantly between 1980 and 2000 (Ceci & Williams, 2007) (Jones et al., 2000) – women still seem to be underrepresented in areas such as physics and technology (Frome et al., 2006) (Wang & Degol, 2017). Several strategies have been suggested in order to achieve a greater participation of women in science and technology (Brotman & Moore, 2008) (Scantlebury & Baker, 2007); however, it seems that girls generally start to lose interest in science at the age of 9-14, and few women choose to follow a relevant career (Vincent-Ruz & Schunn, 2017).

Several reasons have been suggested to explain the lack of interest of female students for science classes. Adamson et al. (1998) suggest that gender differences towards science are already evident in early school years and they claim that sex-segregated groups of students in elementary school contribute 'to the divergence of boys' and girls' approach to science by maintaining sex-stereotypic values and attitudes, including the masculine image of science' (Adamson et al., 1998, p. 855). Parental attitudes and behaviour seem also to influence children's attitudes towards science. Investigating children's and their parents' attitudes towards science, Andre et al., (1999) report that the parents participated rated boys' science skills higher than girls' and they claimed science to be more important to theirs sons than their daughters. In another study, Crowley et al. (2016) report that when visiting a science museum, parents explained the exhibits to their sons three times more often than their daughters. Since this difference was evident even when children were as young as 1 year old, the authors note that parents may contribute to creating sex-specific attitudes towards science learning.

Moreover, it seems that textbooks largely influence the gender differences observed in classroom when it comes to science learning. Textbooks are a source of social and cultural information on the ideas and attitudes that prevail within a society (Gouvias & Alexopoulos, 2018; Regueiro, 2000). The way gender is portrayed in science textbooks is believed to contribute to the sex role socialization of students; gender bias in science textbooks may influence the development of a view that science is a subject addressed more to boys than girls (Elgar, 2004). Researching English and Caribbean science textbooks, Whiteley (1996) argues that men appearing more frequent than women in textbooks' illustrations can lead to small numbers of girls choosing to follow studies in physics. Similar conclusions are reached by Elgar (2004), who report a gender imbalance in text and illustrations of textbooks of Brunei in favour of men, Potter & Rosser (1992), who underline the higher frequency of males depicted in illustrations of American biology textbooks, and Bazler & Simonis (1991), who claim that, although there are changes towards gender fairness in illustrations of American chemistry textbooks in years, in most textbooks men still dominate.

Considering the above, we decided to investigate gender representation in science textbooks. In this article we focus on the illustration of the Gymnasium science textbooks and the research questions formulated are the following:

1. How many men and how many women appear in the illustrations of the Gymnasium science textbooks?

2. How many male and how many female scientists appear in the illustrations of the Gymnasium science textbooks?

METHODS

For this study, we investigated the 7 textbooks of physics, chemistry and biology used in Greek Gymnasium (students aged 12-15 years old) during the school year 2018-2019:

- Physics with experiments (Kalkanis et al., 2013)
- Physics for the 2nd grade of Gymnasium (Antoniou et al., 2013a)
- Physics for the 3rd grade of Gymnasium (Antoniou et al., 2013b)
- Chemistry for the 2nd grade of Gymnasium (Avramiotis et al., 2013)
- Chemistry for the 3rd grade of Gymnasium (Theodoropoulos et al., 2013)
- Biology for the 1st grade of Gymnasium (Mavrikaki et al., 2017a)
- Biology for the 2nd and 3rd grade of Gymnasium (Mavrikaki et al., 2017b)

Initially, all humans who appeared in illustrations were identified and counted according to the following rules:

– For a series of illustrations where the same humans appear more than once (e.g. a human's movement shown in a series of consecutive illustrations) the depicted humans are counted only once.
– When an illustration is repeated in a textbook (e.g. at the end of every section) the humans depicted are counted only once.
– Only humans who are at the forefront of each illustration are counted. Humans who are part of the background or a watermark are not taken into account.
– When only parts of a human body are depicted they are not taken into account.

The identification and counting of humans were made by the two authors independently. In the few cases where there was a disagreement (e.g. whether a depicted human was in the foreground or background of an illustration) the humans involved in the disagreement were not counted.

The two authors classified independently all humans as men, women, and unknown gender (e.g. abstract figures). In the few cases where there was a disagreement, the humans involved in the disagreement were classified as unknown gender.

Moreover, the two authors went independently once more through all the humans identified, as explained above, and counted all the male and female scientists whose name was mentioned in illustration's caption or the adjacent paragraphs. In the few cases where there was a disagreement, humans who were involved in the disagreement were not classified as male or female scientists.

RESULTS

In all textbooks, men depicted are more than women: the difference ranges from 87 men / 17 women (physics for the 2nd grade of Gymnasium) to 52 men / 43 women (biology for the 2nd and 3rd grade of Gymnasium). Overall, men account for 66% of the humans depicted, while the percentage of women is 26% (Figure 1).

With regard to the number of male and female scientists, the difference is even more profound: in a total of 49 scientists shown in illustrations of science textbooks investigated, there are only three female scientists. The biggest number of scientists appear in illustrations of the physics for the 3rd grade of Gymnasium textbook (24) while in two textbooks (physics for the 1st grade of Gymnasium, and biology for 1st grade of Gymnasium) there are no illustrations of named scientists at all (Figure 2).

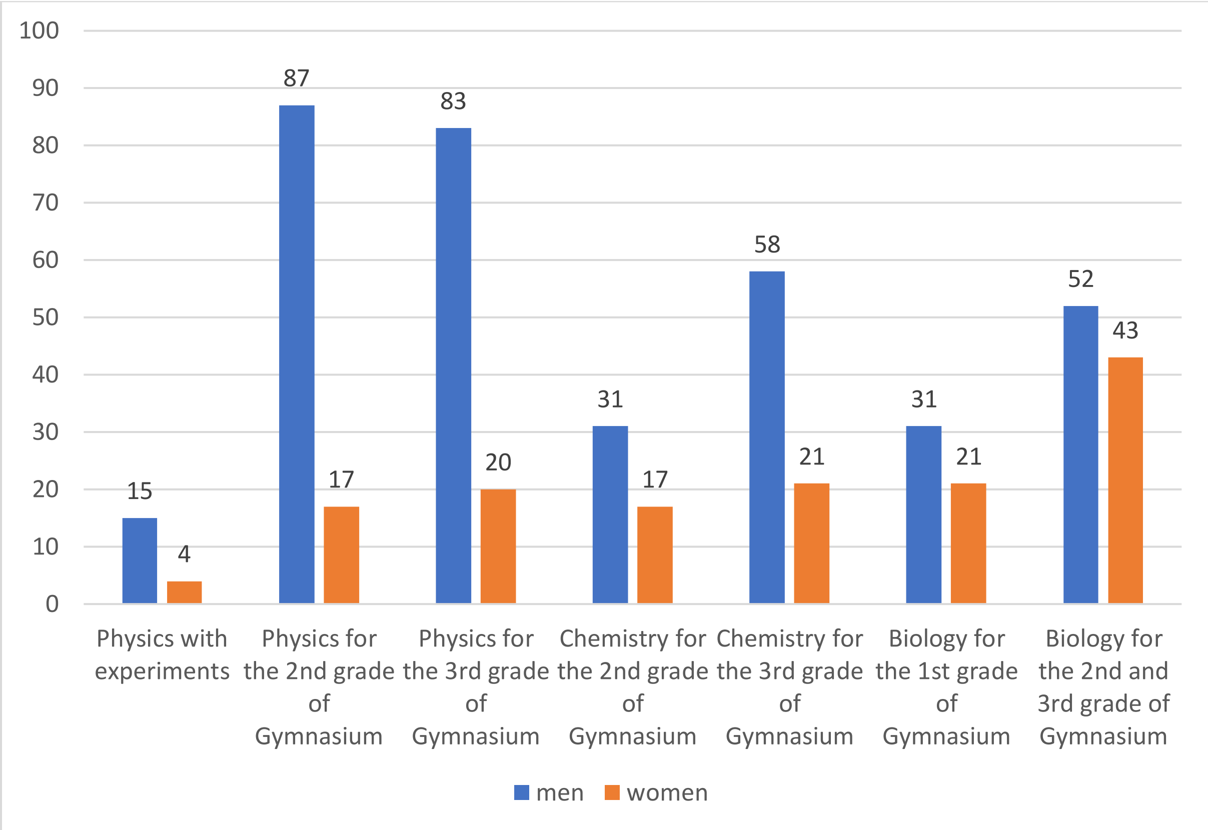

Figure 1. Frequency of men/women's appearance in illustrations of Gymnasium science textbooks.

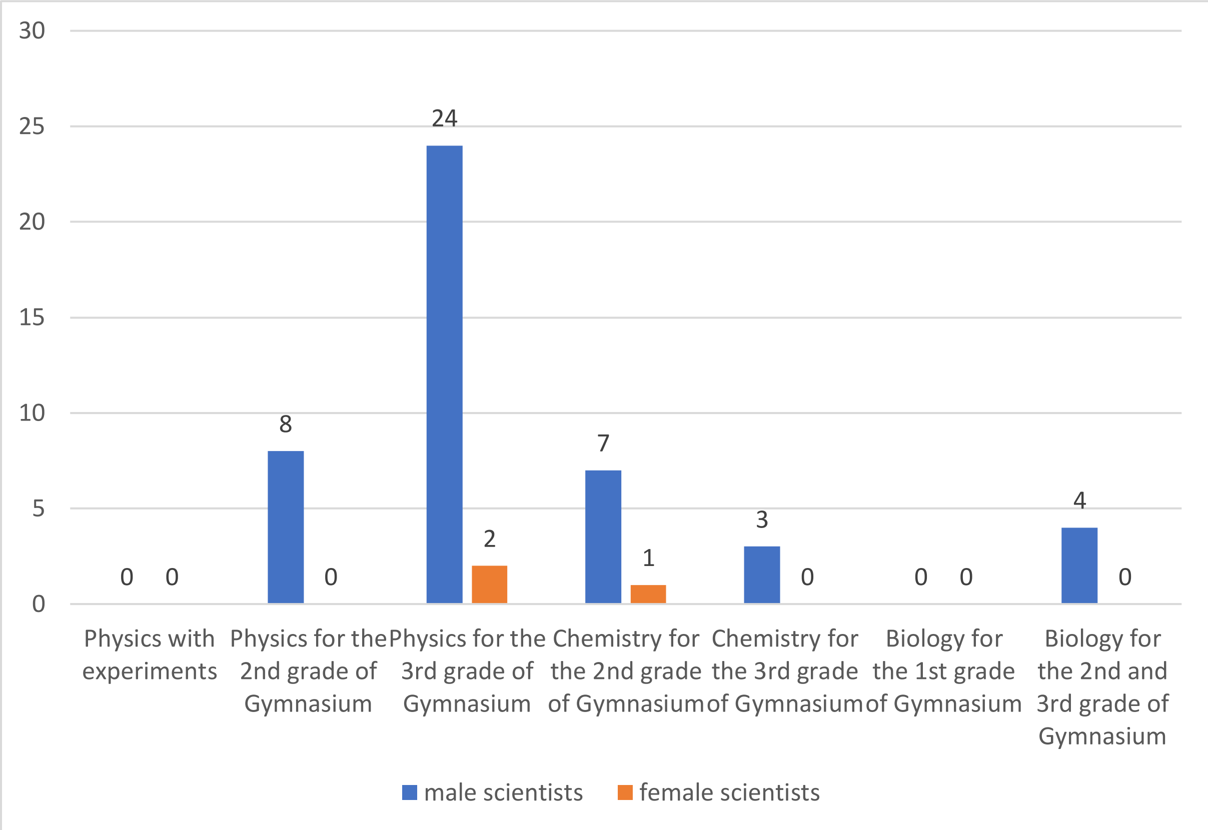

Figure 2. Frequency of male/female scientists' appearance in illustrations of Gymnasium science textbooks.

DISCUSSION

Men appear dominant in the illustrations of science textbooks used in the Greek Gymnasium. Whether appearing static (e.g. anatomy illustrations) or moving (e.g. a human throwing a ball), the human figures included in the illustrations are more likely to be men. A similar picture is formed concerning the proportion of male and female scientists. In a total of 49 scientists, only three illustrations depict female scientists, two of them depicting the same person (Marie Curie).

The dominance of male figures in science textbooks' illustrations may convey the message that males are the norm, the standard regarding science (Brickhouse et al., 2000). On the other hand, the dominance of male scientists in science textbooks' illustrations may convey the message that either the history of science has been written by men or only male scientists worth recognition (Potter & Rosser, 1992). A view that science is addressed more to boys than girls may lead female students to lose interest in science subjects and avoid a future career in science (Elgar, 2004).

Textbooks embody specific constructions of reality, which illuminate certain aspects of possible knowledge (Elgar, 2004; Gupta & Yin, 1990). However, we should acknowledge that their power to influence students' attitudes towards science comes with certain limitations. For instance, we should keep in mind that the way any written text is read depends on each reader's response to that text (Sunderland et al., 2000). Moreover, the way each learner responds to any given text included in a textbook may be related to the way that text is mediated by the teacher and peer students. Focusing on the role of teachers, Sunderland et al. (2000) note that teachers have three options when dealing with gender-biased texts: ignoring, subverting or endorsing the gendered messages.

Considering (a) the role of textbooks in shaping students attitudes towards science subjects, and (b) the under-representation of women and female scientists in the illustration of the Gymnasium science textbooks, we plan to extend our research by moving to the text of the same textbooks and investigating them in search of gendered messages. Finally, we argue it would be interesting to explore the reasons why, although male figures are in all cases more than female figures, the ratio of men to women differs considerably among the textbooks we explored for our research.

REFERENCES

Adamson, L. B., Foster, M. A., Roark, M. L., & Reed, D. B. (1998). Doing a science project: Gender differences during childhood. *Journal of Research in Science Teaching*, *35*(8), 845–857.

Andre, T., Whigham, M., Hendrickson, A., & Chambers, S. (1999). Competency beliefs, positive affect, and gender stereotypes of elementary students and their parents about science versus other school subjects. *Journal of Research in Science Teaching*, *36*(6), 719–747.

Antoniou, N., Dimitriadis, P., Kampouris, K., Papamichalis, K., & Papatsimpa, L. (2013a). *Physics for the 2nd grade of Gymnasium*. CTI Diophantus.

Antoniou, N., Dimitriadis, P., Kampouris, K., Papamichalis, K., & Papatsimpa, L. (2013b). *Physics for the 3rd grade of Gymnasium*. CTI Diophantus.

Avramiotis, S., Angelopoulos, V., Kapelonis, G., Sinigalias, P., Spantidis, D., Trikaliti, A., & Filos, G. (2013). *Chemistry for the 2nd grade of Gymnasium*. CTI Diophantus.

Bazler, J. A., & Simonis, D. A. (1991). Are high school chemistry textbooks gender fair? *Journal of Research in Science Teaching*, *28*(4), 353–362.

Brickhouse, N. W., Lowery, P., & Schultz, K. (2000). What Kind of a Girl Does Science? The Construction of School Science Identities. *Journal of Research in Science Teaching*, *37*(5), 441–458.

Brotman, J. S., & Moore, F. M. (2008). Girls and science: A review of four themes in the science education literature. *Journal of Research in Science Teaching*, *45*(9), 971–1002.

Ceci, S. J., & Williams, W. M. (2007). *Why aren't more women in science? Top researchers debate the evidence*. American Psychological Association Press.

Crowley, K., Callanan, M. A., Tenenbaum, H. R., & Allen, E. (2001). Parents Explain More Often to Boys Than to Girls During Shared Scientific Thinking: *Psychological Science*, *12*(3), 258–261.

Elgar, A. G. (2004). Science textbooks for lower secondary schools in Brunei: Issues of gender equity. *International Journal of Science Education*, *26*(7), 875–894.

Frome, P. M., Alfeld, C. J., Eccles, J. S., & Barber, B. L. (2006). Why don't they want a male-dominated job? An investigation of young women who changed their occupational aspirations. *Educational Research and Evaluation*, *12*(4), 359–372.

Gouvias, D., & Alexopoulos, C. (2018). Sexist stereotypes in the language textbooks of the Greek primary school: A multidimensional approach. *Gender and Education*, *30*(5), 642–662.

Gupta, A. F., & Yin, A. L. S. (1990). Gender representation in English language textbooks used in the Singapore primary schools. *Language and Education*, *4*(1), 29–50.

Jones, M. G., Howe, A., & Rua, M. J. (2000). Gender differences in students' experiences, interests, and attitudes toward science and scientists. *Science Education*, *84*(2), 180–192.

Kalkanis, G., Gkikopoulou, O., Kapotis, E., Gousopoulos, D., Patrinopoulos, M., Tsakonas, P., Dimitriadis, P., Papatsimpa, L., Mitzithras, K., Kapogiannis, A., Sotiropoulos, D., & Politis, S. (2013). *Physics with experiments*. CTI Diofantus.

Mavrikaki, E., Gouvra, M., & Kampouri, A. (2017a). *Biology for the 1st grade of Gymnasium*. CTI Diophantus.

Mavrikaki, E., Gouvra, M., & Kampouri, A. (2017b). *Biology for the 2nd and 3rd grade of Gymnasium*. CTI Diophantus.

Potter, E. F., & Rosser, S. V. (1992). Factors in life science textbooks that may deter girls' interest in science. *Journal of Research in Science Teaching*, *29*(7), 669–686.

Regueiro, P. D. (2000). An Analysis of Gender in a Spanish Music Textbook. *Music Education Research*, *2*(1), 57–73.

Scantlebury, K., & Baker, D. (2007). Gender issues in science education research: Remembering where the difference lies. In S. Abell & N. Lederman (Eds.), *Handbook of research on science education* (pp. 257–286). Lawrence Erlbaum.

Sunderland, J., Cowley, M., Abdul Rahim, F., Leontzakou, C., & Shattuck, J. (2000). From Bias "In the Text" to "Teacher Talk around the Text": An Exploration of Teacher Discourse and Gendered Foreign Language Textbook Texts. *Linguistics and Education*, *11*(3), 251–286.

Theodoropoulos, P., Papatheofanous, P., & Sideri, F. (2013). *Chemistry for the 3rd grade of Gymnasium*. CTI Diophantus.

Vincent-Ruz, P., & Schunn, C. D. (2017). The increasingly important role of science competency beliefs for science learning in girls. *Journal of Research in Science Teaching*, *54*(6), 790–822.

Wang, M.-T., & Degol, J. L. (2017). Gender Gap in Science, Technology, Engineering, and Mathematics (STEM): Current Knowledge, Implications for Practice, Policy, and Future Directions. *Educational Psychology Review*, *29*(1), 119–140.

Whiteley, P. (1996). The gender balance of physics textbooks: Caribbean and British books, 1985-91. *Physics Education*, *31*(3), 169.

MIDDLE SCHOOL GIRLS IN A SCIENTIFIC CONTEXT AND THEIR CONCEPTION ABOUT SCIENTISTS: WHAT CAN BE LEARNED?

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There is a disparity of gender in Science, about 70% of academic students and researchers in the world are men, mainly in research fields related to STEM: Science, Technology, Engineering and Mathematics. In order to verify the students conceptions of scientists, we've used the instrument Draw-A-Scientist Test (DAST), which is a tool to assess stereotypical imagery of scientists. The DAST was administered during the extracurricular science course "Meninas com Ciência", promoted for 50 middle school girls in two stages: One before the beginning of the course and another at the end. The aim of the course was to broaden students' views on the participation of women in the sciences. The course was entirely organized by women teachers and scientists. This exploratory study of the DAST analysis indicated that after the end of the course the number of girls who drew a female scientist significantly increased and, in contrast, the number of drawings of men scientists decreased. In addition, participants added professions of their own choosing in the second DAST application.

Keywords: *Gender Issues, Scientific Literacy, Science Education*

INTRODUCTION

There is concern about what students in elementary and middle school think about what science is and how and by whom it is developed.

We had already used DAST in 2018 in a context of science education, where boys and girls drew a scientist in their daily work. On that occasion, we found the same results as Chambers (1983), that is, for every 3 drawings, one was the figure of a female scientist, the other two being men. This has already pointed out to us an increase in the participation of women, possibly for several reasons such as - media, films, teachers, female scientists.

But that increase is still insufficient, as Chambers' research took place 30 years ago.

The strategy we are developing in Brazil is to implement projects that aim to bring girls closer to science and try to break the gender paradigm that has been established in this field.

How is this accomplished?

This proposal is not innovative, as England has done this for over twenty years with projects such as Girl in Science (SONNERT, 1995). But not that they had an effect, as the author points out.

Our proposal, in this course, is to attract girls aged between 11 and 14 years old, exactly attending EF II (middle school), so that in this way, they are sensitized even before entering high school, pre-university age, time to select their own profession.

The authors of this work have already participated in 3 versions of this course, since 2017. The positive results (frequency of girls during the course, motivation and enthusiasm during participation in activities, testimony from family members reporting the girls' excitement) motivated these initial proposals new projects.

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Our research carried out a survey on the conceptions of the girls participating in the Girls with Science course, which took place in 2018 at USP. The methodology we used was DAST (CHAMBERS, 1983). It is a projective method of surveying students' conceptions of a scientist, through a free drawing, based on the proposal - Draw a scientist in your daily life.

THEORETICAL BACKGROUND

Reason for women's participation in STEM area

The data has shown that there is a disparity between the number of women and men in the scientific area that involves Physics, Chemistry, Mathematics and Technology. Blickenstaff (2005) pointed out at least three arguments for women to be present, in greater numbers, in these related areas.

The first one is that every person should have an equal opportunity to study and work in the subject he or she chooses. The second one tell us that as long as women are underrepresented in STEM**,** a substantial number of talented women are choosing other subject areas in which to study and work. These might be women who could make important contributions to science or engineering if given a chance.The last one is that Scientific and technical endeavors can only be improved by having a greater diversity of perspectives in the search for knowledge and solutions to human problems. As scientists expand their knowledge of the world, the ability to look at questions and answers from different perspectives will help to make scientific explanations more robust and broad.

Conceptions of scientist by drawings

The fact that students usually have the fixed stereotype in their minds of scientists been predominantly male may be a barrier to girls' entry into science. Between the 1960s and 1970s, studies were carried out, in the United States and Canada, which involved the analysis of drawings made by children in the initial grades of elementary school. These drawings illustrate the figure of male scientists wearing mostly aprons, goggles, beards; working in a closed laboratory and surrounded by equipment and glassware. During this period, only 28 children performed drawings illustrating female scientists, which corresponds to 0.6% of the 3000 sample designs (Chambers, 1983).

Although the results presented on these researches were relevant, there was not yet neither an adequate methodology for the data collection nor for the analysis of the drawings. It was Chambers (1983) who developed a projective technique called the Draw-A-Scientist-Test (DAST) in order to investigate, among elementary school students, what the image each had in mind when the subject involved the subject who exercises the profession of scientist. In addition, the author verified other factors that could influence the way of thinking of the children, verified through the drawings. Thus, through the analysis of the results obtained, it was possible to evaluate patterns in the drawings made by these children, as well as their relation with socioeconomic factors, among others.

According to Miller et al. (2018), from the 1960s until the present time, a progressive change of this scenario has been noticed in the United States, that is, the drawings have been presenting a greater number of female scientists. This may be a result of the increase in the number of female representation in scientific circles, as well as television commercials, programs and children's magazines. Because of these notes, Miller et al (2018) noted a shift in this scenario from the use of DAST in research contexts similar to those of the 1960s: about one in three designs represents a female scientist.

RESEARCH GOALS AND QUESTIONS

The goal of our study was to explore the girl's conceptions of a scientist, to answer the following research questions:

1. How can the DAST (Chambers, 1983)* evaluate the potential of a course aimed at bringing girls closer to science?
2. May the results pointed out for DAST* indicate that girls approach to science context?
3. Are there other interesting features?

We had as hypotheses that the course, *Girls in Science* would be a motivator for the girls to approach the sciences.

* DAST - Draw a Scientist Test (Chambers, 1983)

METHODOLOGY

The present research was carried out in the second semester of 2018, during the extracurricular science course "Meninas com Ciência" (Girls with Science), which took place in the city of São Paulo, Brazil, for the first time. This is a differentiated situation, since the course is aimed only at girls with the intention of showing the role of a female scientist in different areas of activity, expanding the horizons of girls attending middle school and humanizing the figure of a scientist.

More than 12,000 girls have applied for the course, which had the limited number of vacancies of only 50. By means of a lottery, 25 girls from public schools and 25 from private schools participated in five weekly meetings, where prominent female scientists in each of the scientific areas, such as Oceanography; Astrobiology; Physics; Education; Astronomy; Paleontology; Geology; Zoology;

Microbiology; Pharmacology; Electrical engineering; Neurosciences; presented workshops, lectures, research experiments, in order to raise awareness about the role played by women in scientific areas.

Thus, the 50 participants were asked to perform the DAST on the first day of class of the course, even before any other activity, without any of them having had contact with the researchers and their lectures. After five meetings, the participants were invited to retake the DAST, so that we could confirm how much the activities, in which they participated, could increase their awareness about the participation of women in the scientific environment.

Participants should draw a free drawing according to the following proposal: They should draw - as they imagined - a scientist in his or her daily life. The methodology we used was DAST (CHAMBERS, 1983). It is a projective method of surveying students' conceptions of a scientist.

RESULTS

In this section we will present the data, which are images of scientists drawn by the participating girls in Girls with Science course. Thus, we use DAST in both situations: before the course and after. The differences are very interesting, because in addition to showing the image that each of the girls had before the course, the first of the photos, also showed that the course may influenced their future professional choices.

Figure 1. At first, the student illustrated a male scientist, and after the end of the five day course, she drew a woman scientist, wearing a T-shirt with a print indicating a degree course (Biology) and a University (Federal University of São Carlos).

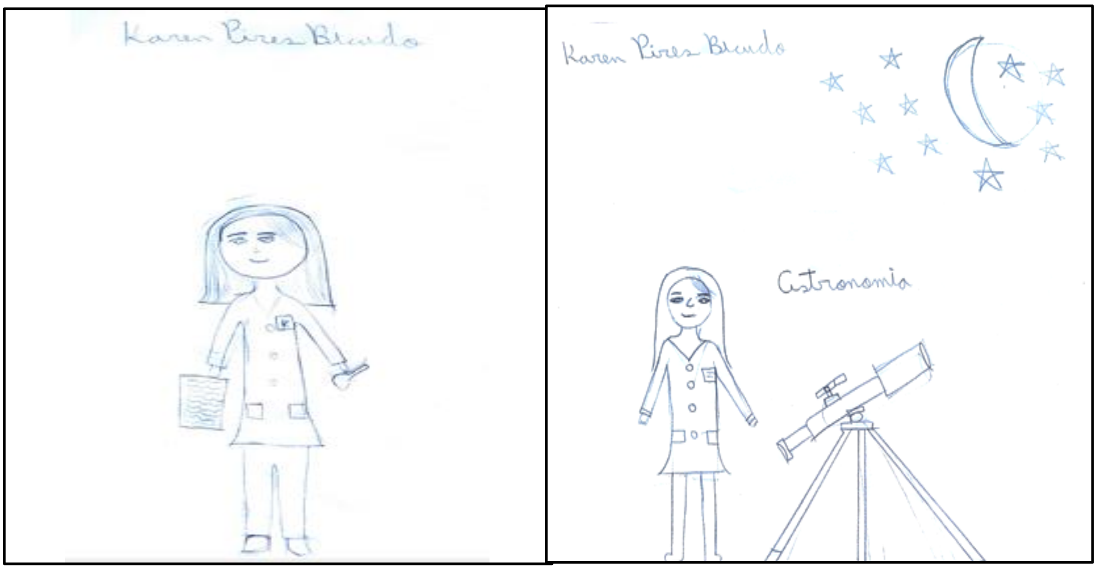

Figure 2. The first picture is a drawing made on the first day of the course. The second one is the image of a scientist after the end of the course.

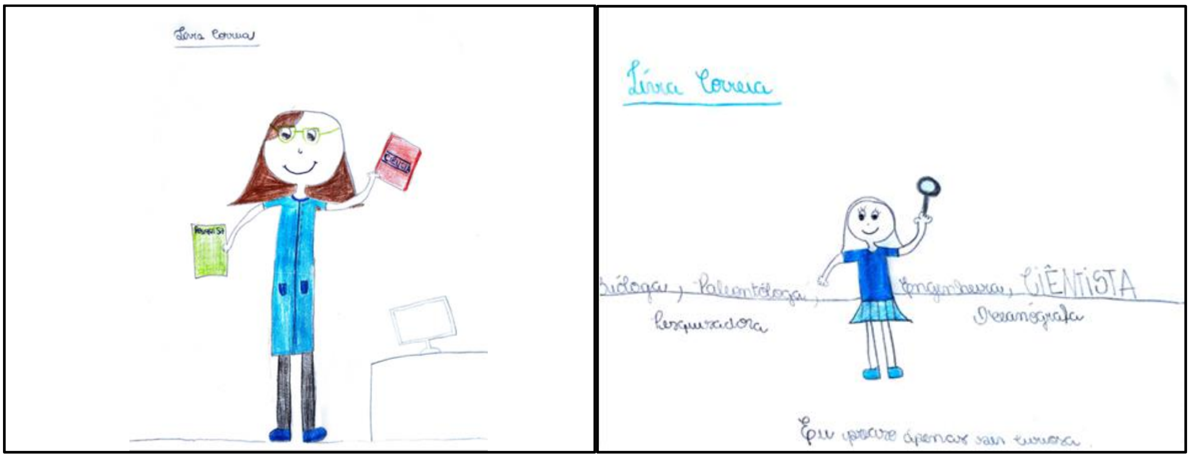

Figure 3. In the first situation, the student drew a girl with science books and a book on "research". In the second situation, she drew a woman with a magnifying lens in her hands and with some areas like Biologist, paleontologist, engineer, scientist, researcher written on the background. And, at the end, she wrote "I just need to be curious".

Analyses of drawings

The table below presents the results found in the drawings made by the participants of the Girls with Science course. As highlighted above, we applied the DAST methodology on two occasions, one before the course started and the other at the end of the course.

Initially, before the course, we had the lack of two girls, resulting in 48 drawings, of which 39 participants represented the figure of a woman as a scientist; 6 drawings represented men as scientists and 3 of the total were indefinite.

After the closing of the course, we had the participation of the total of girls, that is, 50 drawings, of which 45 were figures representing women; 2 represented men and 3 representing indefinite figures.

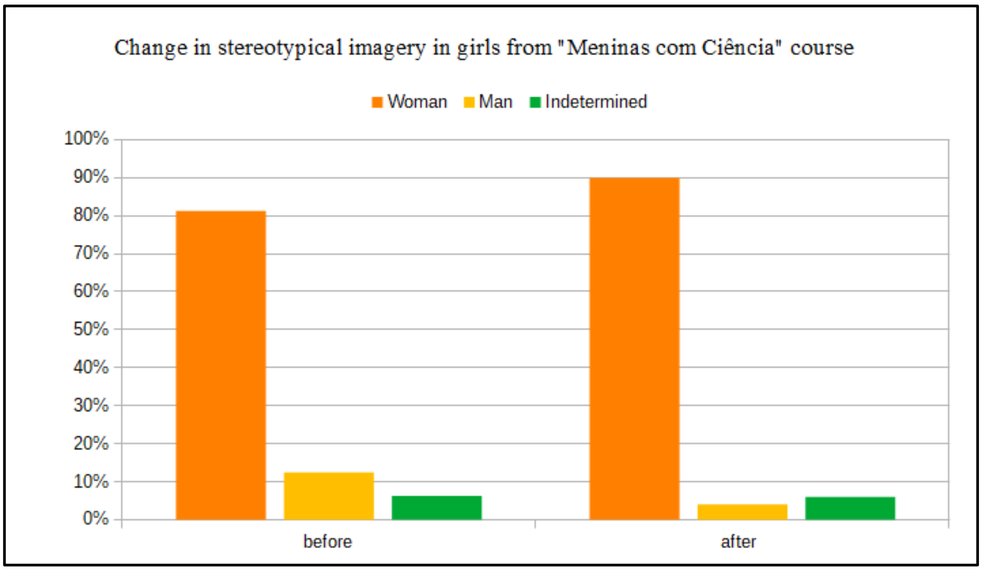

Figure 4. Change in stereotypical imagery in girls from "Meninas com Ciência" course

Table 1. The percentage result of our data

	Before	After
Women	39 (81,5%)	45* (90%)
Men	6 (12,5%)	2 (4,0%)
Undefined	3 (6,0%)	3 (6,0%)
TOTAL	48	50

DISCUSSION AND CONCLUSIONS

Our objective was to verify the conceptions of the girls participating in the Girls with Science course, regarding the gender of the scientists. Our results showed that after the end of the course, with the active and exciting participation of both girls and female researchers, there was a significant increase in the number of drawings referring to the figure of female scientists. But in addition, the participating girls added to their designs wishes for professions involving science, including those that involve the themes present during the course. This shows the possibility of using DAST as well to evaluate the course's potential to encourage choice for a science-oriented profession. It stands out the presence of laboratory instruments, notebooks, books, glasses continue.

REFERENCES

Blickenstaff, J.C. (2006). Women and science careers: leaky pipeline or gender filter?, *Gender Education*, 17, 4, 369-386.

Chambers, D. W. (1983). Stereotypic images of the scientist: The draw-a-scientist test. *Science Education*, 67, 255-265.

Kerkhoven, A.H.; Russo, P.; Land-Zandstra, A.M.; Saxena, A. & Rodenburg, F J. (2016) Gender Stereotypes in Science Education Resources: A Visual Content Analysis. Journal List *PLOS ONE*, 11, 11.

Meninas com Ciência – Universidade de São Paulo, Instituto Oceanográfico. Retrieved from

<https://www.meninascomcienciausp.com.br/>

Miele, E. (2014). Using the Draw-a-Scientist Test for Inquiry and Evaluation. *Journal of College Science Teaching*, 43, 4, 36-40

Reinisch, B; Krell, M.; Hergert, S.; Gogolin, S.& Kruger, D. (2017). Methodical challenges concerning the Draw-A—Scientist Test: a critical view about the assessment and evaluation of leaners' conceptions of scientists. *International Journal of Science Education*, August.

Rodrigues, M.I.R. & Rodrigues, D.R. (2018) **I**mages of Scientists through drawings: an exploratory study about students' conceptions and the genre in Science. *IV International Symposium of Science Teaching (SIEC 2018).*

Sonnert, G. & Holton, G. (1995a). gender differences in science carreers: the project access study (New Brunswick, NJ, Rutgers University Press).

Triviños, A. N. S. (1987). Introdução na Pesquisa em Ciências Sociais: a pesquisa qualitativa em educação. São Paulo: Atlas.

IDENTIFYING ELEMENTS OF EFFECTIVE PROGRAMS FOR PREPARING AMERICAN INDIAN SECONDARY STEM TEACHERS

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American Indian people continue to be underrepresented in STEM and STEM education college degree programs and professions in the United States. Increasing the number of American Indian STEM teachers working with students at the pre-college level is believed to be an important strategy for improving STEM outcomes for American Indian students. This qualitative study was designed to identify essential elements for effectively preparing American Indian secondary STEM teachers. Data were gathered through a two pronged approach: Interviews with a range of education stakeholders on the topic of American Indian STEM teacher preparation and a literature review of studies of American Indian education teacher preparation. Interview participants included American Indian secondary STEM teachers and teacher candidates, education faculty and administrators at colleges and universities that serve significant number of American Indian students, and administrators at secondary schools with high American Indian enrollment. A thematic analysis was conducted on interviewees' responses and relevant publications to identify factors identified as important to the development of effective American Indian secondary STEM teachers. A variety of specific themes emerged falling into three categories: supportive relationships, cultural responsiveness, and reflective practitioners. Implications for teacher preparation programs and recommendations for improving American Indian students' experiences in secondary STEM teacher preparation programs as well as recommendations for future research are offered.

Keywords: Indigenous STEM teacher, American Indian teacher preparation, Indigenous teacher preparation

OVERVIEW OF THE STUDY

American Indian people are underrepresented in science, technology, engineering and math (STEM) caeers and in the attainment of STEM college degrees. In 2015, American Indians and Alaska Natives (AI/AN) combined comprised 0.9% of American citizens of college age (18-24 years of age) but earned only 0.6% of STEM Bachelor's degrees, 0.5% of STEM Master's degrees, and 0.4% of all STEM doctorates awarded at U.S. colleges and universities (National Science Foundation, 2017). This underrepresentation deprives American Indian tribes, the United States, and the world of valuable STEM professionals and contributes to social inequities for American Indian people in the United States. Many American Indian tribes employ STEM professionals in fields like natural resource management, health sciences, accounting, and information technology, positions that could be filled by their own tribal members if they held STEM degrees. Employing one's community members in STEM positions contributes to the local economy, the quality of life for tribal peoples, and the tribe's sovereignty.

Closer examination of multiple measures of achievement suggests that the disproportionately low levels of representation of American Indians in STEM has its roots in the precollege years. For example, AI/AN consistently attain significantly lower scores than White students in math and science on the National Assessment of Educational Progress (NAEP) and on college entrance exams. AI/AN are lower than nearly every other ethnic group on rates of completion of core academic courses and advanced coursework, completion of advanced placement exams, and high school graduation rates. AI/AN have by far the highest percentage of high school drop outs and unemployment than any other ethnic group in the United States (United States Department of Education, 2018).

Employing American Indian secondary science and math educators in schools serving high numbers of American Indians students is believed to be a key strategy for reducing the achievement gap for American Indians in STEM (e.g., Archibald & La Rochelle, 2018; Belgarde, Mitchell & Arquero, 2002; Frances, Torrez & Krebs, 2018; Morcom, Freeman, & Davis, 2017; Oloo & Kiramba, 2019; Vinlove, 2018). Teachers who share Indigenous students' cultural backgrounds are thought to relate more effectively to students, serve as role models for Indigenous students, validate students' cultures, and provide socio-emotional support that fosters Indigenous students' success in college. Unfortunately, these are also professions in which American Indians are sorely underrepresented. According to the 2011-2012 *School and Staffing Survey*, only 0.5% of K-12 teachers in the United States identified as American Indian/Alaska Native, most of whom were teaching at the K-5 level, while over 1% of K-12 students are American Indian (United States Department of Education, 2012). The dearth of American Indian secondary STEM teachers is the central issue driving this study. The overarching research question for the study is as follows: What are the elements of teacher preparation programs that are essential to developing highly prepared American Indian secondary STEM teachers?

METHODS

Qualitative data about the essential elements and challenges encountered in preparing American Indian STEM teachers were gathered through literature review and interviews of educational stakeholders and then subjected to thematic analysis. The literature review included publications identified using keywords such as "Indigenous teacher preparation", "American Indian teacher preparation", "Native STEM teacher preparation", and combinations of these terms. Twenty-three articles that focused on American Indian, Alaska Native, and Canada's First Nations people were included in the literature review. Elements of teacher preparation programs from each were compiled in a spreadsheet, exposing emerging themes.

Interview participants were comprised of American Indian secondary science inservice and preservice teachers, secondary administrators at schools with high American Indian student enrollment, and STEM Education and STEM faculty and administrators in colleges and universities that serve significant numbers of American Indian students. Twenty interviews were conducted using structured interview protocols developed by the two authors of this paper and customized for each stakeholder group. Interviews were conducted both in person and via phone, depending on the interviewee's availability. Interviews were recorded and transcribed, whenever possible. Participants were selected from secondary schools and colleges and universities mainly in the northwestern United States, generally located near or on American Indian reservations. Faculty, administrators, students, and graduates from tribal colleges as well as mainstream universities were included in the interviews.

RESULTS

This is an ongoing study that initially focused on Montana institutions and was expanded in the last year to include additional institutions in the northwestern United States. A variety of specific themes emerged in the analyses of the literature and were affirmed by the interview data. These data will undergo further analyses as the study continues. It is anticipated that some themes will be refined and additional themes may emerge.

Three categories of elements emerged from the literature review as important to programs designed for developing Indigenous secondary STEM teachers. The categories and the most frequent items within each are listed below.

1. Relationships provide guidance and socio-emotional support
   - Caring and supportive faculty, advisors, and mentors are key
   - Students complete their program as a cohort
   - Tribal elders and community members are integral program partners
   - Consideration and involvement of families in program activities is important
2. Cultural elements ground programs in the norms, epistemology and ontology of local Indigenous people
   - Indigenous values
   - Place-based content and contexts
   - Indigenous knowledge
   - Local Indigenous language
   - Examining Indigenous history, contemporary Indigenous issues (e.g., sovereignty), history of Indigenous education
   - Working with elders and other community members
3. Developing reflective and critical practitioners
   - Grappling with social justice issues
   - Examining and expanding beyond mainstream practices and Eurocentric paradigms
   - Customizing practice to support Indigenous students

The twenty interviews conducted, which included all the aforementioned stakeholder groups, produced some variation in their responses. As a group, though, the interviews affirmed the categories found in the literature review.

DISCUSSION AND CONCLUSIONS

This study uncovered a number of practices that are believed to increase the effectiveness of teacher preparation programs for American Indian secondary STEM teachers. Some of the identified practices describe changes in curriculum while others focus on more customized and deliberate efforts to adopt cultural accommodations to better provide socio-emotional support for American Indian students.

Relationality

The theme of relationships in the study's findings is not surprising, given that this is a central value of tribal communities in the United States. Family and community relationships foreground all aspects of life in Indigenous communities, including students' academic journeys. Interviewees in all categories identified caring relationships between students, faculty, and staff as the second most important factor supporting Indigenous students' success in their degree programs, citing their importance in providing guidance, boosting motivation, and fostering persistence during difficult times. This factor's importance was affirmed in the literature review.

Moving through the degree as a cohort was also frequently identified in interviews and was again affirmed in the literature review. Cohorts were described as providing socio-emotional as well as academic support for students. Students described cohort-based study groups and sharing child care and transportation, for example, as significant to their academic success and emotional wellness as they progressed through their degree programs.

Partnering with elders and other community members in the design and delivery of programs was also cited with high frequency in interviews across stakeholder groups and in the literature review. The integral inclusion of multiple mentors such as elders and other cultural experts is a practice common in tribal cultures that bolsters the cultural content and authentic nature of learning experiences, validates students' cultures, and acknowledges the importance of these knowledge-keepers in Indigenous communities.

Relationship-related responsibilities hold an importance that may supersede Indigenous students' academic goals and extend beyond their immediate families to their extended families, friends, mentors, and the tribal community as a whole. Priority for relationships is manifested every day in the lives of students at tribal colleges in the choices they make related to class attendance versus attending relation-based events like caring for infirmed relatives, providing child care, and attending wakes. Student interviewees commonly noted their appreciation for faculty members who accommodated their needs to attend to relationship-related responsibilities by offering extended assignment deadlines, alternative assignments, or flexible content delivery. Faculty members and college administrators interviewed likewise affirmed the importance of such accommodations in supporting Indigenous students' success.

Cultural Grounding

Likewise, the theme of cultural grounding is not unexpected since including cultural content, pedagogy, and values in instruction allows students to "see" themselves in the curriculum and therefore better engages them, supports cultural validation, and facilitates connection of new ideas to existing schema, thereby supporting student success. Interviewees and the research literature identified the inclusion of place-based cultural content in the curriculum more than any other factor as important in secondary STEM education degree programs. Indigenous knowledge and content grounded in culturally relevant issues were specific examples highlighted in interviews as favored content. Experiential learning experiences, working with multiple mentors and especially tribal elders, and visits to culturally important sites were common examples interviewees mentioned as significant to student success. In the values realm, humor, caring attitudes, flexibility, individual choice, trust, and respect from faculty and staff were highlighted as positive attributes that support student success.

Reflective Practitioners

Developing reflective and critical practitioners, the third category, is the ultimate step toward transforming Indigenous teachers' ideas about teaching and learning. By encouraging preservice teachers' deep examination of the dominant Eurocentric teaching paradigm and of the power dynamics and politics in education, Indigenous teachers are fostered in throwing off indoctrination earned through generations of marginalization and their experiences in pre-college schooling, to expand their teaching philosophies to prioritize Indigenous perspectives, and customize their teaching to better support Indigenous learners. Critical analysis of the history of Indigenous people in the United States and particularly the history of Indigenous education were cited as specific topics crucial to developing reflective, empowered Indigenous practitioners.

Implications for Teacher Preparation Programs

Teacher licensure in the United States is under state control and the design of teacher preparation programs is further influenced by entities such as regional accrediting bodies, schools of education at individual colleges and universities, local K-12 schools, and the local communities served. Given the multi-layered system that bounds teacher education and the breadth and depth of items identified in this study's findings, it is clear that real change in teacher education to increase the representation of Indigenous people in secondary STEM education will only be realized if it occurs system-wide through substantive collaborative efforts, partnering schools of education, STEM and STEM education faculty, secondary schools, tribal communities, and ultimately state education agencies and accrediting bodies. Such collaborations require significant investments of time and effort to build trusting, enduring relationships that enable deep conversations with the power to transform teacher preparation. Respect, reciprocity, and recognition of the value and validity of each partner's contribution to the partnership are keys to success in these partnerships. Schools of education are the likely initiators of the work to create change. Engagement with tribal entities such as tribal education departments, tribal governments, tribal school teachers and administrators, tribal elders, and parents of Indigenous students is imperative and should observe tribal protocols.

Substantive integration of culturaly relevant content and adoption of preferred instructional practices and cultural accommodations require deep knowledge of tribal cultures. Many faculty members are not prepared for this work, necessitating substantive professional development in these realms in order to effect meaningful change. Schools of education may want to invite cultural experts to work with STEM and education faculty members, to build instructors' understanding of cultural norms, tribal history, Indigenous epistemologies, and Indigenous STEM and how to integrate them into their instruction and interactions with students. Faculty members will also require time to develop their courses to improve their cultural content and instructional methods. Tribal colleges already use the practices suggested in this study and have proven themselves useful resources for assisting mainstream colleges in making these transformations. Tribes are increasingly active in leading educational change for their people as well. Both will be crucial partners in this transformative work that challenges the status quo. Political will, commitment, willingness to cross cultural borders, and courage on the part of all stakeholders will be essential in realizing true transformation in teacher preparation programs for American Indian secondary STEM teachers.

ACKNOWLEDGMENT

This work was supported through funding from the National Science Foundation, Award #1149364.

REFERENCES

Archibald, J. A., & La Rochelle, J. (2018). Raven's response to teacher education: NITEP, an Indigenous story. In *Promising practices in Indigenous teacher education* (pp. 207-220). Springer, Singapore.

Belgarde, M. J., Mitchell, R. D., & Arquero, A. (2002). What do we have to do to create culturally responsive programs?: The challenge of transforming American Indian teacher education. *Action in teacher education*, *24*(2), 42-54.

Francis, L., Torrez, C. A., & Krebs, M. (2018). ‘Hold Strongly to One Another’: The Development of an Indigenous Teacher Preparation and Professional Development Program. In *Promising Practices in Indigenous Teacher Education* (pp. 221-235). Springer, Singapore.

Morcom, L., Freeman, K., & Davis, J. (2017). Rising Like the Thunderbird: The Reclamation of Indigenous Teacher Education. In *The Curriculum History of Canadian Teacher Education* (pp. 23-40). Routledge.

National Science Foundation, National Center for Science and Engineering Statistics.(2017). *Women, Minorities, and Persons with Disabilities in Science and Engineering: 2017.* Special Report NSF 17-310. Arlington, VA.

Oloo, J. A., & Kiramba, L. K. (2019). A narrative inquiry into experiences of Indigenous teachers during and after teacher preparation. *Race Ethnicity and Education*, 1-20.

U.S. Department of Education, National Center for Education Statistics. (2018). *The Condition of Education 2018*. (NCES 2018-144). Washington, DC.

U.S. Department of Education, National Center for Education Statistics (2012). *Schools and Staffing Survey (SASS), "Public School Teacher Data File," 2011–12.* Washington, DC.

Vinlove, A. (2018). Lessons and Legacies: Forty Years of Alaska Native Teacher Preparation at the University of Alaska Fairbanks. In *Promising Practices in Indigenous Teacher Education* (pp. 11-25). Springer, Singapore.

MAKING USE OF CONTEXTS AND INQUIRY TO ENGAGE ALL STUDENTS IN STEM LEARNING

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Scientific and technological advances along with current societal changes are posing new challenges to education, raising questions about what is relevant to be learnt in the 21st century and which means are appropriate to bring about the desired learning goals. Science teachers need to find new ways to engage students in meaningful and transferable learning, taking into consideration diversity in skills, motivations, academic-achievement and cultural background and to advance their potential as future professionals and citizens. Context-based and inquiry-based learning offer interesting opportunities to meet these goals. Within a European project promoting these two educational approaches, this paper looks at how teachers make use of contexts and inquiry to engage all students in their mathematics and science classrooms. Results from multiple case studies show rich pictures of teachers from different schools and backgrounds articulating their beliefs, values and experiences to enact the context-based and inquiry-based teaching and to adapt to their particular group of students. We discuss which criteria underlying the selection of meaningful and authentic learning contexts in any case and how teachers design, plan and implement inquiry approaches. Lesson plans and classroom observations show differences in the level of structure of the activities, the amount of guidance and support required from the teacher and how they perceived their role in inquiry-based approaches to address diversity.

Keywords: Inquiry-based learning, context-based learning, teacher professional development.

INTRODUCTION

STEM (Science Technology Engineering and Mathematics) education is essential to prepare future scientists and engineers but also to equip non-scientists citizens with the knowledge, skills, values and dispositions to understand the world around them and make informed and responsible decisions in a world deeply influenced by science and technology.

Inquiry-Based Learning (IBL) has been widely supported and highly recommend by several policy documents and experts' report as an appropriate methodology to improve STEM education and has been defined as "one that engages students in authentic, problem-based learning activities, where there may not be one correct answer, experimental procedures and hands on activities, including searching for information, self-regulated learning sequences and discursive argumentation and communication with peers in a process of talking science" (European Commission, 2015, p. 68). The study conducted by Scogin et al. (2018) shows that IBL is among the practices and characteristics of successful science programs in those schools that best support achievement in diverse classrooms.

A critical analysis of research evidence shows that the role of teachers in IBL is essential to foster students' reasoning and that a major emphasis should be placed on the cognitive processes conducive to meaningful learning (Romero-Ariza, 2017). Teachers support these processes through the use of questions that draw students' attention on key aspects and stimulate their critical thinking, empowering them to develop evidence-based explanations.

Along with teaching methods, learning contexts also have a significant impact on students' motivation and engagement and the quality of learning that takes place. Context is defined as the interactive everything in which learning is situated (Finkelstein, 2005). The notion of context has inspired a classical line of work in science education and has recently gained new attention in an attempt to design meaningful, functional and motivating scenarios for STEM learning (Sevian, Dori & Parchmann, 2018).

Given the key role of STEM education in todays' societies and considering the value of inquiry and context-based approaches, this work intends to have a look at how teachers implement those key elements in classrooms with students' diversity after a specific teacher professional development course. The course was specifically designed to support teachers to engage diverse students in active inquiry through meaningful and motivating contexts for STEM learning.

METHOD

A multiple case study methodology was used to get a rich picture of how teachers may use contexts and inquiry to engage students in STEM learning. The scientific rigor of the study is supported by low-inference statements (quotations), the triangulation of information from diverse sources and the involvement of different researchers (Creswell & Plano Clark, 2011). Categories were established in an inductive way to reflect the main themes arising. The content analysis was conducted through iterative cycles to ensure reliability and agreement. The outcomes and interpretation coming from one source of information were triangulated with those coming from the others to ensure consistency.

RESULTS AND DISCUSSION

Lesson plans, classroom observations, reflective notes and students' responses show that in the three case studies, teachers succeeded in developing contexts for STEM learning that engage all students. The categories arising for the analysis of contexts were *authenticity*, *students' ownership* and *utility*.

Table 1. Examples of extracts coded under the categories for the analysis of contexts.

Extract	Category	Source
" it engaged all students, no matter their cultural background because it was connected to something real and close to them"	Authenticity	Interview Teacher A
"….one student suggested the task when I asked what would you like to learn… and I thought why not"	Ownership	Interview teacher B
"…it allowed students to solve a particular problem, in this case, the high level of noise at school…we better live and work without noise"	Utility	Reflective notes Teacher C

The learning contexts used by teachers differed in the criteria used for their selection. In the first case, the teacher designed a task called 'much more than honey" inspired by recent news reporting on the disappearance of *the blue bee* and the importance of bees and their products for the human being (authentic events). According to the teacher's word the task "engaged all students, no matter their cultural background" because it was connected to "something real and close to them" (teacher A).

In the second case, the teacher took a student's suggestion about making slime in the classroom and used it as a context to learn about the properties of matter, mixtures and proportions, encouraging students to inquiry about how to make a 'safe' slime. He highlighted students' motivation and sense of ownership: "I chose the context because it came out in a previous lesson and I thought why not…and I cannot be more satisfied with the experience, with the outcomes and with my students' faces…" (teacher B).

In the third case, the teacher encouraged students to build their own robot to assess noise. When explaining the selection of the context the teacher emphasized its authenticity and utility for the community, stating that "learning will take place when addressing and searching solutions for a problem: the high level of noise at school" (teacher C).

In two of the case studies students developed real products (authenticity) as a result of the process: a robot to assess noise at school and a safe slime. Both products might be considered of special interest or utility from students' perspective (to improve the situation in their community in one case, and to produce a playful staff in the other). However, in the project entitled 'much more than honey' students conducted a sequence of activities to understand the value of bees and the materials and substances they produced, but they did not develop a final product of special interest or utility. However, in the three cases, students reported high levels of interest and engagement in learning and felt valued and appreciated by the teacher and others in the classroom. Results were especially remarkable in a classroom with many low-achievers: "…students felt valued and I could see their self-esteem increased…the experience made them find their space in the school" (teacher B).

In addition, the three teachers designed inquiry tasks, but they significantly varied in the way teaching and learning was planned and finally enacted. Some of the categories appearing when analysing how inquiry might be used to address diversity were *collaborative inquiry, peer learning, teacher prompts, challenges and specific teaching techniques*.

Table 2. Examples of extracts coded under the categories for the analysis of inquiry enactment.

Extract	Category	Source
"I use small challenges they have to address in teams so they can support each other. I want them to make sense together"	Peer learning	Interview Teacher A
"Students were set in groups to address the task collaboratively"	Collaborative inquiry	Observation notes, researcher B
"I really like when her mate saw her mistake and how he made her notice…This is what I want, I want them to support each other, to learn together…"	Peer learning	Interview Teacher A
"…my intervention was crucial for them not to drop off, to gain self-confidence and to believe in the project, in their project…"	Teacher prompts	Reflective notes Teacher B
"The main difficulties were related to the use of new concepts and the application of complex skills: developing a 3D prototype, programming with Bitbloq and Arduino and using appinventor to create an app"	Challenges	Reflective notes Teacher C
"Then I used a strategy we saw in the PD course: setting experts commissions with delegates from the different working groups to get experience in any of the three big challenges. Then they transferred their expertise to their own groups"	Specific teaching techniques	Reflective notes Teacher C

Concerning how inquiry was planned, enacted by students and guided by the teacher, we also found differences in the three case studies. The inquiry about bees was designed as a sequence of carefully planned activities that allowed students to develop key ideas progressively. Activities came with guiding questions aimed at stimulating students' thinking and enabling them to interrelate those key ideas in order to make the whole picture. The classroom observation showed that the initial design was very scaffolded and students were able to successfully conduct the task with minimal guidance from the teacher. The teacher mainly focussed on controlling time to respect the initial lesson plan and to pose stimulating questions to draw attention on the key issues. Though students had autonomy to organise their group work and to decide upon the best way to address any activity, the teacher exhibited a high control of the class at any moment.

The task about '*making-slime'* was introduced as an open task with minimal guidelines and students required the teacher support very often: "…my intervention was crucial for them not to drop off, to gain self-confidence and to believe in the project, in their project…" and "due to perseverance and encouragement …finally all the groups reached their goal" (teacher B).

The case study about noise level in the school was initially designed as an open project where students had to make decisions about how to design and build their own robot. It required new knowledge and complex skills from students and in the interview the teacher recognised feeling a bit frustrated for not being able to support any working group at the same time. However, she decided implementing a technique learnt in the course and set student's 'commission of experts' to facilitate collaborative learning and peer-support.

Finally, the study shows positive effects on the classroom atmosphere and the way students interact with peers and the teacher. Table 3 shows some examples.

Table 3. Examples of extracts showing positive effects and increase in students' self-esteem and sense of inclusion.

Extract	Category	Source
"…It has changed the way the group communicates and interacts and my relationship with them, enhancing empathy and complicity…	Positive interactions	Reflective notes Teacher B
"…the implementation of the task in the classroom has been an inflection point in the story of my classroom, a demarking point between before and after.	Students' identity	Reflective notes Teacher B
"…students felt valued and I could see their self-esteem increased…the experience made them find their space in the school…"	Students' self-esteem	Reflective notes Teacher B
"What was most impacting from the course was to realise that science education was no longer a field for the most smart or capable. The first thing I got from the course is, as you demonstrated repeatedly with examples, that it is absolutely possible to teach STEM in a diverse classroom, achieving very good objectives for all"	Inclusion	Interview Teacher B

The study provides interesting evidence about the positive effect of the pedagogical approach on students' identity and self-esteem and all learners' capacity to engage in the STEM classrooms in a meaningful way.

CONCLUSIONS

The three case studies discussed above allowed us to illustrate different ways in which teachers can make use of contexts and inquiry to enhance all students' engagement in STEM learning, suggesting the importance of providing teachers with opportunities to transfer what they learn in professional development courses to their teaching practice.

ACKNOWLEDGEMENT

This work has been funded by the European Commission under the European project entitled *Supporting mathematics and science teachers in addressing diversity and promoting fundamental values*, MaSDiV project (grant no. 2016 - 2927 / 003 – 001) 2017-2020.

REFERENCES

Bevins, S., Price, G. (2016) Reconceptualising inquiry in science education. International Journal of Science Education 38(1), 17-29.

Creswell, J.W. & Plano Clark, V. L. (2011). Designing and conducting mixed-methods research. (2nd ed.). Thousand Oaks, CA: SGE Publications, Inc.

European Commission (2015). Science Education for Responsible Citizenship. Luxembourg: Offices for Official Publications of the European Communities. Retrieved from http://ec.europa.eu/research/swafs/pdf/pub_science_education/KI-NA-26-893-EN-N.pdf

Finkelstein, N. D. (2005). Learning physics in context: A study of student learning about electricity and magnetism. International Journal of Science Education, 27(10), 1187–1209. https://doi.org/10.1080/09500690500069491.

Romero-Ariza, M. (2017). Inquiry-Based Learning: is there enough evidence of its benefits in science education? Revista Eureka sobre Enseñanza y Divulgación de las Ciencias, 14(2), 286-299.

Sevian, H., Dori, Y. J., & Parchmann, I. (2018). How does STEM context-based learning work: what we know and what we still do not know. International Journal of Science Education, 40(10),1–13. https://doi.org/10.1080/09500693.2018.

Scogin, S. C., Cavlazoglu, B., LeBlanc, J., & Stuessy, C. L. (2018). Inspiring science achievement: a mixed methods examination of the practices and characteristics of successful science programs in diverse high schools. Cultural Studies of Science Education, 13(3), 649-670.

CHEMISTRY TEACHERS' KNOWLEDGE ABOUT CHEMISTRY PROFESSIONS

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In the field of chemistry, school is rather influential regarding students' career aspirations because chemistry-related professions are much less visible in everyday life than other professions. Schools need to provide information about respective professions to enable the students to take a career decision on a proper knowledge base. In Germany, only few students have chemistry related career aspirations, even though the field of employment has a broad range, starting from classical chemistry professions like lab technician or new professions like specialist in wastewater technology. Therefore, it is necessary to know more about the situations at schools to better understand the background of the students' lack of interest to follow a respective career. Thus, it is necessary to investigate how chemistry classes may contribute to career aspirations and career choices. Within the context of our study, the focus lies on getting information about chemistry teachers' regarding chemistry professions and how career education is implemented in their teaching and at their respective schools.

Keywords: Career Education, Teacher-Professionalism, Teacher Professional Development

INTRODUCTION

Schudy (2002) summarizes the term career orientation by assigning four different meanings to it. He distinguishes subjective career orientation, career orientation of the educational content and teaching methods, career orientation in the sense of career choice preparation and career orientation in the sense of work-related general education. The subjective career orientation refers to the individual. Career orientation of educational contents and teaching methods should take account of new requirements of the economy. This should be implemented through the selection of important contents and appropriate methods in the school. By doing this, career orientation in the sense of career choice preparation is addressed at the same time. School activities are designed to help students in this process so that they can ultimately make a rational career decision at the end of schooling. Career orientation in the sense of work-related general education means that general skills are taught in the school, which enable the students to act in as much as possible areas of work. As important soft skills for being successful in a profession, he names judgment, solidarity, self-determination and social competence.

To support students in their career choice, various programs have been developed and integrated into the school system. However, most are focused on general aspects of employability like assessing the students' general skills or how to write an appropriate application. However, school also has the responsibility to guide students with respect to subject-oriented career competencies and support them to develop a vocational identity (Winters, Meijers, Kuijpers, & Baert, 2009).

Besides school students can get in contact with various professions in everyday life. The parents and other adult relatives as well as their friends' parents have a profession and talk about their work; taking part in everyday life also gives an insight in a lot of professions: sellers, doctor's assistants, car mechanics etc. The ten mostly chosen professions in the field of training professions are professions that are visible in everyday life (Bundesinstitut für Berufsbildung [BIBB], 2017). In contrast to this, chemistry training professions are more or less hidden – only the results of their work are visible: safe food, dairy products, kitchenware, cell phones, OLEDs and much more. Whereas chemistry professions that require a study programme at a university, for example a chemist, are known by some students, training professions are mostly unknown, unless someone in the students' family has a respective profession (Haase, 2017). In Germany, there are school types of lower secondary education that do not lead to the Abitur, a graduation that enables the students to enter University. Therefore, a chemistry related career education is of great importance especially at these schools because their students will likely never have the chance to work in the professions they know. Therefore, students interested in chemistry might think that chemistry can never be a basis for their professional life, and it is not possible to get interested in a profession you do not know about. This situation could be changed if teachers would be enabled to provide a proper career orientation in class that is closely related to chemistry.

Holland (1997) describes career choice as an expression of personality. He classifies six idealized personality types, which are characterized by specific abilities, professional preferences, values, life goals, problem-solving styles and self-concepts. Their characterizations are represented by the acronym RIASEC: realistic, investigative, artistic, social, enterprising, conventional. Each person's personality has a focus on one of these six types, the so-called primary type. However, a comprehensive description of a person is only possible by two other predominant types, the secondary and tertiary type. They are weaker than the primary type, but much stronger than the remaining three feature descriptions (Weinrach & Srebalus, 1994). The three types form the Holland Code. Such a code can be created for every profession but also for a person. For example, the profession Distiller has the Holland Code IRE. A match in Holland Codes between profession and person does not automatically guarantee an ideal job for this person but can help to narrow down the wide field of possible professions to a smaller selection.

In addition to the theory of Holland, the developmental psychology approach of Gottfredson (2005) is important for an appropriate career educational at school. According to this theory, the professional self-concept is influenced by factors like sex, status, or personal interests. This self-concept is compared by the individual with his or her professional concept. Above all, this professional concept determines the choice of occupation. A correspondence of self-concept and occupation leads to an individual considering of a profession as desirable. Both the self-concept and the professional concept develop in a long-term process that consists of four phases shown in table 1.

Table 1: The four stages of career orientation according to Gottfredson (2005)

	Stage 1: Size and Power	*Stage 2: Sex roles*	*Stage 3: Social valuation*	*Phase 4: Internal, unique self*
Grade	Preschool	Primary school	Middle school	High school and later
Mental process	Intuitive	Concrete	Less abstract	Abstract
New element of the perception	Big vs. small	Male roles vs. female roles	High prestige vs. low prestige	Personal interest, values, competences

of self and others				

One model that has been developed especially for career orientation at school is the cooperation model of Egloff (1998, pp. 106). The central aspect of the model is therefore the exploration of the professional and working world. The different collaborating partners of the students, e.g. parents, the school, the federal work agency as well as companies in the area of the school, should promote the transition of young people to vocational training or to a suitable upper secondary school and therefore into working life and support them in a role-specific manner.

Cohen, Patterson, Kovank and Chowning (2013) analysed the role of science teachers in promoting the students' interest in STEM careers and identified four factors that teachers need to take into consideration: Awareness (students develop an understanding and appreciation of STEM careers), Relevance (seeing the relevance of the subject matter in their lives), Engagement (engaging with the subject matter and STEM careers) and Self-efficacy (feeling comfortable using the tools of science). Wyss (2013) could show that the usage of videos can foster students' career interests in STEM fields, and Curry, Belser, & Binns (2013) suggest integrating career education in chemistry augmenting the existing classroom resources like providing additional learning material for the students focusing on careers in chemical industry. They stress that career exploration can be easily integrated in the classroom, for in the classroom, the same activities are dealt with as in the varied chemistry professions.

Dreer (2013, p. 145) has identified teachers' subject-related competences that are important for the implementation of career orientation in subject-specific education. They should know about suitable didactic principles of valuable learning opportunities for vocational orientation and based on this being able to design lessons to foster vocational, subject-related competences. Furthermore, they need to know relevant learning content and learning objectives for career education as well as suitable teaching material. This includes in particular the knowledge about different professions. Finally, teachers need to know how to design extra-curricular activities to promote career relevant and subject-related competences by individual preparation and evaluation of extra-curricular activities, for example by teaching students how to write an internship report. Based on these required competences, the following aspects can be derived for chemistry teachers:

- Teachers need to understand vocational orientation as a task of chemistry education at school.
- They need to know about
  - chemical occupations, their fields of application and main activities.
  - different working methods in the chemical industry.
  - characteristics of different chemical occupations
  - educational methods, like open lessons, action-oriented lessons, project lessons or problem-solving lessons, that contribute to career orientation.
- Teachers should have an own insight in the world of chemistry professions and the chemical industry.
- Teachers should be able to design chemistry lessons that foster key competences like autonomy, power to act, and team work.

However, there are currently only a few conversations about chemistry professions in the classroom (Mittenddorff, den Brok, & Beijaard, 2011). All means to foster career education in chemistry classes need to be planned and done by the teacher. Therefore, it is the teacher who is somehow a prerequisite for a suitable career orientation. It is known that only a few students in Germany want to work in STEM-related professions (Kjærnsli & Lie, 2011). To better understand the results of the different studies dealing with career orientation in chemistry classes, it is necessary to take a closer look at the teachers' knowledge about and views on chemistry professions. The following research questions were relevant for evaluation:

1. How important are the natural sciences within the general career education at school?
2. Do chemistry teachers implement career education in chemistry class?
3. To what extent has career education (methodologically or content-related) already been integrated into the chemistry classroom by the teachers?

METHOD

To investigate the research questions, the expert interview method was used, whereas an expert is described as follows: "'*Expert' describes the specific role of the interviewee as a source of specialized knowledge of the social issues to be explored*" (Gläser & Laudel, 2010, p. 12). They have a diverse experience-based knowledge that is usually not directly available but can be accessed in expert interviews. Meuser and Nagel (2009) distinguish between the operational knowledge and the contextual knowledge of the experts. Business knowledge often includes the process knowledge of the experts, which includes a certain amount of self-reflection about one's own actions. Contextual knowledge, on the other hand, means knowledge about the field of action in which the expert is located.

According to Bogner and Menz (2002), three types of expert interviews exist: the explorative, the systematizing and the theory-generating expert interviews. A new field of research can be developed by generating hypotheses and thereby identifying important thematic aspects. Following the systematizing approach, expert interviews serve can help to structure a topic in order to generate a network of knowledge that describes the frame of the topic. In this study, the explorative approach is pursued because little is known about the extent to which chemistry teachers integrate professional orientation into their teaching. Based on the interviews, a framework for implementing chemistry-related vocational orientation in class will be developed. Since the literature about this topic is limited and a qualitative approach was chosen, the results of the survey are not generalizable, but convey the first tendencies that are emerging in the subject of vocational orientation in chemistry lessons.

To answer the research questions, a semi-structured interview was developed and validated by intense discussion with a group of experts (Steinke, 2004, p. 187) as well as doing test interviews with two volunteers. The interview covered four different areas: First, the teachers should describe their individual view on career education. In the second part, they were asked give information about the concept of career education at their respective schools and, in more detail, what role science subjects have. Afterwards, they described their experiences, attitudes and ideas about the implementation of career education in chemistry class. Finally, questions about gender issues were discussed.

The interview guide was tested in a pilot study for clarity and informative value. Subsequently, the interview was transcribed and looked at whether research-relevant aspects are included. Since there were no difficulties in understanding during the interview and that relevant aspects related to the framework conditions for vocational orientation in chemistry lessons were included, no changes had to be made.

Contact with the chemistry teachers was made via the teacher professional development centre of the University of Oldenburg that has a full list of all schools in Lower Saxony and by e-mail to schools in the region of the university. Thus, it should be ensured that all chemistry teachers in Lower Saxony receive the project information and as many teachers as possible agree to participate in the interview study. The e-mail was accompanied by an information letter about the project, in which the teachers received a project overview and the objectives of the study were briefly explained.

For the main study, the interviews were recorded on tape and transcribed with the consent of the participants. The evaluation of the interviews was carried out with the method of qualitative content analysis according to Mayring (2014). For this, the interviews have been transcripted and the teachers' statements have been categorised. The categories were inductively derived from the interviews and have been validated by a consensual validation. The categories are: beginning of vocational orientation, responsibility for organization, offers for vocational orientation, the role of school social workers, and inclusion of the parents.

RESULTS

In total, eleven teachers (five females, six males) have been interviewed. In average, they have been teaching for 15.6 years. Six of them learned a profession before they became chemistry teachers; all the professions have a close relation to science (oecotrophologist, agricultural engineer, chemical lab technician, Master of Science in Chemistry and Biology, respectively). The interviews took between 20 and 70 minutes. All teachers work at a secondary school types that do not lead to Abitur and that traditionally focus much more on career orientation than teachers working at a Gymnasium. These schools offer different profiles in grade 9 and 10 that enables the students to focus on language, economy, technology or health and social affairs.

Table 2: Description of the sample of interviewed teachers

			Professional Biography	
Participant	*Sex*	*Years of teaching experience*	*Teacher Study Program*	*Previous Career*
B1	Female	7	No	Oecotrophologist, Microbiological Assistant, M. Sc. Biology
B2	Female	5	Yes	
B3	Female	8	No	Agricultural Engineer
B4	Female	24	Yes	
B5	Female	19	Yes	
B6	Male	23	Yes	Chemical Lab Technician
B7	Male	11	Yes	Commercial Apprenticeship, M. Sc. Biology

B8	Male	37	Yes	Chemical Lab Technician
B9	Male	7	No	M. Sc. Chemistry
B10	Male	3	Yes	
B11	Male	28	Yes	

Ten participants addressed chemical professions in the classroom, but big differences could be identified. Teachers who have previously worked in another profession tell their students about their experiences. In addition, they can name various professions and precisely describe their activities. Three teachers were able to comprehensively describe some typical activities, three other teachers cannot describe activities, but still name them. The remaining five teachers named two or one activities but did not describe them in detail.

Occupational orientation in chemistry classes is most taught by doing factory tours or working on a project like cosmetics or food chemistry. Two teachers still have contact with their former companies. Another teacher is currently planning to cooperate with a local chemical company. Apart from that, the teachers named project weeks as a possible contribution of science subjects to career orientation. In total, the relevance of science classes for career orientation was rated as low by ten teachers. The inclusion of career orientation in regular chemistry lessons was not usually included in lesson planning. In fact, the chemistry teachers tend to point out the professions by chance when they spontaneously see connections to the content to be taught.

When asked for possible different interests of boys and girls with respect to career aspirations, six teachers described differences which they noticed during their teaching. They claim that boys and girls try to live up to the classic role classification anchored in society. Girls would be seeking careers in the field of health or social affairs and would have no interest in technology or science, boys orientate themselves the opposite way. However, girls would place their occupational decision on a broader basis and would be more targeted than boys. Three teachers pointed out that there are still old stereotypes at school, with one teacher who considers it critical to break them up.

DISCUSSION AND CONCLUSIONS

The results show that teachers are only able to give their students some career orientation in the field of chemistry if they have learned a respective profession themselves, or at least they are far better able to do so. But even if they have learned a chemistry profession, career orientation is taking place accidently within the regular chemistry classes, with teachers focusing mainly on teaching chemistry-related content. Therefore, career orientation is currently no teaching goal for the teachers that needs to be considered. They see more possibilities to include career orientation within extracurricular activities like factory visits or more special activities like project weeks to give the students an insight into chemistry professions. This result closely relates to the circumstance that most of the teachers in this study have only little knowledge about chemistry professions. Although they can name a few occupations, only few teachers can provide information on the typical activities of these occupations. Therefore, all teachers in this study do not meet the four factors for suitable career orientation according to Cohen et al. (2013). However, the small number of participants in the study must be considered, and it would be useful to verify the results by a questionnaire study.

The results suggest that teachers need much more knowledge about chemical professions to incorporate career orientation in the classroom. This is of relevance because few adolescents in Germany have science-related career expectations and do not know chemistry professions from their daily life.

Usually, chemistry professions are much less visible in society than other professions, and therefore students depend on information from school. Chemistry classes could provide a way to introduce chemistry professions and to bring the students closer to the multi-faced professional world of chemistry. Because many typical activities of chemical professions are already part of the school, it is easy to provide a suitable career orientation easily (Curry, Belser, & Binns, 2013). Therefore, career orientation needs to be implemented into teacher education, considering both the study programmes as well as professional development courses.

Teachers also reported that gender stereotypes still exist for career orientation. Even gender equity is an important big issue in society, girls and boys still tend to follow "male" or "female" professions. This result shows once more the relevance of the theory of Gottfredson that the career choice is mainly influenced by the own gender and other factors are of secondary importance (Gottfredson, 2005). Therefore, it will need much more effort from society, beginning in Kindergarten, to overcome a gender-focused career choice.

At school, teachers can incorporate vocational orientation into their lessons with a small amount of measures that do not require to change their teaching fundamentally. To integrate information about chemistry professions, teachers need to have some basic knowledge about chemistry professions. Valid information can be found in the WWW from different stakeholders like the Federal Agency for Work or the Federal Employers Association Chemistry e.V. Based on this, they could develop teaching materials that put the students in a context that shows the relation between the experiment and a profession. This can also easily be done for topics that are part of the core curriculum for Chemistry, and teachers do not need to teach any additional topics for implementing career orientation. For example, instead of just doing an acid-base titration the teachers could design a context of a lab technician who has, as part of a goods receiving inspection, to check the acidity of a delivery of hydrochloric acid. This is just one example of a combination of chemistry-related content and the inclusion of a chemistry profession. At the University of Oldenburg school labs were developed and evaluated that show even more possibilities where chemistry professions were combined with typical tasks the workers have to do in their jobs. In addition, teachers could invite people into chemistry classes to do a chemical job, report on their activities and their professional environment.

In summary, not only previous research but also this study shows a still existing outdated role understanding by the student. Therefore, it is still a big challenge to foster science career interests of female students. But this means that career education has to be incorporated more and better in science education in schools. With the overall goal to motivate more students for science career it is necessary to break up outdated but still existing role understandings and ends with implementing more career orientation not only in extracurricular activities but in each science subject. This is possible in ways which previously have been described but have to be extended to a much larger group of teachers. Therefore, it is worth thinking about changing the course of study in teacher training courses at University and enhance the chemistry teachers' knowledge about chemistry professions.

REFERENCES

Bundesinstitut für Berufsbildung [BIBB] (2017). *Rangliste 2017 der Ausbildungsberufe nach Neuabschlüssen in Deutschland* [Ranking 2017 of the training occupations after new contracts in Germany]. Retrieved from https://www.bibb.de/dokumente/pdf/naa309_2017_tab67_0bund.pdf

Bogner, A., & Menz, W. (2002). Das theoriegenerierende Experteninterview [The theory-generating expert interview]. In Bogner A., Menz W. (eds) *Das Experteninterview [The Expert Interview]*. VS Verlag für Sozialwissenschaften, Wiesbaden, 33-70.

Cohen, C., Patterson, D. G., Kovarik, D. N., & Chowning, J. T. (2013). Fostering STEM Career Awareness: Emerging Opportunities for Teachers. *Washington State Kappan, 7(1),* 12-18. Retrieved from https://nwabr.org/sites/default/files/pagefiles/PDK%20STEM%20Career%20 Awareness.pdf (23.01.2019).

Curry, J. R., Belser, C. T., & Binns, I. C. (2013). Integrating postsecondary college and career options in the middle level curriculum: Middle level educators must find ways to integrate postsecondary education and career exploration throughout the curriculum. *Middle School Journal, 44(3),* 26-32. DOI: 10.1080/00940771.2013.11461852

Gottfredson, L. S. (2005). Using Gottfredson's theory of circumscription and compromise in career guidance and counseling. In S. D. Brown & R. W. Lent (Eds.). *Career development and counseling: Putting theory and research to work* (pp. 71-100). New York: Wiley.

Gläser, J., & Laudel, G. (2010). *Experteninterviews und qualitative Inhaltsanalyse [Expert interviews and qualitative content analysis]*. Springer-Verlag.

Haase, L. (2017). *Kenntnisse, Einstellungen und Bewertungen von Jugendlichen bezüglich chemischer Berufe: Ergebnisse einer Fragebogenstudie in der Sekundarstufe I an allgemein bildenden Schulen [Knowledge, attitudes and assessments of young people related to chemical occupations: results of a questionnaire study in lower secondary education at general education schools]*. Carl von Ossietzky Universität Oldenburg. Retrieved from https://d-nb.info/1138027553/34 (31.08.2019).

Holland, J. L. (1997). *Making vocational choices: A theory of vocational personalities and work environments.* Psychological Assessment Resources.

Kjærnsli, M., & Lie, S. (2011). Students' preference for science careers: International comparisons based on PISA 2006. *International Journal of Science Education, 33(1),* 121-144. DOI: 10.1080/09500693.2010.518642

Mayring P., (2014). *Qualitative content analysis: theoretical foundation, basic procedures and software solution.* Klagenfurt: Beltz, Retrieved from https://pdfs.semanticscholar.org/1888/ 2a33873fc61b0f026f8ee31440a934eaa4a9.pdf (24.01.2019).

Meuser M., & Nagel U. (2009) Das Experteninterview - konzeptionelle Grundlagen und methodische Anlage [The expert interview - conceptual basics and methodical approaches]. In: Pickel S., Pickel G., Lauth HJ., Jahn D. (eds) *Methoden der vergleichenden Politik- und Sozialwissenschaft [Methods of comparative political and social science]*. VS Verlag für Sozialwissenschaften, 465-479. DOI: 10.1007/978-3-531-91826-6_23.

Mittendorff, K., den Brok, P., & Beijaard, D. (2011). Students' perceptions of career conversations with their teachers. *Teaching and Teacher Education, 27(3),* 515-523.

Schudy, J. (2002). Berufsorientierung als schulstufen- und fächerübergreifende Aufgabe [Career orientation as a school cross stage and interdisciplinary task]. In J. Schudy (Ed.): *Berufsorientierung in der Schule. Grundlagen und Praxisbeispiele [Career orientation in school. Basics and practical examples]*. Bad Heilbrunn: Klinkhardt, 9-16.

Steinke, I. (2004). Quality Criteria in Qualitative Research. In U. Flick, E. v. Kardoff & I. Steinke, A (eds) *Companion to Qualitative Research.* London: SAGE Publications, 184-190.

Weinrach, S. G., & Srebalus, D. J. (1994). Die Berufswahltheorie von Holland [The career choice theory of Holland]. *Karriere-Entwicklung [Career-Development], 2,* 43-74.

Winters, A., Meijers, F., Kuijpers, M., & Baert, H. (2009). What are vocational training conversations about? Analysis of vocational training conversations in Dutch vocational education from a career learning perspective. *Journal of Vocational Education and Training, 61(3)*, 247-266. DOI: 10.1080/13636820903194690

TRANSLANGUAGING IN THE SCIENCE CLASSROOM: LEARNING ENGINEERING IN MULTILINGUAL CONTEXTS

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Demographic shifts due to immigration in the United States have increased the number of multilingual learners in schools. While this population trends continue, schools have recently implemented frameworks for elementary and secondary science education that incorporate engineering and the language demands associated with the field into the science education. These changes pose new challenges and opportunities for culturally and linguistically diverse (CLD) students. CLD students are now expected to engage in the language-intensive practices of engineering while developing basic literacy in English. However, research on immigrant communities in the United States often assumes a homogenous experience in learning settings while omitting the complexity within these communities. Contemporary research has yet to understand the relationship between language practices and engineering learning within the elementary science classroom. Drawing both on the literature of language in science education and translanguaging, this study investigates how students negotiate language in science and engineering and their perceptions around notions of language boundaries in schools. Through event mapping of participants' video data, this paper seeks to understand language negotiation in three different linguistic contexts during an engineering program at a university in Northern California. The results suggest that participants negotiated linguistic resources and meaning during the engineering lesson in four ways: rejection, loan, leasing, and ownership. Students' responses during the course also suggest that they perceived schools as spaces where language boundaries are reinforced. Learners expressed that educational institutions consider their capacity to transgress language boundaries as a negative behaviour. In summary, this study unpacks the intricacy of language value by showing the way pedagogical conditions provide affordances for language use in specialized learning environments.

Keywords: bilingualism, STEM, language in Science Education

INTRODUCTION

Language is important for science learning, especially for students who are speakers of non-dominant varieties. The number of speakers of languages other than English in schools has increased considerably in the United States in recent decades mainly due to factors such as immigration. As a result of these changes in national demographic trends, cultural and linguistic diversity has become a central force that shape education in the United States (Vogel, Ascenzi-Moreno, & García, 2018). A culturally and linguistically diverse student (CLD) is a learner whose ways of speaking, being and knowing in the world differ from those of the dominant society. According to recent Census data, culturally and linguistically diverse (CLD) learners will soon become the majority of students in U.S. public schools (U.S. Census data, 2015). These diverse learners perform poorly on academic achievement, exhibiting the lowest scores on performance and graduating at the lowest rates of all students (Darling-Hammond, 2015). Scholars have offered alternatives to ameliorate this issue. These alternatives range from focusing on the linguistic register of classroom-based science as a resource for learning (Halliday & Martin, 1993; Fang & Schleppegrell, 2008), supporting students engagement in the ways of talking and engaging in the scientific enterprise (Lemke, 1990; Engle & Conant, 2002; Osborne, 2012) to addressing the learning needs in content and language of traditionally marginalized students (Lee, Buxton, Lewis, & LeRoy, 2006; Brown, 2006; Lee, Quinn & Valdés, 2013). Most researchers investigating this dilemma frame language barriers in science education as an important component to the failure of schools to serve students. However, few researchers in the area of science education and language focus their work on understanding the role of language barriers for CLD students (c.f. Lee, 2005). The applied linguistics research on language practices in the context of science could contribute to the literature on language in science education by reimagining ways to negotiate language use and linguistic resources in learning environments (Bravo and Garcia 2004; Poza, 2016). To this end, educational research could look at the divisions of languages, which are socially imposed, in relationship with science learning. Both factors are important elements to consider in understanding how marginalized students access, interact with, and engage with, conceptual understanding of science and engineering. This work in progress seeks to provide empirical data to the question of how do students negotiate language when learning engineering in science learning environments.

THEORETICAL FRAMEWORK

The efforts to establish what students need to know and be able to do in science can be trace back to the 1800s with the Committee of Ten and recently to the integration of engineering in the science education frameworks. Two major perspectives emerged from these reforms: the cognitive-centred and the sociocultural-centred perspective (Brown, Reveles & Kelly, 2005). The cognitive centred perspective, based on earlier definitions of scientific literacy (Hurd, 1998; Thomas & Durant, 1987), focuses on developing scientific knowledge for extrinsic purposes, such as college and career readiness. Sociocultural approaches consider the relevance of literacy to a particular task within a meaningful social context (Jenkins, 1994; Kelly & Brown, 2003) or within the fundamental sense of literacy (Norris & Philips, 2003). The sociocultural perspective holds a view of language as a variable resource where forms emerge in use. From the sociocultural tradition emerge the theory and pedagogy of translanguaging. Inspired by Bakhtin (1934), Garcia (2009) define translanguaging as "the deployment of a speaker's full linguistic repertoire without regard for watchful adherence to the socially and politically defined boundaries of named languages." According to the author students build on their full linguistic repertoire to make meaning and use their semiotic resources to know, act and be. An important idea in translanguaging is the notion of language boundaries or imaginary division between languages (e.g. Spanish and English as different systems) connected to nation-state and political borders.

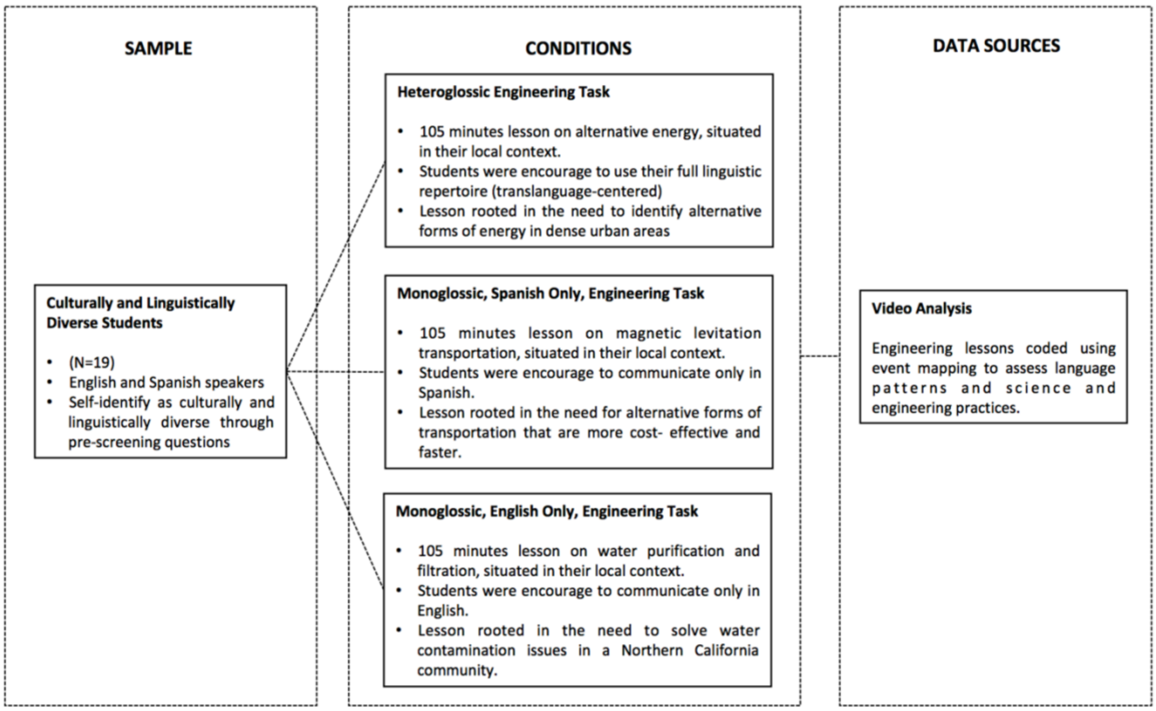
METHOD

In this qualitative study, nineteen elementary and middle school students, aged 7 to 13 years, participated. The manuscript explores how students negotiate language during their participation on a summer science program with a focus on engineering design in different language contexts. All participants identified as Hispanics, except for two of them who identified as African American and Latinx-Asian. Participants experienced three different linguistic contexts in the following order: translingual context, Spanish-only and English-only (see Figure 1). In the translanguaging context or heteroglossic engineering task, students were encouraged to engage in mixing the languages (both

English and Spanish) when designing a windmill for a community in Northern California. In the Spanish-only and English-only lesson or monoglossic engineering tasks, students were expected to interact in Spanish or English. Learners designed a magnetic levitation train and a water purification system respectively. Adult facilitators model the language practices associated with the lesson for students. We provided the instructional materials in accordance with the language context. All students participated in all three settings, enabling comparisons of their affordances. The research team recorded program to captured students negotiation of language when engaging in engineering tasks in the science classroom. Through event mapping analysis of video data of participants (Brown & Spang, 2007), this preliminary work explores the connections between language negotiation and the linguistic context during an engineering program. Specifically, this work investigates the following questions:

1. What do culturally and linguistically diverse students do with language when engaging in science talk and social talk?
2. What are students' perceptions on how schools impose language boundaries in science?

Figure 1. Study Design Summary



RESULTS

When coding the students' video and audio during the engineering tasks in the different linguistic contexts, the author noted an intriguing pattern of language negotiations where students deployed linguistic resources based on the situation.

To answer the question of what do culturally and linguistically diverse students do with language in science talk, the researcher draw on the video and audio recording of participants to identify language patterns. After participating in the engineering tasks with various language expectations, students negotiated linguistic resources and meaning in four ways: *rejection, loan*, *leasing, and ownership.* In a linguistic rejection, the student refuses to use a linguistic element that may not be congruent with their linguistic system. The linguistic leasing is characterized by the situations where the speaker performs a linguistic construct, but does not continue its use during the utterance or after unless is prompted. In the linguistic loan, the speaker tentatively accepts an utterance. In the last one, linguistic ownership, the learner comes to the conversation with a sense of *como es la lengua*. The speaker reaches ownership in a linguistic element when they feel more comfortable expressing their ideas using those resources for an intended audience and context.

The researcher provided preliminary data about students' perceptions on normative views of language in school-based science. For this purpose, the researcher two analyse video and audio episodes and conducted a small qualitative analysis of these two illustrative cases in the sample to suggest a mechanism for understanding the different language patterns identified for research question one. During the program, especially in the translingual lesson, students offer rationales for their language practices. In their comments, they described the monoglossic and monolingual norms of schools that restrict their language repertoire when learning science. Learners explained how notions of language in the classroom equate the use of their full repertoire with violent behaviours. In one of the instances, the student suggest that speaking English in the science class, which it is taught in Spanish at the dual language school where the students attends, was equated with being mean to other children. The data suggests that ideologies of language that reinforce monoglossic and monolingual norms in schools may be restricting students' experiences in learning science and engineering.

CONTRIBUTION TO THE ESERA COMMUNITY

In alignment with the conference theme "The beauty and pleasure of understanding: engaging with contemporary challenges through science education", the empirical paper presented here addresses current topics and challenges in line to the learning of science and engineering and an intrinsic link between science education and social domains. For instance, our finding that notions of language boundaries in schools influence students' experiences in the science classroom implies that there is an opportunity for educators to reimagine equitable and inclusive learning environments in science and engineering. Broadening our views of what knowledge and ways of talking are valued in science open doors for populations traditionally marginalized in the specialized fields of science and engineering.

REFERENCES

Bakhtin, M. M. [1934] (2010). *The dialogic imagination: Four essays* (Vol. 1). University of Texas Press.

Bravo, M., & Garcia, E. (2004). Learning to write like scientists: English language learners' science inquiry and writing understandings in responsive learning contexts. In *annual meeting of the American Educational Research Association, San Diego, CA*.

Brown, B. A., & Spang, E. (2007). Double Talk : Synthesizing Everyday and Science Language in the Classroom. *Science Education*, *92*(4), 708–732. https://doi.org/10.1002/sce.20251

Brown, B. A. (2006). "It isn't slang that can be said about this stuff": Language, identity, and appropriating science discourse. *Journal of Research in Science Teaching*, 43, 96–126.

Brown, B. A., Reveles, J. M., & Kelly, G. J. (2005). Scientific literacy and discursive identity: A theoretical framework for understanding science learning. *Science Education*, *89*(5), 779–802. https://doi.org/10.1002/sce.20069
Darling-Hammond, L. (2015). *The flat world and education: How America's commitment to equity will determine our future.* Teachers College Press.
Faltis, C. J., & Valdés, G. (2015). Preparing teachers for teaching in and advocating for linguistically diverse classrooms: A vade mecum for teacher educators. *Handbook of Research on Teaching* (Vol. 0).
Fang, Z., & Schleppegrell, M. (2008). *Reading in secondary content areas: A language-based pedagogy.* Ann Arbor, MI: University of Michigan Press.
García, O. (2009). Bilingual education in the 21st century: A global perspective. Malden, MA: Wiley-Blackwell.
Halliday, M. A. K., & Martin, J. R. [1993](2003). *Writing science: Literacy and discursive power*. Routledge.
Hurd, P. D. (1998). Scientific literacy: New minds for a changing world. *Science education*, *82*(3), 407-416.
Jenkins, E. W. (1994). Public understanding of science and science education for action. *Journal of Curriculum Studies*, *26*(6), 601-611.
Kelly, G. J., & Brown, C. (2003). Communicative demands of learning science through technological design: Third grade students' construction of solar energy devices. *Linguistics and Education*, *13*(4), 483-532.
Lee, O. (2005). Science education with English language learners: Synthesis and research agenda. *Review of educational research*, 75(4), 491-530.
Lee, O., Quinn, H., & Valdés, G. (2013). Science and language for English language learners in relation to Next Generation Science Standards and with implications for Common Core State Standards for English language arts and mathematics. *Educational Researcher*, 42(4), 223-233.
Lee, O., Buxton, C. A., Lewis, S., & LeRoy, K. (2006). Science inquiry and student diversity: Enhanced abilities and continuing difficulties after an instructional intervention. *Journal of Research in Science Teaching*, 43, 607–636.
Lemke, J. L. (1990). *Talking science: Language, learning and values.* Norwood, NJ: Ablex.
Moore, C. (2017). *Creating Scientists: Teaching and Assessing Science Practice for the NGSS*. Routledge.
Norris, S.P., & Phillips, L. M., (2003) How literacy in its fundamental sense is central to scientific literacy. Science Education, 87, 224-240.
Engle, R. A., & Conant, F. (2002). Guiding principles for fostering productive disciplinary engagement: Explaining an emergent argument in a community of learners' classroom. *Cognition and Instruction*, 20, 399–483.
Osborne, J. (2012). The role of argument: Learning how to learn in school science. In *Second international handbook of science education* (pp. 933-949). Springer, Dordrecht.
Poza, L. E. (2016). The language of ciencia: translanguaging and learning in a bilingual science classroom. *International Journal of Bilingual Education and Bilingualism*, *21*(1), 1-19.
Thomas, G., & Durant, J. (1987). Why should we promote the public understanding of science. *Scientific literacy papers*, *1*, 1-14.
U.S. Census Bureau (2015). *Community Survey (ACS) from the Census Data* (2015). Retrieve from https://www.census.gov/programs-surveys/acs/

Vogel, S., Ascenzi-Moreno, L., & García, O. (2018). An Expanded View of Translanguaging: Leveraging the Dynamic Interactions Between a Young Multilingual Writer and Machine Translation Software. *In Plurilingualism in Teaching and Learning* (pp. 105-122). Routledge.

PART 13: STRAND 13

Pre-service Science Teacher Education

Co-editors: *Maria Evagorou & María Ruth Jimenez Liso*

CONTENTS

STRAND 13: INTRODUCTION

PRE-SERVICE SCIENCE TEACHER EDUCATION

While we are preparing this introduction, the coronavirus disease (COVID-19) is spreading, and the world is facing a situation that raises many questions and a lot of uncertainties. Almost all aspects of our daily lives have been affected in some way, amongst them education. One of the questions we have been considering as science educators during the pandemic has to do with whether we have been preparing science teachers to navigate a complex situation as the one we are currently facing. Do we provide our pre-service teachers with the necessary skills, practices and behaviors? Do we support them to prepare their own students to think critically and understand the uncertainties of science? Doubts about the effectiveness of current teacher training have been raised for a long time. More than a decade ago, the internationally influential report Teachers Matters. Attracting, Developing and Retaining Effective Teachers of the OECD (2005) placed teachers as the backbone of the education system and recognized the growing concern of all countries about the scarce links between teacher training and school needs, questioning whether the teachers have the knowledge and skills necessary to respond to such school needs. We conclude, from the large number of submissions in Strand 13 (180 submissions), that as a science education community we are concerned about preparing our future teachers and narrowing the gap between research and teaching practice.

As part of the ESERA 2019 conference, we invited researchers to submit under Strand 13 studies related to professional knowledge of teachers, pre-service teacher preparation, instructional methods in pre-service teacher education, programs and policy, field experience, relation of theory with practice, and issues related to pre-service teacher education reform. 180 papers were reviewed for the 13th biennial conference held in Bologna in August 2019, and we would like to thank all reviewers for their time and effort. This volume of the e-proceedings brings together 28 submissions from different countries representing four of the continents: Europe, Africa, Asia and America, highlighting in that way the international nature of the conference. The papers in this strand illustrate the trends in pre-service science teacher (PSTs) education across the world currently, and focus on a variety of issues and science disciplines. The topics range from studies on PSTs as learners engaging in argumentation, modeling and inquiry; PSTs as thinkers, as designers and as reflective practitioners.

The majority of studies in this strand are especially linked to analyzing the PSTs' scientific practices of inquiry, modeling and argumentation, and this is probably linked to earlier critics of science teacher training programs as being too abstract and theoretical, out of context and removed from the reality of their future classrooms (Bryan & Abell, 1999; Darling-Hammond, 2005), as well as on recent emphasis on scientific practices and scientific competences (OECD, 2018; Osborne, 2014). Furthermore, submissions in Strand 13 focused on PCK, emphasizing on few aspects depending on the different roles of the PSTs: teachers as learners, teachers as thinkers, teachers as reflective practitioners, and teachers as designers (Silm, et. al., 2017). Finally, in the selected studies there is an evolution from the traditional research line on PSTs conceptions to assess relevance, competencies and other issues that contribute to their PCK development.

We anticipate that this collective volume will become the basis of conversations discussing the changes and challenges in pre-service science teacher education, and that the interest in Strand 13 will continue to grow and will evolve following the changes brought by the pandemic.

M Rut Jiménez-Liso & Maria Evagorou

References

Blackburn, V., & Moissan, C. (1986). *The in-service training of teachers in the twelve Member States of the European Communities*. Educational Policy Series. Presses Interuniversitaires. Européen Union.

Bryan, L.A. & Abell, S.K. (1999). Development of professional knowledge in learning to teach elementary science. Journal of Research in Science Teaching, 36(2), 121-139.

Darling-Hammond, L. (2006). Assessing teacher education: The usefulness of multiple measures for assesssing program outcomes. Journal of Teacher Education, 57(2), 120-138.

OECD. (2005). *Teachers matter: Attracting, developing and retaining effective teachers*. Organisation for Economic Co-operation and Development Publishing.

OECD (2018). *PISA 2018 Assessment and Analytical Framework*. https://doi.org/10.1787/b25efab8-en

Osborne, J. (2014). Teaching Scientific Practices: Meeting the Challenge of Change. *Journal of Science Teacher Education*, 25(2), 177–196. http://doi.org/10.1007/s10972-014-9384-1

Silm, G., Tiitsaar, K., Pedaste, M., Zacharia, Z. C., & Papaevripidou, M. (2017). Teachers' Readiness to Use Inquiry-Based Learning: An Investigation of Teachers' Sense of Efficacy and Attitudes toward Inquiry-Based Learning. *Science Education International*, *28*(4), 315-325.

PRE-SERVICE ELEMENTARY SCIENCE TEACHERS' VIEWS ABOUT SCIENTIFIC INQUIRY. A PILOT STUDY

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Inquiry is a scientific practice that allows, from researchable questions, the development of logic and critical thinking, and so is the need to consider alternative explanations. These characteristics make it especially suitable for science teaching-learning processes, as it has been recognized in different international reports. This paper is a pilot study carried out with 53 Spanish Pre-service Elementary Science Teachers (PSESTs) in Spain, which tries to know their ideas about the need to start a research from a question and the differences between research and experiment. For this purpose, the first dimension of the international questionnaire Views About Scientific Inquiry (VASI) was used, formulated as "scientific investigations all begin with a question and do not necessarily test a hypothesis". One of the contributions of this work is the breakdown of the categorization of responses proposed by Lederman et al. (2014) into five levels instead of three, to adapt it to the evaluation of the PSESTs. The main result obtained is that the vast majority of PSESTs does not distinguish between research and experiment and does not recognize that a research is based on a researchable question. On the other hand, no statistically significant differences have been found in the demographic variables considered: sex and previous scientific training. These results indicate the need to develop a specific training programme for PSEST's in this sense.

Keywords: Initial teacher education (Pre service), diagnostic tools, science inquiry

INTRODUCTION

The inquiry, understood as the various ways in which scientists study the natural world and propose explanations based on the evidence derived from their work (NRC, 1996, p.23), is an inherent activity of scientific practice. In this respect, the investigative approach in the teaching-learning processes of science, according to Caamaño (2012, p. 84) allows students to work in a similar way, to the fact that scientists solve problems by allowing them to familiarize themselves with scientific work and acquire a procedural understanding of science. Nevertheless, Couso (2014) considers that, from this point of view, taking the inquiry to the science classroom highlights, the importance of making students understand the nature of science from their participation in scientific practices as authentic as possible.

In Europe, since the publication of Science Education Now (Rocard, 2007), numerous pedagogical proposals have emerged focusing on inquiry-based science teaching. According to NRC (2000, p. 1) "… yet the activities and thinking processes used by scientists are not always familiar to the educator seeking to introduce inquiry into the classroom", therefore, there is a need to train pre-school and primary school teachers in inquiry skills. In this way Mosquera, Puig & Blanco (2018, p. 9) point out "the identification of questions and concepts that guide scientific research, its design and implementation, formulation of scientific explanations, recognition and analysis of explanations and alternative models, as well as the communication and defense of a scientific argument".

Thus, the purpose of this study is to implement inquiry as a teaching-learning strategy for science in the Preservice Elementary Science Teachers (PSESTs) training. Lee and Shea (2016) have shown how the understanding of inquiry-based teaching of the PSESTs increases after a training programme, being this program a key step in developing their confidence and effectiveness in science teaching. The aim of this paper is to evaluate the scientific research views of the PSESTs as a starting point to develop an inquiry-based training programme.

METHODS

The sample of this study consisted of 53 PSESTs from the Maria Inmaculada Teacher Training Centre at the University of Malaga (Malaga, Spain). 52.8% were women and 47.1% were men. 85% had not taken a baccalaureate in science, so their last contact with formal training in science had been 5 years earlier.

The data collection instrument was the international and validated VASI (Views About Scientific Inquiry) questionnaire (Lederman et al., 2014), which was translated and adapted into Spanish. The VASI questionnaire is conceived by the authors as a powerful tool to evaluate students' conceptions of essential aspects of scientific inquiry, in line with the vision established in the next generation science standards (Lederman et al. 2014, p. 65). These conceptions refer to 8 dimensions:

> "(1) scientific investigations all begin with a question and do not necessarily test a hypothesis; (2) there is no single set of steps followed in all investigations (i.e. there is no single scientific method); (3) inquiry procedures are guided by the question asked; (4) all scientists performing the same procedures may not get the same results; (5) inquiry procedures can influence results; (6) research conclusions must be consistent with the data collected; (7) scientific data are not the same as scientific evidence; and that (8) explanations are developed from a combination of collected data and what is already known." (Lederman et al., 2014, p. 68).

Initially this questionnaire was used to assess the vision of scientific research by students with at least 6th grade (middle school) reading and writing ability, but can be appropriately applied to college level students too (Lederman et al., 2019).

The objective of this paper is to test the first dimension of the VASI questionnaire in Spain with PSESTs and analyze the first results. This dimension is assessed in the VASI questionnaire with items 1.a), 1.b) and 2). The statements of these items are included in Table 1.

Table 1. Statements of items 1.a), 1.b) y 2) of the VASI questionnaire (Lederman et al., 2014).

A person interested in birds looked at hundreds of different types of birds who eat different types of food. He noticed that birds who eat similar types of food, tended to have similar shaped beaks. For example, birds that eat hard-shelled nuts have short, strong beaks, and birds that eat insects have long, slim beaks. He wondered if the shape of a bird's beak was related to the type of food the bird eats and he began to collect data to answer that question. He concluded that there is a relationship between beak shape and the type of food birds eat.

1.a) Do you consider this person's investigation to be scientific? Please explain why or why not.

1.b) Do you consider this person's investigation to be an experiment? Please explain why or why not.

2. Two students are asked if scientific investigations must always begin with a scientific question. One of the students says "yes" while the other says "no". Whom do you agree with and why?

The aim of item 1.a) is to identify whether or not the experience described was an investigation justifying why, while item 1.b) sought to know whether or not the same experience was an experiment. Item 2 demanded to reason on whether or not scientific research should be based on a question.

These items are open and demand an explanation from the students, hence the importance of building an appropriate rubric. The answers were categorized by authors' consensus, based on the categories proposed by Lederman et al. (2014) and adding more levels (called "our levels" in Table 2) to adequately address the range of answers offered by the PSESTs. The criteria used to sequence the performance levels of the answers were: a) to assess the presence or absence of an explanation and b) to assess the degree to which the explanations provided were closer to the most accepted ideas on the aspect asked.

The statistical treatment of the data obtained was performed with the SPSS 21.0 programme. The mean and median were calculated for each of the items analyzed and the variables studied, sex and scientific backing. The existence of statistically significant differences according to sex and the existence, or not, of previous scientific training was studied using the non parametric Mann-Whitney U test.

RESULTS

Table 2 shows the system of categories used, their relationship with the categories of Lederman et al. (2014) and the percentages of responses recorded. For each of the levels used in this study the criteria for categorizing the responses of the PSESTs are indicated and illustrated with an example of them.

88.6% of the PSESTs (levels 2, 3 and 4) considered in item 1.a) that the experience described was an investigation, and being 26.4% at the most appropriate level when indicating, in addition, two or more important aspects of the investigation.

For item 1.b), 67.9% of the responses were at levels 0 and 1, the most inadequate levels, showing that PSESTs confuse research with experiment. Only 13.2% were able to relate an experiment with variable control.

Table 2. Relationship between items, concordance of evaluation rubrics, examples and results obtained.

Item	Rubrics: Lederman et al. (2014) level	Our level	Criterion	Example	(%)
1.a) Do you consider this person's investigation to be scientific? Please explain why or why not.	Naïve	0	Yes or no without explanation.	Yes.	5.7
		1	No with explanation.	No, because he has conducted scientific experiments to validate his hypothesis.	5.7
	Transitional	2	Yes with some vague or imprecise explanation of the research aspects.	Yes, because research has a basis.	26.4
	Informed	3	Yes, indicating an important research aspect	Yes, because one investigates something with analysis and tests.	35.8
		4	Yes, indicating two or more important research aspects.	Yes, because for a period of time he has been observing and taking data to reach the conclusion that there is a relationship between the types of peaks and the type of feeding they have.	26.4
1.b) Do you consider this person's investigation to be an experiment? Please explain why or why not.	Naïve	0	Yes or no without explanation	Yes.	11.3
		1	Yes or no with some vague and imprecise explanation.	Yes, for he experiments with birds.	56.6
	Transitional	2	No, indicating that observation/data collection are different things from an experiment.	No, since he has only collected information.	18.9
	Informed	3	No, relating an experiment with variable control (intervenes, modifies, etc.) or with an alteration of reality	No, whereas it has not included factors that alter or modify the object of study.	13.2
2. Two students are asked if scientific investigations must always begin with a scientific question. One of the students says "yes" while the other says "no". Whom do you agree with and why?	Naïve	0	Yes or no without explanation	Yes.	11.3
		1	No with explanation.	Yes, since everything must start from something.	62.3
	Transitional	2	Yes, with some vague or imprecise explanation about the research questions.	There is no level example 2.	0.0
		3	Yes, mentioning some important research aspects.	Yes, because in order to investigate something you have to start from a question and get more information.	13.2
	Informed	4	Yes and give a meaning to the research question.	I agree with the boy who says yes, since for me all research starts from a concern and starts looking for a reason to some internal question of the individual.	13.2

Regarding item 2, 73.6% were in the least adequate levels (0 and 1). At the most appropriate level, which gives meaning to the research question, only 13.2% of the PSESTs were at this last one.

Table 3 shows the results for the variables studied. No statistically significant differences were found for the variables sex (Z = -1.637; p = 0.102) and previous scientific training (Z = -1.019; p = 0.308) in any of the three items.

Table 3. Results for items 1.a, 1.b. and 2, mean, median and Mann Whitney U test, depending on the variables studied.

Item	**Sex**				**Scientific backing**			
	Mean / Median		**Mann Whitney U Test**		**Mean / Median**		**Mann Whitney U Test**	
	Women (N=28)	**Men (N=25)**	**Z**	**p-value**	**Scientific (N=11)**	**Non-scientific (N=42)**	**Z**	**p-value**
1.a)	2.50 / 3	2.96 / 3	-1.637	0.102	2.45 / 3	2.79 / 3	-1.019	0.308
1.b)	1.29 / 1	1.40 / 1	-0.406	0.685	0.91 / 1	1.45 / 1	-1.817	0.069
2.	1.61 / 1	1.48 / 1	-0.103	0.918	1.36 / 1	1.60 / 1	-0.417	0.677

CONCLUSIONS

The results obtained are in accordance with those found by Lederman et al. (2019) for Spanish students at the end of primary school. According to the authors "the Spanish students hold a naïve understanding for all the aspect of scientific inquiry" (p. 30) and attribute this situation to the teaching methods and content in which scientific inquiry is lacking as relevant scientific curriculum content. They also point out, among others things, the lack of explicit and reflective teaching and the lack of effective teaching approaches to the teaching of scientific research.

The results obtained shows that it is necessary to address with the PSESTs an explicit treatment on research aspects, oriented to differentiate between a research and an experiment and to recognize that research requires to start from a question formulated in a clear and precise way, and so is the sense that this question has for the research.

These and other aspects will be attempted by designing a training program for PSESTs.

ACKNOWLEDGEMENTS

This work was supported by the Spanish government through it 2017 research calls [EDU2017-82197-P, R&D Project].

REFERENCES

Caamaño, A. (2012). ¿Cómo introducir la indagación en el aula? *Alambique, Didáctica de las Ciencias Experimentales, 70*, 83-92.

Couso, D. (2014). De la moda de "aprender indagando" a la indagación para modelizar: una reflexión crítica. En M. A. De las Heras, A. A. Lorca, B. Vázquez, A. M. Wamba & R. Jiménez (Coords.), Conferencia plenaria inaugural en *XXVI Encuentro de Didáctica de las Ciencias Experimentales*. Huelva: Universidad de Huelva.

European Commission (Ed.). (2007). *Science education now: A renewed pedagogy for the future of Europe*. Brussels: European Commission Directorate-General for Research. Retrieved from https://bit.ly/2FDAAWN.

Lederman, J. S., Lederman, N. G., Bartos, S. A., Bartels, S. L., Meyer, A. A., & Schwartz, R. S. (2014). Meaningful assessment of learners' understandings about scientific inquiry—The views about scientific inquiry (VASI) questionnaire. *Journal of Research in Science Teaching, 51*(1), 65-83.

Lederman, J., Lederman, N., Bartels, S., Jimenez, J., Akubo, M., Aly, S., ... Zhou, Q. (2019). An international collaborative investigation of beginning seventh grade students' understandings of scientific inquiry: Establishing a baseline. *Journal of Research in Science Teaching*, 56(4), 486-515.

Lee, C. K., & Shea, M. (2016). An Analysis of Pre-service Elementary Teachers' Understanding of Inquiry-based Science Teaching. *Science Education International, 27*(2), 217-237.

Mosquera Bargiela, I., Puig, B., & Blanco Anaya, P. (2018). Las prácticas científicas en infantil Una aproximación al análisis del currículum y planes de formación del profesorado de Galicia. *Enseñanza de las Ciencias, 36*(1), 7-23.

National Research Council [NRC] (1996). *National science education standards*. Washington, DC: National Academy Press.

National Research Council [NRC] (2000). *Inquiry and the national science education standards: A guide for Teaching and Learning*. Washington, DC: National Academy Press.

PRE-SERVICE SCIENCE TEACHERS' CONCEPTIONS ON SCIENTIFIC INQUIRY: A PRACTICAL EXPERIENCE

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Abstract: The following study presents the analysis of the conceptions of 40 future teachers when they are presented with a practical case related to the thermal properties of materials. This case is proposed as an experimental activity in which students must develop and reflect on the strategies of scientific research processes. For this, they are induced to explain: 1. The hypothesis from which they start to respond to the predetermined problem, 2. The experimental design to address it, 3. The results and 4. The conclusions obtained. The results indicate the existence of two tendencies, a majority related to common-sense thinking and another more counter-intuitive and scientific to explain natural phenomena.

Keywords: Practical Work in Science, Experiential Learning, Scientific Inquiry; Pre-service Teacher Education

CONTEXT, OBJECTIVE AND THEORETICAL FRAMEWORK

The current reforms in scientific education emphasize the importance of developing an informed understanding of science, its nature and the processes that generate it (that is, scientific research) as fundamental elements for reaching scientific literacy (AAAS, 1993; National Research Council [NRC], 1996; Rocard et al., 2007). Therefore, understanding its nature and the methods that generate it are essential for making appropriate scientific decisions in the social and personal sphere (Lederman, Lederman, & Antink, 2013). These authors suggest the relevance of the Nature of Science (NOS) and Scientific Research also known as Scientific Inquiry (SI) as elements that are related and interact in an important way. Focusing on scientific research, it is known that students and science teachers do not have sophisticated knowledge about science and its practices (Schwartz et al., 2002; Lederman & Lederman, 2004; Lederman, Lederman, & Antink, 2013). One of the reasons is due to the distorted vision that they have about it (Lederman, 2007). The reasons can be diverse e.g., the information provided by the media, the education received, among others. In addition, there are very few studies that systematically evaluate conceptions about this component (Capps, Crawford, & Costas, 2012).

Scientific research is related to scientific processes. In other words, the steps associated with the collection, analysis, and establishment of conclusions in response to one or more problems, but extends beyond the mere fact of developing procedural skills, such as observing, inferring, classify, predict, question, interpret, and analyze data. It also refers to the combination of these processes with scientific knowledge, scientific reasoning and critical thinking to build science (Crawford, 2014). In other words, developing a meta-knowledge about the nature of science and the processes that generate it requires understanding, explicitly and critically, the logic and relationship between the two constructs (Millar, 2004; Schwartz, Lederman, & Crawford, 2004; Lederman, Lederman, Kim, & Ko, 2012).

Our great challenge as researchers and trainers of future Primary Education science teachers is to ensure that learning of a more optimal and functional knowledge about the nature of science and scientific research occurs through non-communicative strategies. We intend, in particular, to facilitate research-based learning, promoting the immersion of students in scientific processes in a cooperative manner. We think that influencing the conceptions of teachers in their initial training is key to achieve it.

The present study was developed in the context of a teacher training course to learn how to teach science, whose educational reference is school teaching research (Porlan et al., 2010, Rivero et al., 2017) and is based on research of fundamental professional problems such as, what is science, what is its nature, how scientific knowledge is built, what science to teach, how to do it, and so on. In this line, we have selected one activity that has been used and described by some authors to study the thermal properties of certain materials (Ariza, Aguirre, Quesada, Abril, & García, 2016a). In our particular case, we intend to examine the conceptions that future science teachers have to develop appropriate training strategies and adjusted to the characteristics of these conceptions. To that end, we have considered curricular reforms and current research as a frame of reference (Rocard et al., 2007; Lederman et al., 2014; Schwartz et al., 2014; Ariza et al., 2016a).

METHODS

The study took place during the academic year 2017-18 in a cohort corresponding to the 2nd year of Primary Education Degree in the subject of Experimental Science Didactics at the University of Seville, Spain. Participants were a group of 40 students whose average age is in their 20s, although the range is between 18 and 37 years old. The majority of students are females (62.5% of the cohort). They were grouped into working groups of three and five participants each in order to be able to address the case. At the moment in which this content topic was developed, students have already completed others related courses based on content knowledge (Fundamentals I and II of Natural Sciences, and Fundamentals of Matter Sciences) and with some courses addressing pedagogical knowledge (General Teaching, Basic Sociological Processes in Education and Educational Psychology), although they have not yet completed Teaching Practices or practicum sessions at schools.

For the study, a qualitative research design was carried out framed in a descriptive and interpretative paradigm (Creswell, 2013) to examine the understanding of future science teachers of the University of Seville. In relation to the data collection and data analysis, the following instrument was used and presented to the students as a case study: After an air accident we made an emergency landing in the Sahara desert and the flight attendants told us that the plane carried some very valuable and important medicines that we have to protect at all costs while we wait for the rescue. For this, we have wool cloths and metal pots. How do you think we can get the medicines to stay as cold as possible? Wrapping them with wool? Putting them in the pots? Using something else? Once the case was exposed, students should try to explain to the rest of the classmates the hypotheses suggested by this case. The information was collected as a personal report of the activity. Next, they had to design the procedures that they consider necessary to verify their hypotheses. Materials were available for the students in order to carry out investigations that allow them to test their hypotheses. Afterward, they have to explain the detail of the results and conclusions obtained before and after the discussion to their classmates. In total, we have 40 personal reports on the experience.

With respect to the analysis of information, we identified and classified units of information relevant to the construction of propositions that summarize, in an organized manner, the aspects investigated; Hypothesis (H), Experimental Design, (D) Results and Conclusions (C). The categorization has been made according to the degree of complexity of the answers. That is, the minimum value of 1 would correspond to a level of formulation of knowledge more naive or less sophisticated and the value 4, the level of greater complexity or reference. In this line we have for the category "Hypothesis" the levels H1, H2, H3, and H4; for the category "Experimental design" (D) we have the levels D1, D2, D3, and D4 and for the category "Results-Conclusions" we have the levels C1, C2, C3, and C4. Levels 2 and 3 correspond to intermediate or transitional values between extreme levels 1 and 4. Finally, the categories have been validated through triangulation processes among several researchers. Two researchers have performed the analysis of the responses separately so that at least 80% agreement is reached. In addition, to manage this task, we have helped with the ATLAS.ti, V.8 program.

RESULTS

After the analysis of data, the results by categories are the followings:

Hypothesis (H)

Regarding this aspect, we detected a group of future teachers (12.5%) who consider metal as the most suitable material for preserving the medications (H1). They justify their choice without arguing it or with naive arguments and based on every day and sensory perceptions. Some examples:

> [If we put the medications] inside the metal pot, the medications will be kept (Student 15, Hypothesis level 1, E15.H1).
>
> [If we put the medications] inside metal, [then] the cold will be preserved because the wool produces heat (E39.H1).

On the other hand, 52.5% of the students believe that the combination of the metal plus wool would allow them to be better preserved the medications (H2). Some of them reveal tautological reasoning to defend their choice. In other cases, they think that both materials behave similarly and together they are enhanced, acting as a kind of barrier to heat; or they believe that the final effect of both materials is similar, although for different reasons: wool insulates from heat and metal retains cold.

> [If we put the medicines] inside the metal saucepan, we wrap it in wool and close it with polystyrene foam, [then] the ice will last longer, so they will be better preserved (E5.H2).
>
> [If we put the medicines] in the metal pot wrapped with wool [then] when protected from the heat they do not melt and are preserved (E27.H2).
>
> [If we put the medicines] in wool and in the shaded saucepan [then] the medicines will remain cold because the wool does not allow heat to pass and the saucepan is a cold container, so it keeps the cold (E7.H2).

Finally, we identify 35% of the students who choose wool as the most suitable material, contributing arguments of science (wool is an insulating material, or wool is insulating, and metal is conductive, recognized the latter only by a student of this group) (H3):

> I think the best way to keep medications cold is to insulate them with wool because it is a very good thermal insulator since we are in the desert (E8.H3).
>
> Wrapped in wool, then the medicine will be better preserved than in the container. If the medicines are wrapped in wool, a non-conductive material, the ice will be better preserved than if it were in direct contact with the metal, conductive surface. (E32.H3)

Experimental design (D)

Regarding the experimental design, we identified a large group of students (57.3%) that carried out a unique experience to obtain tests. Among them, we identify those who carry out an experimental design in an inconsistent or independent way from the starting hypothesis (10 %) and another group of students, majority, who do experience incoherence or dependent on it (47.3 %). We have defined the first case as Design level 1 (D1) and, the second, level 2 (D2). Let's see some examples:

> Hypothesis: they are better preserved medically in the saucepan, which keeps the cold]: Design: We have taken the ice, we have put it in the metal saucepan, we have wrapped it in wool and polystyrene foam so that it does not escape. Burying it in moist soil could benefit the one that does not melt the ice (Student 3. Level 1 design, D1.)
>
> [Hypothesis: they are better preserved with both the dipper and the wool]: Design: To preserve the medications well we have thought about taking the metal saucepan and introducing the ice in the saucepan and closing it. When closing it, we took a wool coil and wrapped the wool dipper (E14.D2.)

On the other hand, we detect another group (37.5 %) that performs two or more experiences, trying to develop some control of variables, but in whole or in part inconsistent or independent of their hypothesis –D3-. Let's see an example:

> [Hypothesis: you have to use wool, which is insulating]: Design: In principle, we have decided to make two proposals: 1. Wrap the ice cube in wool and leave it in the open air. 2. Wrap the ice in wool and, in turn, put it in the aluminum dipper (E4.D3.)

And 5% of students design two or more experiences consistent with their hypotheses for obtaining results (D4):

[Hypothesis: you have to use the wool that is insulating. Design: To test the hypothesis, we make two checks: first, we wrap the ice in wool and, secondly, we put the ice in a metal saucepan (E1.D4.)

[Hypothesis: you have to use the wool that is insulating] Design: We take a piece of ice and put it in the metal dipper. The other piece is wrapped in wool. We also put a piece on the outside and another wrapped in wool and, in turn, inside the saucepan. After a few minutes, we see which piece of ice keeps the temperature the most (E2.D4.)

Results and Conclusions (C)

Regarding this category, 32.5 % of the students express their conclusions in an inconsistent/independent manner of the results they have obtained.

[Hypothesis: the combination of the two materials. Design: ice inside the dipper and the dipper wrapped in wool]. Results and Conclusions: the ice has melted after a while. We accept the hypothesis because it is conserved for a long time, but with difficulty because it melts for a long period. (Student 3, E3. Level 1, C1 conclusions)

[Hypothesis: wool must be used, which is insulating. Design: Ice inside the saucepan and wrapped all in wool]. Results and Conclusions: After 25-30 min we have returned the saucepan and we have observed that the ice remained, although they had melted a little, so we believe that at the time they would end up melting completely. Our theory has worked partially since wool has not been a good insulator (E24.C1)

On the other hand, 47.5% do develop conclusions that are more or less consistent or dependent on the results obtained (C2). However, the conclusions are made based only partially on the initial assumptions or the results obtained:

Hypothesis: You have to use wool, which is insulating. Design: Two experiences: ice wrapped in wool and ice wrapped in wool and introduced in the saucepan]. Results and Conclusions: In the end, we have verified that the wool-wrapped medicines are better preserved than those with wool in the aluminum saucepan. This occurs because wool is a very good insulator (E4.C2).

Finally, 20% of students develop conclusions consistent with the experiences and results obtained (C3). Let's see some examples:

[Hypothesis: You have to use wool, which is insulating. Design: Two experiences: ice wrapped in wool and ice introduced in the saucepan]. Results and Conclusions: The ice wrapped in wool does not melt, however, the ice in the metal saucepan does. We approve that wool is a thermal insulator and metal is not. (E1.C3)

[Hypothesis: You have to use wool, which is insulating. Design: Four experiences: ice wrapped in wool, ice introduced in the saucepan, ice in the air, ice wrapped in wool and introduced in the saucepan]. Results and Conclusions: Those who were wrapped in wool have maintained their temperature more than those who were not. Wool is a good thermal insulator; it helps the body maintain its temperature. Metal, on the other hand, is a conductor of energy, so the temperature varies, increases. (E2.C3)

CONCLUSIONS

It seems, then, that there is a majority group of future teachers who present common sense thought in front of another group that presents a counter-intuitive and scientific thought (Yu & Cole, 2014). Putting them in a position to carry out an investigation allowed to reveal these different levels of thinking and their review by the students themselves, which allowed them to make a solid, although the gradual, approach to the knowledge of reference about the characteristics of scientific research.

We are aware of the complexity of constructing and explaining in a grounded way the nature of this meta-knowledge as suggested by current reforms and paradigms (Millar, 2004; Schwartz, Lederman & Crawford, 2004; Rocard et al., 2007; Lederman, et al., 2012). Teachers will not be able to develop effective and coherent classroom practices with socio-constructivist and research perspectives if they do not have a sophisticated vision and in relation to the epistemological and procedural aspects of scientific research (Schwartz, Lederman and Crawford, 2004; Antink- Meyer, et al., 2016).

The findings suggest that more studies be carried out to analyze the conceptions of science professors when they pursue professional development and teacher research programs, including the understanding of scientific research as a teaching and learning objective and their connection with those strategies that allow improving this knowledge (Capps, Crawford and Constas, 2012).

The purpose of this study has been to examine and improve the conceptions of participating science teachers as a first step to improve teacher training. In a way that allows us to obtain reference data to develop appropriate training strategies and adjusted to the characteristics of said knowledge.

REFERENCES

American Association for the Advancement of Science. (1993). *Benchmarks for science literacy*. New York, NY: Oxford University Press.

Ariza, M.R., Aguirre, D.,Quesada, A., Abril, A.M.,García. F.J. (2016). ¿Lana o metal? Una propuesta de aprendizaje por indagación para el estudio de las propiedades térmicas de materiales comunes. *Revista Electrónica de Enseñanza de las Ciencias*, 15(2), 297-311.

Capps, D. K., Crawford, B. A., & Constas, M. A. (2012). A review of the empirical literature on inquiry professional development: alignment with best practices and a critique of the findings. *Journal of Science Teacher Education*, 23, 291-318

Crawford, B. (2014). From Inquiry to Scientific Practices in the Science Classroom. In N. G. Lederman, & S. K. Abell (Eds.), *Handbook of research on science education, volume II*, (pp. 515–541). New York: Routledge.

Creswell, J.W. (2013). *Qualitative Inquiry & Research Design: Choosing Among the Five Approaches.* Thousand Oaks, CA: SAGE Publications, Inc. (pp. 77-83)

Lederman, J. S., Lederman, N. G., Bartos, S. A., Bartels, S. L., Meyer, A. A., & Schwartz, R. S. (2014). Meaningful assessment of learners' understandings about scientific inquiry- The views about scientific inquiry (VASI) questionnaire. *Journal of Research in Science Teaching*, *51*(1), 65-83.

Lederman, J.S., Lederman, N.G., Kim, B.S. & Ko, E. K. (2012). Teaching and Learning of Nature of Science and Scientific Inquiry: Building Capacity Through Systematic Research-Based Professional Development. In M. Khine (ed), *Advance in Nature of Science Research: Concept and Methodologies*. New York: Springer Dordrecht Heidelberg London, (pp.125-152).

Lederman, N. G. (2007). "Nature of science: Past, present, and future". In *Handbook of research in science education*, Edited by Abell, S. K., and Lederman, N. G. Englewood cliffs, NJ: Erlbaum Publishers.

Lederman, N.G. & Lederman, J.S. (2004). Revising Instruction to Teach Nature of Science. *The Science Teacher, 71* (9): 36-39.

Lederman, N.G., Lederman, J.S., & Antink, A. (2013). Nature of science and scientific inquiry as contexts for the learning of science and achievement of scientific literacy. *International Journal of Education in Mathematics, Science and Technology, 1*(3), 138-147.

Millar, R. (2004). The role of practical work in the teaching and learning of science. Paper prepared for the meeting: High school science laboratories: Role and vision. *National science education standards*. Washington, DC: National Academic Press.

National Research Council (1996). *National science education standards*. Washington, DC: National Academic Press.

Porlán, R., Martín del Pozo, R., Rivero, A., Harres, J.,Azcárate, P., & Pizzato, M. (2010). El cambio del profesorado de ciencias I: Marco teórico y formativo, *Enseñanza de las Ciencias*,28 (1), pp. 31-46.

Rivero, A., Martín del Pozo, R., Solís, E., Azcárate,P., & Porlán, R. (2017). Cambio del conocimiento sobre la enseñanza de las ciencias de futuros maestros. *Enseñanza de las Ciencias* , 35 (1), pp. 29-52.

Rocard, M., Csermely, P., Jorde, D., Lenzen, D., Walwerg Henriksson, H., & Hemmo, V. (2007). *Science Education Now: A Renewed Pedagogy for the Future of Europe. European Commission. Community Research*.

Schwartz, B., Ward, A., Monterosso, J., Lyubomirsky, S., White, K., & Lehman, D. R. (2002). Maximizing versus satisficing: Happiness is a matter of choice. Journal of Personality and Social Psychology, 83(5), 1178-1197

Schwartz, R. S., Lederman, N.G., & Crawford, B. A. (2004). Developing views of nature of science in an authentic context: An explicit approach to bridging the gap between nature of science and science inquiry. *Science Education, 88*, 610-645.

Yu, C. H., & Cole, J. M. (2014). Friend or Foe? Common Sense in Science Education from the Perspective of History and Philosophy of Science, Brit*ish Journal of Education, Society & Behavioural Science*, 4(5), p. 673-690

THE INTEGRATION OF EXPERIMENT DURING IMPLEMENTATION OF INQUIRY-BASED TEACHING

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This study investigates whether pre-service primary teachers can integrate experimental activities into inquiry-based teaching scenarios. Our sample consists of 110 pre-service teachers' teaching scenarios for Electromagnetism; they were collected in the context of an Introductory Didactics of Science Laboratory course in which participants experienced inquiry-based teaching and learning. A Thematic Analysis of the data shows that most pre-service teachers can set teaching objectives in their scenarios which are achievable through experiments. Furthermore, participants can integrate appropriate experimental activities into their scenarios – worksheets, in the context of inquiry-based teaching. Moreover, they suggest experiments in the interpretation and discussion phases. The difficulties faced mostly relate to hypothesis generation. In several scenarios, there is no hypothesis expressed, while in other scenarios only a general question, unrelated to either the research question or the teaching objectives, is expressed in the place of a hypothesis.

Keywords: inquiry-based teaching

INTRODUCTION

Science education has the goal of contributing to scientific literacy, a goal directly related not only to the content of the lessons learned in science classrooms, but also to the didactic methods. The implementation of inquiry-based teaching and learning is considered crucial to improve science education at the international level (Abd-el-Khalick et al., 2004; Dorier & Garcia, 2013; Rocard et al., 2007).Inquiry-based teaching and learning is a method which prioritizes students' questions, ideas and analysis. However, there is a lack of agreement on the meaning of inquiry in the field of science education (Barrow, 2006; Minner et al., 2010)). In a broad sense, the term refers to teaching which follows the procedures involved in the scientific inquiry and the investigation of an open question or problem.

The present study follows the theoretical scheme proposed by Pedaste et al. (2015), which identifies and summarizes the core features of inquiry-based learning by means of a systematic literature and includes the following phases: *orientation, conceptualization, investigation, conclusion and discussion*. Some of these phases are divided into sub-phases; the *conceptualization* phase is divided into two sub-phases: *questioning and hypothesis generation*; the *investigation* phase is divided into three sub-phases: *exploration* and *experimentation* leading to *data interpretation*.

An extensive analysis of the conditions and constraints which might favor or hinder the implementation of inquiry-based learning has been conducted (Dorier & Garcia, 2013). The literature revealed that in most countries, pre-service primary school teachers must be offered sufficient support if they are to overcome their general disinclination towards science and deepen their knowledge so they are in a position to use inquiry-based teaching flexibly in class (Davis et al., 2006; Kim& Tan, 2011; Tseng et al., 2013). A key factor for the successful implementation of inquiry-based learning approaches in science classrooms is the teachers' education (Crawford, 2007; Yoon & Young, 2011; Capps et al. 2013; Tseng, et al., 2013).The literature also supports the assertion that it is not science teacher education alone that makes an inquiry-oriented teacher (Trna, et al., 2012). One of the critical factors influencing a pre-service teacher's intentions and abilities to teach science as inquiry, is their complex set of personal beliefs about teaching and about science (Crawford, 2007: Battacharyya et al., 2009; Kim & Tan 2011; Lebak, 2015). Moreover, pre-service teachers have a lack of knowledge on science process skills and for that reason they often fail when attempting to build a learning sequence based on inquiry (Kim & Tan, 2011; Chabalengula et al., 2012; Binns & Popp, 2013; Capps & Crawford, 2013; Montero-Pau et al., 2017). Thus, a pre-service teacher predisposed to inquiry-oriented teaching will benefit most from science teacher education: learning orientations, past experiences in schools, and experience in teaching and doing science appear to support the critical aspects of an inquiry-oriented science teacher education program (Eick & Reed, 2002; Davis et al., 2006; Kim & Tan, 2011; Binns & Popp, 2013; Garcia – Carmona et al., 2016; Montero – Pau et al., 2017). In this line, in the context of science teacher education programs, there is a need to design inquiry-based activities that will reactivate pre-service teachers' interest in these disciplines.

This is the issue under consideration in this study, which aims to investigate the extent to which pre-service primary teachers are able to design structured, inquiry-based lessons and materials, and specifically, the extent to which they integrate experimentation activities into structured, inquiry-based scenarios, in the context of their science education program. The present study is part of a broader research investigating pre-service teachers' ability to implement inquiry-based teaching in relation to the content knowledge (electromagnetism, mechanics, etc).

RESEARCH METHODOLOGY

Fieldwork was carried out in Athens, at the Department of Primary Education of the National and Kapodistrian University of Athens during the spring semester of 2017-2018.

The Sample

The sample consisted of 110 pre-service teachers' teaching scenarios of Electromagnetism, developed in the context of an Introductory Didactics of Science Laboratory Course (IDSLC). Participants were selected due to convenient access. Learners were divided into five classes of 22 persons whose members worked in pairs. The IDSLC comprised of four independent two-hour laboratory exercises once a week: 1) teaching NoS, 2) electromagnetism, 3) photosynthesis and 4) heat. Pre-service teachers had inquiry-based learning experiences during the four laboratory exercises. In particular, the aim of the second laboratory exercise was pre-service teachers to experimentally determine the relationship between electricity and magnetism and conceptualize the working principles of electric motors and electromagnets. As part of their final assessment, participants were asked to develop four inquiry-based teaching scenarios, including a lesson plan and the related work sheets, that corresponded to the content knowledge of the four laboratory exercises.

Data Analysis

Our data, the teaching scenarios, were analyzed by means of Thematic Analysis, a process which identifies the important issues in the context of qualitative data analysis. It differs from Content Analysis (Vaismoradi, Turunen & Bondas, 2013) in that the results are presented qualitatively with no reference to quantitative data (Guest, 2012 p.11; Maguire & Delahunt, 2017). Thematic Analysis was chosen as it allows for more flexible data analysis and can thus identify relations among the qualitative data elements that derive from the multiple level analysis, irrespective of the sample volume (Nowell, Moules, & Norris, 2017).

Considering that the main aim of this study is to investigate the integration of experimentation in various phases of the inquiry-based Electromagnetism teaching scenarios, the determining and categorizing was performed in the sense of the cross-sectional reference of the main Theme, which is the experimental activities, in the various phases of the inquiry-based teaching scenario.

Therefore, the Themes are formulated as follows:

1st Theme: Experimental activities – Research question / Teaching objectives; this refers to whether the teaching objectives could be achieved through the proposed experimental activities.

2nd Theme: Experimental activities –Hypothesis; this refers to whether a formulated hypothesis could be experimentally tested.

3rd Theme: Experimental activities – Teaching objectives; this refers to whether, and to what extent, the proposed experimental activities play a role in the achievement of the teaching objectives, either implicitly or explicitly. Such analysis enables further investigation of the relationship between the proposed experimental activities and the implicit or explicit objectives.

4th Theme: Experimental activities –Interpretation of results; this refers to whether, and to what extent, experimental activities were suggested during the result interpretation and discussion phases.

Considering the important role experimentation plays in inquiry-based learning approaches within science education, further research into how the experiments are presented in the worksheets – scenarios designed by pre-service teachers has been conducted. Importance was given to whether actual experimental activities were suggested, or experimental activities were limited to images, software or video. Finally, an attempt was made to interrelate the results from certain Themes.

RESULTS

1st Theme :Experimental activities related to Research question / Teaching objectives: most pre-service teachers could set at least one teaching objective related to proposed experimental activities. One of the most popular topics that pre-service teachers set as teaching objective in their scenarios, was the construction and explanation of the generator, while the construction and explanation of electromotor was less popular.

2nd Theme: Experimental activities related to Hypothesis: in most teaching scenarios, no hypothesis was formulated before experimentation. For example, a pre-service teacher (PST 58) in his scenario asked students to make the experiment in order to determine what happens when a compass approaches a wire with electric current, without asking them to make an initial hypothesis on the phenomenon under consideration. There were a considerable number of scenarios in which the formulated hypothesis was strongly related to the research question and the experimental activities that followed. In a very few scenarios, instead of a hypothesis, a question was set which related to neither the research question nor the teaching objectives and was supposed to aid orientation. For example, a pre-service teacher (PST 45) included in his scenario the question "why we use the compound word electromagnetism instead of the two separate words electricity and magnetism". This is a question that may help motivate students to think about the topic under discussion, but it is not a hypothesis.
3rd Theme: Experimental activities related to Teaching objectives: most of the teaching scenarios included experimental activities in the context of inquiry implementation. Such activities were proposed by pre-service teachers with a view to their contributing to structured inquiry and the achievement of the objectives. For example, most pre-service teachers proposed the experimental set up of an electromotor in order to teach how electrical energy is converted to mechanical energy.
4th Theme: Experimental activities related to Interpretation of results: some pre-service teachers included in their scenarios experimental activities into the results interpretation phase, mainly suggesting videotaped experiments. Most of these scenarios were related either to the electric motor or to the electromagnet.

CONCLUSIONS

Teaching science by inquiry in primary education has been one of the biggest challenges in science education for many years. One of the main obstacles is the education of pre-service teachers. This study sets out to investigate the extent to which pre-service primary teachers are able to design structured inquiry-based teaching scenarios and, specifically, the extent to which they integrate experimentation activities into the context of their science education program. The initial findings show that the majority of the pre-service teachers could both set teaching objectives achievable through experimental activities and propose well-targeted experimental activities in order to guide "their students" through the scenario to achieve their learning objectives. Some pre-service teachers proposed the use of videotaped experiments in the result interpretation phase, too.
Regarding their difficulties, the analysis of the scenarios revealed that the majority of pre-service teachers faced difficulties during the hypothesis formulation phase (Kim &. Tan, 2011). Some of them did not include a hypothesis phase in their scenario posing a general question. It seems that pre-service teachers do not value the hypothesis formulation phase as important in the context of inquiry-based teaching and learning procedure. While they give emphasis on experimental activities, they do not find hypothesis as conceptual preparation of the experimental procedure. They find experiment important "per se", an idea that is not in line with the nature of scientific investigation. In addition, in some teaching scenarios difficulties arose with the implementation of experimental activities which were incompletely presented. Some pre-service teachers had difficulties in determining the variables, so they failed to

articulate the experimental process clearly in the students' sheets. Such difficulties show pre-service teachers' limited level of knowledge on science process skills (Lee & Shea, 2016; Montero-Pau et al., 2017).

Finally, in the overwhelming majority of the pre-service teachers' scenarios most the inquiry-based teaching phases were included whereas in some of them the phases were incomplete and in some others the phases were not clearly distinguished.

Further research in the field could shed light to pre-service teachers' ability to implement inquiry-based teaching in relation to the content knowledge: Does the specific subject, eg electromagnetism, heat, photosynthesis, etc affect pre-service students' ability in implementing inquiry-based teaching? Are there topics that pre-service teachers prefer implementing inquiry-based teaching to others and what are their specific characteristics?

Although most pre-service students managed to keep almost all the phases of the inquiry, this does not guarantee that the teaching scenario is inquiry-based. The reason for that is that the authentic development of scientific research is more complicated than implementing the steps. Overall, our results provide evidence that pre-service primary teachers need more training in science process skills.

REFERENCES

Abd-el-Khalick, F., Boujaoude, S., Duschl, R., Ledermann, N. G., Mamlok-Naaman, R.,&Hofstein, A. (2004). Inquiry in science education: International perspectives. *Science Education*,*88*(3)*,* 398–419.doi.org/10.1007/s11858-013-0512-8

Barrow. L. (2006). A Brief History of Inquiry from Dewey to Standards. *Journal of Science Teacher Education*,*17*(3),265-278.doi.org/10.1007/s10972-006-9008-5

Battacharyya, S., Volke, T. & Lumpe, A. (2009). The Influence of an Extensive Inquiry-Based Field Experience on Pre-service Elementary Student Teachers' Science Teaching Beliefs. *Journal of Science Teacher Education,* 20 (3), 199-218.. doi10.1007/s 10972-009-9129-8

Binns, I. & Popp, S. (2013). Learning to Teach Science Through Inquiry: Experiences of Pre-service Teachers. *Electronic Journal of Science Education,* 17(1), 1-24

Capps, D. K. & Crawford, B. A. (2013). Inquiry-based instruction and teaching about nature of science: Are they happening? *Journal of Science Teacher Education,* 24(3), 497-526. Doi.org 101007/510972-012-9314-7

Capps, D.K., Crawford, B.A. & Constas, M.A. (2012). A review of empirical literature on inquiry professional development: Alignment with best practices and a critique of the findings. *Journal of Science Teacher Education,* 23, 291-318

Chabalengula, V.M., Mumba, F. &Mbewe, S. (2012). How Pre-service Teachers' Understand and Perform Science Process Skills. *Eurasia Journal of Mathematics, Science and Technology Education,* 8(3), 167-176

Crawford, B. A. (2007). Learning to teach science as inquiry in the rough and tumble of practice. *Journal of Research in Science Teaching,* 44, 613-642

Dorier, J., & Garcia, F. J. (2013). Challenges and opportunities for the implementation of inquiry-based learning inday-to-day teaching.*The International Journal on Mathematics Education, 45*(6), 837-849.doi.org/10.1007/s11858-013-0512-8

Eick, C.,& Reed, C. (2002). What Makes an Inquiry-Oriented Science Teacher? The Influence of Learning Historieson Student Teacher Role Identity and Practice. *Science Education*, *86,* 401–416.doi.org/10.1002/sce.10020

Garcia - Carmona, A., Criado, A.M. & Cruz – Guzman, M. (2016). Primary pre-service teachers' skills in planning a guided scientific inquiry. *Research in Science Education,* 1-22

Guest, G. (2012). *Applied thematic analysis.* Thousand Oaks, California: Sage

Kim, M. &Tan, A. L. (2011). Rethinking difficulties of teaching inquiry-based practical work stories from elementary pre-service teachers. *International Journal of Science Education,* 33(4), 465-486

Lebak, K. (2015). Unpacking the complex relationship between beliefs, practice, and change related to inquiry-based instruction of one science teacher. *Journal of Science Teacher Education,* 26(8), 695-713 doi.org/101007/510972-015-9445-0

Lee, C. & Shea, M. (2016). An Analysis of Pre-service Elementary Teachers' Understanding of Inquiry-based Science Teaching. *Science Education International,* 27(2), 219-237

Maguire, M.,& Delahunt, B. (2017). Doing a Thematic Analysis: A Practical Step-by- Step Guide for Learning andTeaching Scholars. *AISHE-J: The All Ireland Journal of Teaching and Learning in Higher Education, 9* (3),33501-33514.Retrieved from http://ojs.aishe.org/index.php/aishe-j/article/view/335

Minner, D. D., Levy, A. J. & Century, J. (2010). Inquiry-based science instruction. What is it and does it matter? Results from a research synthesis years 1984-2002. *Journal of Research in Science Teaching,* 47 (4), 474-496. Doi.10.1002/tea.20347

Montero-Pau, J., Tierno, S. P. &Tuzon, P. (2017). Are pre-service Primary Schools teachers prepared to teach science by Inquiry? *Proceedings of 3rd International Conference on Higher Education Advances, HEA'd,* 1294-301, Vlencia, 2017. Doi.org/10.4995/HEAd 17.2017.5586

Nowell, L., Moules, N.,& Norris, J. (2017). Thematic Analysis: Striving to Meet the Trustworthiness Criteria. *International Journal of Qualitative Methods, 16*, 1-13.doi.org/10.1177/1609406917733847

Pedaste, M., Mäeots, M., Siiman, L., Jong, T., van Riesen, S., Kamp, E., Manoli, C., Zacharia, Z., &Tsourlidaki, E. (2015). Phases of inquiry-based learning: Definitions and the inquiry cycle. *Educational Research Review,14*, 47-61.doi.org/10.1016/j.edurev.2015.02.003

Prince, M.,& Felder, R., (2007). The many faces of Inductive Teaching and Learning. *Journal of College ScienceTeaching, 36*(5)*,* 14-20.Retrievedfrom http://www.jstor.org/stable/42992681

Rocard, M., Csermely, P., Jorde, D., Lenzen, D., Walberg-Henriksson, H., &Hemmo, V. (2007). Science Education NOW: A renewed Pedagogy for the Future of Europe. Brussels: European Commission. Retrieved fromhttps://ec.europa.eu/research/science-society/document_library/pdf_06/report-rocard-on-science-education_en.pdf

Trna, J., Trnova, E. & Sibor (2012). Implementation of inquiry-based science education in science teacher training. *Journal of Educational and Instructional Studies in the World,* 2(4), 199-209

Tseng, C. H., Tuan, H. L., Chin, C. C. (2013). How to help teachers develop inquiry teaching: Perspectives from experienced science educators. *Research in Science Education ,* 43(2), 809-825

Vaismoradi, M., Turunen, H.,&Bondas, T. (2013). Content analysis and thematic analysis: Implications for conducting a qualitative descriptive study. *Nursing and Health Sciences*, *15*(3)*,* 398-405. doi.org/10.1111/nhs.12048

Yoon, H-G, &Joung, Y. J. (2011). The challenges of Science Inquiry Teaching for pre-service teachers in elementary classrooms: Difficulties in and under the Scene. *Research in Science Education ,* 42(3), 589-608

PRESCHOOL TEACHER STUDENTS VIEWS'S INFLUENCE ON THEIR INTENTION TO USE TAUHGT INQUIRY METHODS

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In this research we investigated preschool teacher students' views that could possibly influence their intention to use inquiry methods, which they have been taught during a one-semester laboratory-type course, concerning concepts of science and their teaching methods. During this inquiry-based course, the teacher students (N=17) participated in several experiments concerning phenomena that are usually negotiated in the frame of preschool education, e.g., floating – sinking, magnets, air properties, etc. Moreover, the teacher students were explicitly taught the reasoning of the Control of Variables Strategy (CVS), as one of the course's goals was to provide understanding of aspects of the inquiry method. According to Ajzen & Fishbein's theory, our hypothesis was that teacher students' intention to use this taught method (CVS) in their classes as preschool teachers, depends also on teacher students' views about specific categories of social factors: (a) personal gains and losses, (b) important people that would approve or disapprove, and (c) personal features that would help or impede them. A six-task questionnaire was used to investigate teacher students' intention to use CVS method in their classes, at their first teaching year, focusing on the three aforementioned categories of social factors. Data were analyzed initially through a bottom-up approach, taking into account the answers of the teacher students, and afterwards using a K-means Cluster Analysis. The results have revealed three independent teaching professional profiles.

Keywords: teacher preparation, social interaction, inquiry-based teaching

INTRODUCTION

Current guidelines for effective instruction in science education suggest teaching both with and about the procedure scientists follow in their experimentation and scientific practices such as the Control of Variables Strategy (CVS), a method for designing and implementing fair experiments in order to test a variable's influence on a phenomenon (Chen & Klahr, 1999). Moreover, students of all ages confront difficulties with scientific reasoning pertained to CVS, such as hesitancy to make inferences from data, failure to realize that the value of a variable must be changed to test its impact and failure to recognize the need of controlling the rest of the variables (Boudreaux, Shaffer, Heron & McDermott, 2008; NRC, 2012).

There is evidence that explicit teaching of experimentation reasoning of the CVS method is necessary for a holistic understanding of the method (Lorch et al., 2010; Zoupidis, Strangas & Kariotoglou, 2017). Educating teachers such a way focuses on the expectation that they could spontaneously include such teaching approaches, when they will get started on their own teaching implementations. However, this expectation seems to be degraded when it is about teaching science content, because of preschool teachers' broader hesitant stance with regards to science and its instruction (Andersson, Gullberg, Danielsson, Scantlebury, & Hussénius, 2019).

One of the most influential and popular conceptual frameworks for the study of human action is the theory of planned behavior (Ajzen & Fishbein, 2001; Ajzen, 2002). According to the planned behavior theory, human behavior is guided by three kinds of considerations: (a) beliefs about the likely consequences or other attributes of the behavior (personal gains or losses), (b) beliefs about the normative expectations of other people (important people that would approve or disapprove), and (c) beliefs about the presence of factors that may further or hinder performance of the behavior (personal features that would help or impede them from doing so). The first consideration, attitude beliefs, produces a favorable or unfavorable attitude towards the behavior. The second consideration, normative beliefs, result in perceived social pressure and the third consideration, control beliefs, give rise to the perceived ease or difficulty of performing the behavior (Ajzen, 2002). In combination, all three considerations lead to the formation of a behavioral intention, which is expected to be carried out when the opportunity arises.

RATIONALE

Following the trends described in introduction, preschool education teacher students in the focal University usually follow a science laboratory lesson, during which the teacher students have the opportunity to design and implement several experiments concerning phenomena that are usually negotiated in the frame of preschool education, e.g., floating – sinking, magnets, air properties, etc. In parallel, the teacher students are explicitly taught aspects of the experimentation reasoning, such as the CVS method. The results of this approach concerning the understanding of the method have been proved to be positive (Zoupidis, Strangas & Kariotoglou, 2017).

Following though Ajzen & Fishbein's (2001) (A-F) framework, we hypothesized that the intention of the preschool teacher students to use the taught CVS method when they design and implement teaching scenarios for science education issues is influenced by social factors such as personal gains and losses (attitude beliefs), important people that would approve or disapprove (normative beliefs), and personal features that would help or impede them (control beliefs), from using the CVS method. In short, we think that the question, if and how preschool teacher students would use CVS method in their classes, is still an open question and that an answer to this question, even in a primary level, would be convenient in the sense that it could influence our teaching practices (Andersson & Gullberg, 2014).

METHOD

This research has been realized during a university, laboratory-type and inquiry-based course in the frame of the preschool science education. The participants were seventeen second grade teacher students. During the course, the teacher students participated in several inquiry-based experiments concerning phenomena that are usually negotiated in the frame of preschool education, e.g., floating – sinking, magnets, air properties, etc., investigating, among other issues, the variables that could influence those phenomena. Moreover, the teacher students were explicitly taught the reasoning of the Control of Variables Strategy (CVS), as one of the course's goals was to provide understanding of aspects of the inquiry method. For instance, the teacher students had the opportunity to deal with both unconfounded and confounded experiments and to justify their choices during the activities (Figures 1 and 2).

- We sink an object into the water. A colleague claims that « the shape influences floating or sinking of an object, that is cylinder-spape objects sink and sphere-shape objects float». The following four experiments were realized.

	Experiment 1		*Experiment 2*		*Experiment 3*		*Experiment 4*	
Variable	Test1	Test2	Test1	Test2	Test1	Test2	Test1	Test2
Weight	10 g	10 g	10 g	10 g	10 g	100 g	10 g	10 g
Material	foam	iron	foam	foam	foam	iron	foam	iron
Shape	sphere	sphere	sphere	rod	sphere	rod	sphere	rod

Which of the above experiments you think is or are fair to test this claim?
Please justify your answer:

....

....

Why did you exclude the rest of the experiments?

....

....

....

Figure 1. The teacher students are prompted to characterise experiments (fair or unfair) and justify their choices.

« You have in front of you two magnets (bar magnet and horseshoe magnet).
Weigh them on the electronic balance.
The large magnet weighs ....
The small magnet weighs ....
Approach them now to the heap of the clips. Which one attracts more clips? »

Please, propose a change in order the experiment to become fair.

....

....

....

Execute the experiment.

Figure 2. The teacher students are prompted to find the error in the experiment and propose a change in order that the experiment becomes fair.

A six-task questionnaire was used to investigate teacher students' intention to use CVS method in their classes, at their first teaching year, focusing on the three aforementioned categories of social factors. Specifically, attitude beliefs were investigated asking the teacher students about what their personal gains and losses would be if they used the CVS method in their classes, the first year that they would teach. Respectively, teacher students' normative beliefs were investigated asking them the reasons that specific for them important third people would approve or disapprove their teaching choices. Last but not least, teacher students' control beliefs were investigated, asking them to provide their personal features that could help or impede them from successfully implementing such a teaching approach.

Data analysis followed a bottom-up approach (Strauss & Corbin, 1994) taking into account teacher students' answers, so that categories of teacher students' beliefs would be revealed. Afterwards, data were analyzed using K-means Cluster Analysis, scale 1,0 (1: the category is present, 0: the category is absent), which was implemented to partition the teacher students into clusters that present behavioral intention similarity.

RESULTS

The categories of teacher students' beliefs that were revealed from the bottom-up analysis of their answers to the six-task questionnaire are presented in Table 1.

Table 1. The categories of teacher students' beliefs in the three relatively differentiated clusters.

	Cluster1 (17 teacher students)
1. Personal gains	a. Understanding of science, b. Enhance teaching skills, c. Pleasant / efficient classroom climate, d. Satisfaction for helping children
2. Personal losses	a. Time to make them understand, b. Loosing self-confidence lead to frustration or/and discouragement
3. Important thirds approve due to	a. Children's improvement (Parents), b. Understanding of method's importance (Colleagues), c. Emphasis on my strengths and abilities (Relatives), d. My professional development (Relatives)
4. Important thirds disapprove due to	a. Dangerous and excessive method for this age range, b. Not understand method's importance (Colleagues)
5. Personal features that help	a. Patience and perseverance, b. Being methodical, c. Critical thinking / research glance
6. Personal features that impede	a. Classroom management skills, b. Self-management skills

Cluster Analysis was implemented to the data that revealed from the qualitative analysis of the teacher students' answers. The teacher students were partitioned into three relatively differentiated clusters (Table 2). So, according A-F analysis framework, three teaching professional profiles, each corresponding to one of the three clusters, have been revealed.

Table 2. The categories of teacher students' beliefs in the three relatively differentiated clusters.

	Cluster1 (6 teacher students)	Cluster2 (5 teacher students)	Cluster3 (6 teacher students)
1. Personal gains	1a, 1b*	1b, 1c	1a, 1d
2. Personal losses	-	2a	2b
3. Important thirds approve	3a, 3b	3a, 3b	3c, 3d
4. Important thirds disapprove	-	4a	4b
5. Personal features that help	5a	5a, 5b, 5c	5a
6. Personal features that impede	6a	6b	6b

*categories from Table 1

Specifically, six out of seventeen teacher students (cluster1) advocate that the use of the CVS method helps both the teacher and the children to understand science. It also enhances teachers' teaching skills. The method offers recognition from important thirds due to children's improvement and teacher's knowledge and succeeds only through patience and perseverance until the children understand. On the other hand, it has a risk in terms of classroom management.

Five out of seventeen teacher students (cluster2) advocate that CVS method can provide pleasant and efficient classroom climate and also enhances teachers' teaching skills. The method offers recognition from important thirds due to children's improvement and teacher's knowledge. It succeeds through patience and perseverance, being methodic, but also through critical thinking and research glance on the part of the teacher. On the other hand, it takes time to make the children understand, has a risk in terms of self-management issues and could be accused from important thirds that do not know the method for involving the children in dangerous and excessive activities.

Finally, six out of seventeen teacher students (cluster3) advocate that the use of the CVS method helps both the teacher and the children to understand science and provides satisfaction for helping children. The method offers recognition from important thirds due to teacher's abilities and professional development. It succeeds only through patience and perseverance until the children understand. On the other hand, issues of losing self-confidence could appear or important thirds that do not know the method could disapprove the teacher.

DISCUSSION AND IMPLICATIONS

The aim of this research was to investigate teacher students' intention to use CVS method in their classes, at their first teaching year. So, there is a need to connect teacher students' beliefs about social factors (attitude, normative and control beliefs) to their beliefs concerning the use of the CVS method, which they have been taught during the laboratory course. To realize this connection, we use the following analysis framework: (a) their beliefs about their personal gains and losses reveal the direction that teacher students appreciate that the method can get them, (b) the content of important thirds attitude towards the use of the method reveals the positive results or the possible resistance that will show up as a consequence of the use of the method, and (c) from their beliefs about personal features that could further or hinder the use of the method we can recognize the aspects of the method that teacher students appreciate as crucial to its success.

The results have revealed three independent teaching professional profiles. Teacher students that belong in the first profile approach the innovative method as it could simply be implemented in a traditional teaching environment like any other method, without challenging the class. Teacher students belonging in the second profile appreciate the method, recognize and very possibly would strive to provoke traditional teaching environment implementing the method. Finally, teacher students that belong in the third profile perceive the method within a framework that they have the total responsibility of its successful implementation. Each teacher students profile provides important information that could lead to useful teaching implications.

Specifically, the teaching implications that arise from the above analysis are that apart from understanding the CVS method, teacher students should also be helped: a) to distinguish this method from other traditional ones, emphasizing its procedural character, b) to take the risk of sacrificing teaching time in order to succeed introducing such an innovative method, and c) to consent that passing to their students responsibilities to implement the innovation would be pleasant and fruitful for the teaching and learning procedure.

ACKNOWLEDGEMENTS

The research work was partially supported by the Hellenic Foundation for Research and Innovation (H.F.R.I.) under the "First Call for H.F.R.I. Research Projects to support Faculty members and Researchers and the procurement of high-cost research equipment grant" (Project Number: 1828)

REFERENCES

Anderson, K., & Gullberg, A. (2014). What is science in preschool and what do teachers have to know to empower children? *Cultural Studies of Science Education, 9*(2), 275-296. doi:10.1007/s11422-012-9439-6

Anderson, K., Gullberg, A., Danielsson, A., Scantlebury, K., & Hussénius, A. (2019). Chafing borderlands: obstacles for science teaching and learning in preschool teacher education. *Cultural Studies of Science Education,* 1-20. https://doi.org/10.1007/s11422-019-09934-x

Ajzen, I., & Fishbein, M. (2000). Attitudes and the attitude–behavior relation: Reasoned and automatic processes. In W. Stroebe & M. Hewstone (Eds.), *European review of social psychology, 11*, 1–33. Chichester, UK: Wiley.

Ajzen, I. (2002). Perceived behavioral control, self-efficacy, locus of control, and the theory of planned behavior. *Journal of Applied Social Psychology, 32*(4), 665-683.

Zoupidis, A., Strangas, A., & Kariotoglou, P. (2017). The influence of explicit instruction in understanding the control of variables strategy: the case of preschool students. In B.C. Dimov (Ed.), *Education Across Borders: «Education and research across time and space» (pp. 412 – 418)*. Bitola, FYROM: ISBN ISBN 978-9989-100-51-2.

Boudreaux, A., Shaffer, P., Heron, P., & McDermott, L. (2008). Student understanding of control of variables: Deciding whether or not a variable influences the behavior of a system. *American Journal of Physics, 76*(2), 163-170. doi:10.1119/1.2805235

Chen, Z., & Klahr, D. (1999). All other things being equal: acquisition and transfer of the control of variables strategy. *Child Development, 70*(5), 1098-1120.

Lorch, R. F., Lorch, E. P., Calderhead, W. J., Dunlap, E. E., Hodell, E. C., & Freer, B. D. (2010). Learning the control of variables strategy in higher and lower achieving classrooms: Contributions of explicit instruction and experimentation. *Journal of Educational Psychology, 102*, 90–101. doi:10.1037/ a0017972.

National Research Council. (2012). *A framework for K-12 science education: Practices, crosscutting concepts, and core ideas*. Washington, DC: National Academy Press.

Strauss, A., & Corbin, J. (1994). Grounded theory methodology: An overview. In N. Denzin & Y. Lincoln (Eds.), *Handbook of qualitative research* (pp. 273-285). Thousand Oaks, CA: Sage.

PRE-SERVICE SCIENCE TEACHERS' PERCEPTIONS OF HOW THEY LEARN TO FACILITATE INQUIRY-BASED PRACTICAL WORK

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This paper reports on the results of a needs analysis stage of a larger design-based research project on how pre-service teachers learn to facilitate inquiry-based practical work (IBPW) in science classrooms. Using a case study of one university in South Africa, a questionnaire with close-ended question items was completed by 31 final year pre-service science teachers in the postgraduate certificate in education (PGCE) and bachelor of education (BEd) intermediate phase programmes. The concept of opportunities to learn (OTL) was used to guide the experiences measured by the questionnaire. Descriptive statistics, the Mann-Whitney U test and Pearson correlation coefficient were used to analyse the quantitative data. The findings indicated that the pre-service teachers from both programmes brought similar experiences of OTL from school. The PGCE pre-service teachers perceived that the OTL on how to facilitate IBPW were significantly enhanced during tertiary education experiences. However, the intermediate phase pre-service teachers did not perceive that the tertiary education experiences significantly enhanced the OTL how to facilitate IBPW. The study indicates nine positively correlated experiences that present OTL how to facilitate IBPW. A recommendation to increase and diversify OTL how to facilitate IBPW experiences is made.

Keywords: inquiry-based science, pre-service teacher training, practical work in science

INTRODUCTION AND BACKGROUND

There have been widespread adoptions of inquiry-based science teaching by most national science curricula. Crawford (1999) defines inquiry as a process of looking for answers to questions posed using methods similar to the ones used by scientists. Some of the national science curricula that have adopted inquiry-based science include the National Science Education Standards in the US (National Research Council, 1996) and the Curriculum and Assessment Policy Statement (CAPS) for natural sciences and technology as well as CAPS for physical sciences in South Africa (Department of Basic Education, 2011a, 2011b; Ramnarain, 2014). The reform drive is an attempt to address and reverse effects of traditional teaching practices such as rote learning of science (Gaigher, Lederman & Lederman, 2014). Based on the widespread adoptions of inquiry-based science teaching in most national curricula, Tatar (2012) makes an extrapolation that one of the aims of science teacher education is to prepare pre-service teachers for the teaching of science through inquiry. Inquiry-based science teaching is commonly implemented through practical work (Leon, 2015). Millar (2004) points out that practical work facilitated through more open-ended and investigative type approaches develops the learners' tacit knowledge about scientific inquiry.

Research reports on the implementation of inquiry through practical work reflect a practice fraught with challenges (Barrow, 2006; Lunetta, Hofstein & Clough, 2010). Crawford (1999) contends that facilitating inquiry for learners may be challenging even to the most expert of teachers. Sporea and Sporea (2013) and Kidman (2015) contend that not all teachers have been trained in the use of inquiry-based science teaching. Facilitating inquiry through practical work is a specialised teacher task that calls for proper training (Hofstein, 2004). The training may be provided to teachers during initial teacher training programmes. Accordingly, there is a growing body of research that advocates for the inclusion of inquiry-based science teaching modules in the programmes for pre-service teachers (Nivalainen, Asikainen, & Hirvonen, 2013; van den Herrick, Luis & van den Berg, 2013; Kidman, 2015; Koller, Olufsen, Stojanovska, & Petrusevski, 2015; Finlayson, Maciejowska, Ctrnactova, 2015; Lee & Shea, 2016).

Teachers have been observed to possess differing understandings of inquiry-based science teaching (Barrow, 2006; Leon, 2015). Leon (2015) concluded that teachers associate inquiry-based science teaching with only some of its characteristics. Similarly, some pre-service teachers' understanding of inquiry-based science has been found to be erroneous and incomplete. In a study conducted by Saribas and Ceyhan (2015), pre-service teachers understood the scientific method as a step-by-step process meant to verify facts oblivious to the notion that it can also be an iterative and inquiry-based process. Finlayson *et al.* (2015) and Kidman (2015) recommend that pre-service teachers should experience inquiry themselves as students and get an opportunity to try out the approach with learners.

Crawford (1999) posits that it is realistic to expect pre-service teachers to begin to design and implement inquiry-based instruction. Accordingly, pre-service science teachers should be prepared so that they can facilitate inquiry through practical work. Meaningful inquiry starts by being inquisitive about the natural world around us and developing questions that culminate in authentic investigations (Chin & Brown, 2002). This study was conducted against a backdrop of a 'recurriculation' process at one university in South Africa. It was the first stage of a larger design-based research project, which according to Reeves (2000) entails the analysis of practical problems by researchers and practitioners (needs analysis). Accordingly, the purpose of the study was to investigate the pre-service science teachers' experiences of how they learn to facilitate inquiry-based practical work through. Hence, the main research question of the study is, *what are the pre-service science teachers' perceptions of they learn to facilitate inquiry-based practical work?*

LITERATURE REVIEW

It will be unfair to expect teachers who have not experienced inquiry-based instruction through practical work to be able to implement it during their practice only because science curricula expect them to do so. McBride, Bhatti, Hannan and Feinburg (2004) propose that the best way to teach inquiry strategies is by engaging the pre-service teachers in inquiry science activities. Inquiry in science is driven by significant questions that should be answered through methods used by scientists such as experimentation (Crawford, 1999). Facilitating the development of questioning skills in students initiates them to engage in learning through inquiry (Chin *et al.,* 2002). Through inquiry, students can be involved in investigations and do the following, (1) confirm expectations or challenge currently accepted scientific concepts, (2) resolve unexpected puzzles and develop more insights on the currently accepted scientific concepts and (3) provide differing explanations for particular scientific phenomena and fill knowledge gaps (Chin *et al.,* 2002; McBride *et al.,* 2004).

Akuma and Callaghan (2019, p. 65) describe inquiry-based practical work as a type of practical work whereby students

> …collaboratively manipulate a combination of hands-on and/or computer-based science education equipment and materials, or existing data sets, to better understand the natural world as they engage in scientific practices through structured, directed, or open inquiry.

Although, the primary duty of science teachers is not to be professional scientists, they should be able to facilitate and implement inquiry-based practical work. The study by Chabalengula, Mumba and Mbewe (2012) on 91 elementary pre-service science teachers revealed that the participants had a limited conceptual understanding of science process skills, which according to Anderson (2002), form an important part of scientific inquiry. The science process skills include measuring, observing, inferring, classifying, controlling variables, formulating hypothesis, experimenting, interpreting data and communicating (Chabalengula *et al.,* 2012). The limited conceptual understanding of the science process may hinder efforts by teachers to facilitate inquiry-based practical work for learners.

The National Science Foundation (2003) posits that experiences such as open inquiry experiments enhance the quality of undergraduate science education. Students engage actively in the pursuit of knowledge by engaging in scientific inquiry projects that involve experimentation (Crawford, 1999). Besides developing practical skills associated with laboratory work, students develop skills in conducting scientific literature searches; read, interpret and extract information relevant to the project; operate instruments and operate laboratory techniques that are not usually available in the laboratories; interact professionally with other students and professors and communicate results orally and in writing (*ibid*). Widely engaging students in open inquiry experiments at undergraduate level is a way of providing equitable access to research opportunities for all students (National Science Foundation, 2003). Students from multicultural backgrounds in terms of race, gender, class and so forth will have access to the scientific inquiry activities. This is significant for South Africa in its protracted efforts to tackle issues of accessibility and equity by correcting imbalances created by a pre-independence education system defined by race (Selod & Zenou, 2003).

In the wake of critical skills shortages in the country, recruiting students by kindling their interest towards areas that experience the shortages is crucial. Science teachers can play a significant role in recruiting students to study fields in the scarce skills category. Harlen (2010) points out that one of the goals of science education is to develop in students, scientific capabilities and attitudes such as those espoused in scientific inquiry. The National Science Foundation (2003) points out that sustaining and diversifying the technical workforce requires significant creativity and investment in educational infrastructure. Furthermore, the focus should expand from merely developing a technical workforce but also students who are able to pursue research in the science fields (*ibid*). Accordingly, there is a need to train science teachers who are able to advance and support that vision.

Conceptual framework

The study used the opportunities to learn (OTL) concept to investigate the pre-service science teachers' experiences of IBPW. The concept of OTL is based on the notion that what students learn is related to the time they spend learning it (Cogan & Schmidt, 2015). Accordingly, the close-ended questionnaire was developed to measure the IBPW experiences in school science, tertiary science and methods courses. These experiences were regarded as opportunities to learn. Chin *et al.* (2002) posit that inquiry activities are question-driven. Therefore, the generation of questions by students is critical for the IBPW instruction model. Students may have autonomy over part or the whole inquiry process from problem conception, posing questions, hypothesising, designing experiments, gathering and analysing data, drawing conclusions and communication of results (Kipnis & Hofstein, 2008). McBride *et al.* (2004) posit that students should be taught inquiry in the context of real life. For science classroom contexts, Llewelyn (2013) suggests a process by which teachers and pre-service teachers can facilitate the generation of questions for inquiry. The pre-service teachers can facilitate question generation by doing the following, (i) introducing the topic, (ii) assessing prior knowledge, (iii) providing exploration, (iv) raising and recording questions, and, (v) sorting and revising questions.

METHOD

Using a case study of one university, quantitative data were collected by means of a questionnaire with close-ended items from 31 pre-service science teachers. The study was a needs analysis part of a larger design-based study to develop a conceptual framework to prepare pre-service science teachers who can successfully implement IBPW in the classroom. The needs analysis aimed to investigate the pre-service science teachers' experiences of IBPW by establishing opportunities to learn it. The convenient sample of participants consisted of 13 out of 18 PGCE pre-service science teachers at campus A of the university and all 10 PGCE pre-service teachers at campus B. The PGCE pre-service teachers specialised in secondary school life and physical sciences (Grades 10-12). Eight out of the 12 Bachelor of Education (BEd) intermediate phase (Grades 4-6) natural sciences pre-service teachers also participated in this study. The intermediate phase teachers were from campus A since campus B was not offering the programme at the time of the study. The questionnaire had 33 close-ended items that were reduced to nine categories of OTL which were (1) practical work experiences in school-PWS (2) inquiry experiences in school-IES, (3) practical work experiences during teacher training-PWT, (4) inquiry experiences during teacher training-IET, (5) open inquiry experiences at tertiary-OIE, (6) interest in practical work-IPW, (7) use of laboratory work as an instructional strategy-ULS, (8) use of laboratory work as an instructional strategy-ULS and (9) ensuring laboratory safety-ELS. A 6-point Likert scale was used to give a measure of the perception on each of the question items. The 6 points were as follows: 0 "never been true", 1 "not true", 2 "somewhat true", 3 "moderately true", 4 "true" and 5 "very true". A reliability test was run using the Cronbach's alpha coefficient for the 33 question items. A Cronbach's alpha score of 0.907 was obtained.

Data analysis

In order to answer the main research question the four objectives were formulated for the study. The study aimed to,

(i) calculate the means and standard deviations for each of the nine categories,

(ii) compare the distribution of the categories between PGCE pre-service teachers of campus A and campus B using the Mann-Whitney U test,

(iii) compare the distribution of categories between the PGCE pre-service teachers and the intermediate phase pre-service teachers using Mann-Whitney U test for independent samples, and

(iv) determine the correlation among the categories using the Pearson correlation coefficients.

Accordingly, means, standard deviations, the Mann- Whitney U tests and the Pearson correlation coefficient were used to analyse the data.

RESULTS

The table below shows the means (M) and the standard deviations (SD) for each of the categories for campus A and Campus B PGCE groups. The means and standard deviations of the categories for both campuses together were also calculated.

Table 1. Summary of category means for the PGCE groups

Campus		FI	OIE	PWS	IES	PWT	IET	ULS	ELS	IPW
A	Mean	**3.9**	**4.1**	**2.9**	3.2	3.4	3.2	**4.3**	**4.9**	**4.3**
	SD	**0.9**	**1.2**	**2.1**	1.7	1.5	1.3	1.2	**0.3**	1.1
B	Mean	**3.9**	**4.3**	3.5	3.4	4.1	4.1	**4.5**	**5.0**	**4.6**
	SD	**1.0**	**0.7**	1.7	1.4	1.4	0.8	**0.5**	**0.0**	0.6
A & B	Mean	**3.9**	**4.2**	**3.2**	**3.3**	3.7	3.6	**4.4**	**4.95**	**4.4**
	SD	**0.9**	**1.0**	**1.9**	**1.6**	1.5	1.2	**0.9**	**0.2**	**0.9**

Key: FI- facilitating inquiry; **OIE**- open inquiry experiences at tertiary; **PWS**- practical work experiences in school; **IES**- inquiry experiences in school; **PWT**- practical work experiences at tertiary; **IET**- inquiry experiences at tertiary; **ULS**- use of laboratory work as an instructional strategy; **ELS**- ensuring laboratory safety; **IPW**- interest in practical work

According to the results in Table 1 the PGCE pre-service teachers perceived that five of the category experiences presented them with opportunities to learn IBPW the most by responding with "true" and "very true" on the Likert scale. The categories were (i) facilitating inquiry- FI with M= 3.9, (ii) the open inquiry experiences at tertiary- OIE with M= 4.2, (iii) use of laboratory strategies- ULS with M= 4.4, (iv) interest in practical work with M= 4.4 and (v) ensuring laboratory safety with M= 4.95. The standard deviations for the five categories range from SD= 0.2 to SD= 1.0 implying that most of the responses were fairly close to the mean. Although the perceptions of the PGCE pre-service teachers were above the average mean (M= 2.5) in all the nine categories, they considered the school experiences to present them with lowest levels of learning opportunities. These experiences were (i) practical work at school- PWS and (ii) inquiry experiences at school- IES. The opportunities to learn at tertiary level had the highest scores.

In order to establish whether or not the distribution of the categories across campus A and campus B was the same or not, a Mann-Whitney U was run to compare the means for each category and the results are displayed in Table 2 below.

Table 2. Distribution of categories Mann-Whitney U test across the PGCE groups

	FI	PWS	OIE	IES	PWT	IET	ULS	ELS	IPW
Mann-Whitney U	63.0	63.0	60.5	63.0	44.0	41.0	58.0	60.0	55.5
Z	-0.1	-0.1	-0.3	-0.1	-1.3	-1.5	-0.5	-0.9	-0.6
Asymp. Sig. (2-tailed)	**0.9**	**0.9**	**0.8**	**0.9**	**0.2**	**0.1**	**0.6**	**0.4**	**0.5**
a. Grouping Variable: Campus									

The test assumes that the distribution is the same in both groups if the level of significance is more than 0.05. The levels of significance range from P= 0.1 to P= 0.9 for all nine categories and are greater than 0.05. Therefore it was assumed that the distribution of the nine categories was not different for the two campuses. This information was important to establish because the needs analysis results would be applied to both campuses.

In Table 3 the intermediate phase pre-service teachers considered two of the tertiary experiences to have presented them with the most learning opportunities for IBPW. These categories were (i) ensuring laboratory safety with M= 4.1 and (ii) interest in practical work with M= 3.9. However, the standard deviations ranged from SD= 1.2 to SD= 1.8 suggesting that some of the responses fell a bit further from the mean.

Table 3. Summary of category means and standard deviation for the PGCE groups

Campus		FI	OIE	PWS	IES	PWT	IET	ULS	ELS	IPW
A	Mean	**2.1**	3.1	2.7	2.8	**2.3**	2.8	3.4	**4.1**	**3.9**
	SD	**1.6**	1.4	1.9	1.7	**1.7**	1.3	1.6	**1.8**	**1.2**

Key: FI- facilitating inquiry; **OIE**- open inquiry experiences at tertiary; **PWS**- practical work experiences in school; **IES**- inquiry experiences in school; **PWT**- practical work experiences at tertiary; **IET**- inquiry experiences at tertiary; **ULS**- use of laboratory work as an instructional strategy; **ELS**- ensuring laboratory safety; **IPW**- interest in practical work

The intermediate phase pre-service teachers considered the two categories, facilitating inquiry-FI with M= 2.1 and practical work experiences at tertiary- PWT with M= 2.3 to have presented them with the least learning opportunities. These categories were scored as "somewhat true" on the Likert scale and were below the average M= 2.5. The SD values ranged from 1.2 to 1.9 which suggested that some of the responses fell a bit further from the mean.

In order to determine whether the distribution of the nine categories was the same in the PGCE pre-service teachers and the intermediate phase a Mann- Whitney U test for independent samples was run and the results are in Table 4. The test worked with a null hypothesis, H_0, that assumes that the distribution of categories were the same across the programmes.

Table 4. Hypothesis test summary (Independent-samples Mann-Whitney U test)

	H_0	Sig.	Decision
1	The distribution of **ULS** is the same across categories of programme	.132	Retain H_0
2	The distribution of **FI** is the same across categories of programme	**.006**	Reject H_0
3	The distribution of **PWS** is the same across categories of programme	.464	Retain H_0
4	The distribution of **IES** is the same across categories of programme	.437	Retain H_0
5	The distribution of **PWT** is the same across categories of programme	.067	Retain H_0
6	The distribution of **IET** is the same across categories of programme	.110	Retain H_0
7	The distribution of **OIE** is the same across categories of programme	**.043**	Reject H_0
8	The distribution of **ELS** is the same across categories of programme	.386	Retain H_0
9	The distribution of **IPW** is the same across categories of programme	.386	Retain H_0

The results showed that the distribution of the two categories, (i) facilitating inquiry- FI and (ii) open inquiry experiences at tertiary- OIE was not the same across the two programmes with levels of significance P= 0.006 and P= 0.043 respectively. These categories presented fewer OTL for the intermediate phase pre-service teachers than the PGCE pre-service teachers.

The Pearson' correlation coefficients calculated at the level of significance P= 0.05 showed a positive correlation among the nine categories in Table 5. The positive correlation seems to suggest that the increase in experiences of OTL defined by each of the categories positively impacted the other experiences of OTL in IBPW.

Table 5. Inter-item correlation among the nine categories

	PWS	IES	PWT	IET	OIE	ULS	FI	ELS	IPW
PWS	1.0	**0.8**	0.5	0.5	0.5	0.4	0.3	0.3	0.6
IES	**0.8**	1.0	0.6	0.6	0.6	0.6	0.5	**0.2**	0.7
PWT	0.5	0.6	1.0	0.6	0.7	0.7	0.6	0.4	0.6
IET	0.5	0.6	0.6	1.0	0.5	0.6	0.5	0.3	0.6
OIE	0.5	0.6	0.7	0.5	1.0	**0.9**	0.6	0.3	**0.8**
ULS	0.4	0.6	0.7	0.6	**0.9**	1.0	0.7	0.4	**0.8**
FI	0.3	0.5	0.6	0.5	0.6	0.7	1.0	0.5	0.5
ELS	0.3	**0.2**	0.4	0.3	0.3	0.4	0.5	1.0	0.4
IPW	0.6	0.7	0.6	0.6	**0.8**	**0.8**	0.5	0.4	1.0

However, it can be noted that the correlation between the categories inquiry experiences at school-IES and ensuring laboratory safety-ELS was the weakest. The strongest correlations were between practical work at school-PWS and inquiry experiences at school-IES; open inquiry experiences at tertiary-OIE and use of laboratory strategy-ULS; interest in practical work- IPW and open inquiry experiences at tertiary- OIE; and finally, interest in practical work- IPW and use of laboratory strategy- ULS.

DISCUSSION AND CONCLUSION

The study set out to investigate pre-service science teachers' perceptions of how they learn to facilitate IBPW. The study was part of a needs analysis stage of a larger design-based study on how a teacher training programme can prepare pre-service science teachers to facilitate IBPW. The results showed that pre-service teachers experience OTL of how to facilitate IBPW during their years in school and at tertiary. These OTL include practical work activities and inquiry experiences at school. They also experience OTL at tertiary when they further engage in practical work and open inquiry activities. McBride *et al*. (2004) affirm that engaging pre-service teachers in inquiry activities helps them to learn how to teach using inquiry strategies.The pre-service teachers perceived that they also experienced OTL when they facilitated inquiry for learners, used laboratory strategies, ensured laboratory safety and had an interest in practical work activities. What is important to note is that the pre-service teachers in this study did not come to the teacher training programme as blank slates in terms of experiences that might translate to knowledge about IBPW. The PGCE pre-service teachers perceived the tertiary experiences of facilitating inquiry to learners, open inquiry, use of laboratory strategies and ensuring laboratory safety and interest in practical work to have presented them with more OTL than experiences accumulated in school. Koller *et al.* (2015) point out the marked differences between practical work facilities in tertiary institutions and those found in schools. The marked differences may also extend to OTL. However, the intermediate phase pre-service teachers did not perceive the OTL experienced at tertiary as significantly more than those experienced at school. The intermediate phase teachers considered facilitating inquiry to learners as the experience that presented them with least OTL. This result may suggest that they were not exposed to the OTL of facilitating inquiry significantly. Cogan and Schmidt (2015) explain that OTL are experienced when time is spent learning something. The limited OTL may be the reason why Leon (2015) and Saribas and Ceyhan (2015) indicate that some pre-service teachers demonstrate incomplete conceptions and misconceptions about inquiry-based practical work

The Pearson correlation coefficient showed that the OTL experiences for IBPW were positively correlated suggesting that experiences accumulated previously impacted on future experiences. Hence, a recommendation is made in this study to increase and diversify the pre-service science teachers' OTL how to facilitate IBPW.

The results of the study have implications for the larger design-based project by taking note of the following, (i) the PGCE pre-service teachers in campus A and B experienced similar OTL for IBPW, (ii) the intermediate phase teachers experienced less OTL through facilitating inquiry for learners and practical work at tertiary, and, (iii) the intermediate phase pre-service teachers experienced less OTL at tertiary even though their school experiences were similar to those experienced by PGCE pre-service teachers. A follow-up qualitative study will be conducted to explore how the pre-service teachers experience OTL for IBPW in the teacher-training programme as a way of validating their perceptions in this study.

ACKNOWLEDGEMENT

This study is part of project funded by the NRF Thuthuka of South Africa.

REFERENCES

Akuma, F.V. & Callaghan, R. (2019). Teaching strategies linked to the implementation of inquiry-based practical work in certain science classrooms. *Journal of Research in Science Teaching 56*, 64-90.

Anderson, R.D. (2002). Reforming science teaching. What research says about inquiry. *Journal of Science Teacher Education, 13*(1), 1-12.

Barrow, L.H. (2006). A brief history of inquiry: From Dewey to standards. *Journal of Science Teacher Education*, 17, 265-278.

Chabalengula, V.M., Mumba, F. & Mbewe, S. (2012). How pre-service teachers understand and perform science process skills. *Eurasia Journal of Mathematics, Science and Technology,* 8(3), 167-176.

Chin, C., & Brown, D.E. (2002). Student-generated questions: A meaningful aspect of learning in science. *International Journal of Science Education*, 24(5), 521-549.

Cogan, L.S. & Schimdt, W.H. (2015). The concept of opportunity to learn (OTL) in International Comparisons of Education. In Stacey, K. & Turner, R. (eds). Assessing Mathematical Litaeracy (pp 207- 216). SpringerNature: Switzerland.

Crawford, B.A. (1999). Is it realistic to expect a pre-service teacher to create an inquiry-based classroom? *Journal of Science Teacher Education*, 10(3), 175-194.

Department of Basic Education, (2011a). *Curriculum and assessment policy statement. Grades 4-6. Natural sciences and Technology.* Government Printing Works.

Department of Basic Education. (2011b). *Curriculum and assessment policy statement. Grades 10-12. Physical sciences.* Pretoria: Government Printing Works

Finlayson, O., Maciejowska, I., Ctrnactova, H. (2015). *Inquiry based chemistry instruction*. I. Maaciejowska & B. Byers (eds). A guide of good practice for the pre-service training of chemistry teachers (pp. 109-124). Krakow: Faculty of Chemistry, Jagiellonian University.

Gaigher, E., Lederman, N., & Lederman, J. (2014). Knowledge about inquiry: A study in South African high schools. *International Journal of Science Education*, 36(18), 3125-3147.

Harlen, W. (2010). *Principles and big ideas of science education.* Gosport, Hants: Great Britain Ashford Colour Press Ltd.

Hofstein, A. (2004). The laboratory in Chemistry Education: Thirty years of experience with developments, implementation, and research. *Chemistry Education: Research and Practice, 5*(3), 247-264.

Lee, C.K. & Shea, M. (2016). An analysis of pre-service elementary teachers' understanding of inquiry-based science teaching. *Science Education International*, 27(2), 219-237.

Llewelyn, D.J. (2013). *Teaching high school science through inquiry and argumentation*. USA: Corwin Press.

Leon, M.R. (2015). Science teachers understanding of inquiry-based science teaching (IBST): Case of Rwandan lower secondary school science. *Rwandan Journal of Education*, 3(1), 77-90.

Kidman, G. (2015). Facilitating meta-learning in pre-service teachers: Using integration and slow-motion. *Procedia-Social and Behavioral Sciences*, 167, 117-123.

Kipnis, M., & Hofstein, A. (2008). The inquiry laboratory as a source for development of metacognitive skills. *International Journal of Science and Mathematics Education*, 6, 601-627.

Koller, H.G., Olufsen, M., Stojanovska, M. & Petrusevski, V. (2015) *Practical work in chemistry, its goals and effects*. I. Maaciejowska & B. Byers (eds). A guide of good practice for the pre-service training of chemistry teachers (pp. 87-106). Krakow: Faculty of Chemistry, Jagiellonian University.

Lunetta, V.N., Hofstein, A., & Clough, M.P. (2010). Learning and teaching in the school science laboratory: An analysis of research, theory and practice. In S.K. Abell & N.G. Lederman (Eds.). *Handbook of research on science* (pp. 393-441.). New York: Routledge.

McBride, J.W., Bhati, M.I., Hannan, M.A., & Feinburg, M. (2004). Using an inquiry approach to teach science to secondary school science teachers. *Physics Education*, 39(5), 1-6.

Millar, R. (2004). *The role of practical work in the teaching and learning of science. High school science laboratories: Role and vision*. National Academy of Sciences, Washington, DC.

National Research Council (NRC). (1996). National Scinence Education Standards. Washington, DC: National Academy Press.

National Science Foundation. (2003). Exploring the concept of undergraduate research centres. *A report on the NSF workshop*, 30 March-1 April 2003.

Nivalainen, V., Asikainen, M.A. & Hirvonen, P.E. (2013). Preservice teachers objectives and their experiences of practical work. *Physical Review Special Topics-Physics Education Research*, doi: 10.1103/PhysRevSTPER.9.010102.

Ramnarain, U.D. (2014). Questioning the validity of inquiry assessment in a high stakes physical sciences examination. *Perspectives in Education*, 32(1), 179-191.

Reeves, T. (2000). Enhancing the worth of instructional technology research through "design experiments" and other development research strategies. *Paper presented at the Annual AERA Meeting*, April 24-28, New Orleans.

Saribas, D. & Ceyhan, G.D. (2015). Learning to teach scientific practices: Pedagogical decisions and reflections during a course for pre-service science teachers. *International Journal of STEM Education*, 2(7), doi: 10.1186/s40594-015-0023-y

Selod, H. & Zenou, Y. (2003). Private versus public schools in post-apartheid South African cities: Theory and policy implications. *Journal of Development Economics,* 71, 351-394.

Sporea, D. & Sporea, A. (2013). *IBSE in-service training with teachers and their pupils in Romania*. Ed van den Berg (ed). Making IBSE durable through pre-service teacher education (pp.31-32). Netherlands: Hogeschool van Amsterdam.

Tatar, N. (2012). Inquiry-based science laboratories: An analysis of pre-service teachers' beliefs about learning science through inquiry and their performances. *Journal of Baltic Science Education*, 11(3), 248-266.

MODELLING IN STEM: THE TALE OF TWO COUNTRIES IN CENTRAL ASIA

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International testing in STEM, such as PISA, has demonstrated that students across the world have difficulty with scientific reasoning but especially in Kazakhstan and Turkey. One suggestion to improve students' reasoning skills is to teach using more authentic science methods. The authentic science practice of science modelling has shown promise towards improving student gains in conception and reasoning skills. In order to accomplish this, secondary teachers need to be prepared to teach using these authentic science practices such as science modelling. A decade ago published studies demonstrated the existence of teacher confusion about models and modeling and led to reform suggestions for pre and in-service science educators. But, do we know if science educators are doing a better job? Kazakhstan has been undergoing massive curriculum changes, which includes a nationwide teacher professional development plan. Turkey has been working towards STEM education improvements for a number of years. Are these initiatives having an effect on teacher perceptions? This study's goal is to explore Kazakhstani and Turkish in-service teachers' perceptions about the authentic science practice of scientific modelling. An interview protocol was used with 22 STEM secondary teachers. Open coding was used to analyze the interviews. When teacher perceptions were compared across countries the preliminary findings show that in these two countries major confusion exists,. Coding revealed that the most common model representation used in both countries was that of physical models. The use of demonstrations, the teaching of a process and step by step inquiry labs were considered forms of modeling. However, Turkish teachers' codes were more focused than that of the Kazakhstani teachers possibly due to a longer period of professional development opportunities. This work in progress has led to tentative science education suggestions for Central Asia.

Keywords: Models in Science, Teaching Practices, Teacher Professional Development

SCIENCE MODELLING IN STEM

The Programme for International Student Assessment (PISA) studies suggest that there is a need for students in Kazakhstan, Turkey and other countries to not only acquire but practice higher order thinking skills in classrooms (Mullis, Martin, Goh, & Cotter, 2016; OECD, 2016). In Kazakhstan, students score well on TIMMS but very low on PISA. This is ascribed "to the unfinished agenda of raising student learning achievement beyond basic literacy and numeracy" (World Bank, 2012). Turkish students have been performing below the OECD average and these scores have been consistent since 2006 (OECD, 2015).

Science Models and Modelling In Practice

The use of science modelling encourages students to design experiments, interpret the data, use the data to construct science models with multiple representations (e.g., pictorial, graphical, verbal, computer, and mathematical), make predictions and draw conclusions about scientific phenomena. These multiple representations that make up a science model allow students to see how each representation leads to similar predictions and can make the model more meaningful to them. See Figure 1 for a diagram of a science model and its multiple representations. Thus, using it in science classrooms should help to improve this situation. Past studies have shown that the implementation of modelling practices has produced improved student conceptual gains, usage of multiple representations, scientific reasoning skills and model-based reasoning (e.g., Liang, Fulmer, Majerich, Clevenstine, Howanski, 2012; Malone, Schuchardt, Sabree, 2019; Miller & Kastens, 2017).

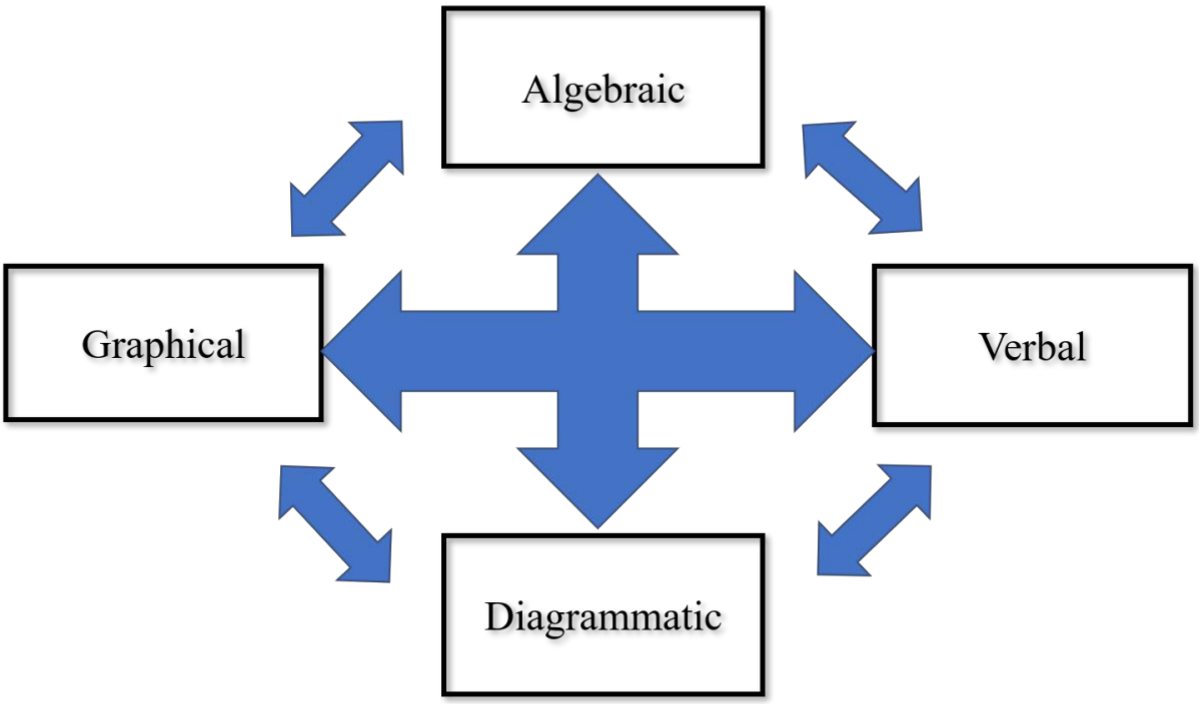

Figure 1. Science Models with connected representations. Adapted from Stammen, Malone & Irving, 2018.

Scientific Modelling is a cycle that is practiced by professional scientists (Gilbert & Justi, 2016; Hestenes, 2010). The cycle is used when developing models as well as using models to study new scientific phenomena. The cycle allows for students or scientists to develop experiments that will allow them to determine the nature of a physical phenomenon that is being studied. The empirical data collected can be used to develop a science model consisting of multiple representations as seen in Figure 1. The cycle continues by having the students then use the model to see how well it corresponds or makes predictive the physical phenomenon originally being studied. The development of this scientific model is a part of scientific modelling. Scientific modelling also consists of then using the developed science models to predict and study other scientific phenomenon of interest. When data is obtained that is different from the model predictions than the student or scientist must either refine their model to account for these differences or start the process again in order to develop a new model. This modelling cycle is portrayed in Figure 2.

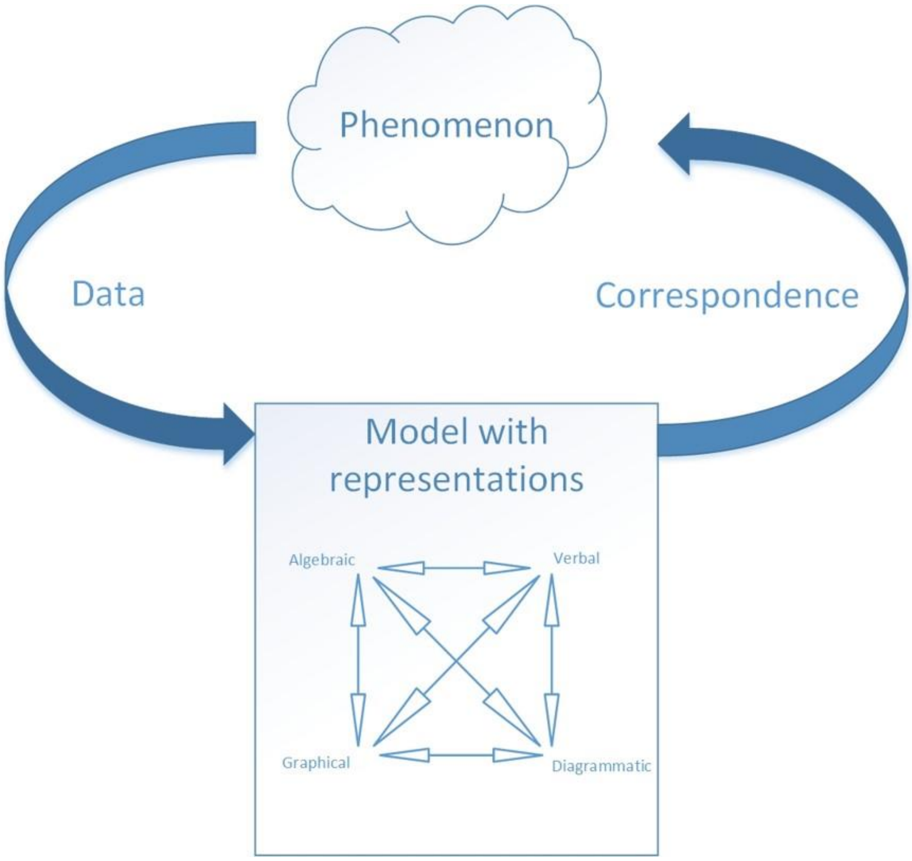

Figure 2. The Scientific Modelling Cycle. Adapted from Malone, Schuchardt & Sabree, 2019)

Teacher Perceptions about Models and Modelling

In the early 2000's research on in-service teachers' perceptions about models and modelling demonstrated that in multiple countries knowledge of and about the use of this type of authentic practice was extremely lacking (e.g., Henze, Van Drield & Verloop, 2007; Justi, & Gilbert, 2003). Thus, the recommendation was that pre-service science education courses and professional development (PD) worldwide should educate teachers on this in order to impact usage of the practice in classrooms. In order to encourage the use of science modelling, educational policies need to be more focused on incorporating science models and scientific modeling into pre-service university education as part of the instruction during every lesson. More specifically, pre-service teachers at the universities should be required to use science models and scientific modeling during their pre-service education. Through modelling such approaches at the pre-service level it was thought that the role of models and scientific modeling in classroom activities would be enhanced. Thus, these trained pre-service teachers would in turn serve as the vehicle to deliver solutions to understanding and exploring the phenomenon. Thus, if the original recommendations in the early 2000's had been implemented we should observe teachers worldwide who not only understand the nature of science models and science modelling but actively utilize it in their own classrooms as part of their daily practice.

However, the international testing results bring into question whether this situation has improved any over the years? Recent work in United States (US) and Germany with biology teachers has revealed that teachers responses are still similar to those found a decade prior (Krell & Kruger, 2016; Ware, Malone, Irving & Mollohan, 2017). However, models and modelling may be seen to be too difficult to put into practice in biology classrooms but easier and more practical to use in other subjects which consist of more visual elements for students such as in physics. Thus, interviewing teachers from multiple STEM disciplines might allow for a different picture to emerge.

Educational Reform and Authentic Practices in Kazakhstan and Turkey

In Kazakhstan curriculum reform efforts include professional development for teachers across the country to improve their abilities to teach using 21st century reasoning skills along with an increased focus on STEM education nationwide (Bridges, 2014; OECD, 2014). Turkey has been introducing a reformed curriculum since 2005 which supports modelling in science (Şentürk & Aydogmus, 2017). To examine the results of these efforts on teacher competencies in scientific modelling this exploratory study was conducted with the following guiding question:

What kind of teacher competencies in scientific modelling exist in Turkey and Kazakhstan?

Only by discovering the STEM competencies in these countries can changes be made to pre-service STEM teacher education and in-service professional development.

METHODS

Research Design

A qualitative semi-structured interview approach was selected in order to obtain an in depth understanding of teachers' perceptions of models and modelling. The participants, in-service schoolteachers who teach science disciplines, were selected for the study in two countries. The 22 teachers participating in the study were asked to discuss their understanding of models and modelling, how these terms compare and to give specific examples of their use in their classrooms.

Participants

In terms of gender of participants and the level of education there was a difference between the two countries. The participants from Turkey were mostly female with a 69% to 31% female to male ratio. The participants from Kazakhstan were the reverse with a 60% to 40% male to female ratio. The level of education or graduate education level of in-service teachers showed that 31 % of the teachers from Turkey had a graduate education in comparison to only 20% of the Kazakhstani teachers. Thus, participants from Turkey and Kazakhstan have significant differences in educational level with a greater number of teachers from Turkey having graduate degrees in education while their Kazakhstani counterparts possessed mostly undergraduate degrees. However, while the participants from each country were not closely matched according to educational level, they were evenly matched according to years of teaching experience with the teachers from both countries having taught on average for 9 years. Thus, the majority of the teachers graduated from a pre-service teacher education within the past 10 years. This means that the majority of the participants were relatively new to teaching and were pre-service teachers well after the studies completed by Justi and Gilbert (2003).

Data Analysis

The interviews were conducted in Russian, Kazakh and Turkish. The interviews were transcribed and translated into English for coding purposes. Two interviews were initially coded by two researchers and a code book emerged. The convergencies in two researchers' answers have been taken as the core themes and those themes were used to group and interpret the data from the rest of the interviews. Thus, nine major converging themes were jointly created to code for the use and understanding of scientific models. Eight major themes emerged for the coding of scientific modelling. All of the codes were included in a codebook. The codebook included the name of theme or code as well as a few exemplars for each code. The finalized codebook was then used to code the rest of the interviews.

After all the interviews were coded an interrater check was conducted using 10% of the transcripts or two randomly selected interview transcripts. The Cohen's Kappa score for these transcripts was determined to be 0.83. This indicator or convergence in interpretation of field data among two researchers is considered as significant since the correlation can vary between 0 and 1. The range of scores from 0.81 to 1.00 is considered to have "almost perfect agreement" (McHugh, 2012, p. 279). Thus, the coded transcripts is considered excellent for comparative analysis.

RESULTS

Figure 3 outlines the 9 sub-codes that describe what teachers in this study considered a scientific model. The scientific models codes that emerged based on teacher comments focused mostly on specific model representations. For example, teachers would discuss the physical representations of a particular model such as the crystal lattice model as a 'physical model'. They did not seem to clearly recognize that scientific models consist of multiple representations such as physical, pictorial and mathematical (refer to Figure 1). The idea of a physical model was most commonly referred to by interview participants regardless of nationality (i.e., 87% vs 60%, Turkey and Kazakhstan, respectively).

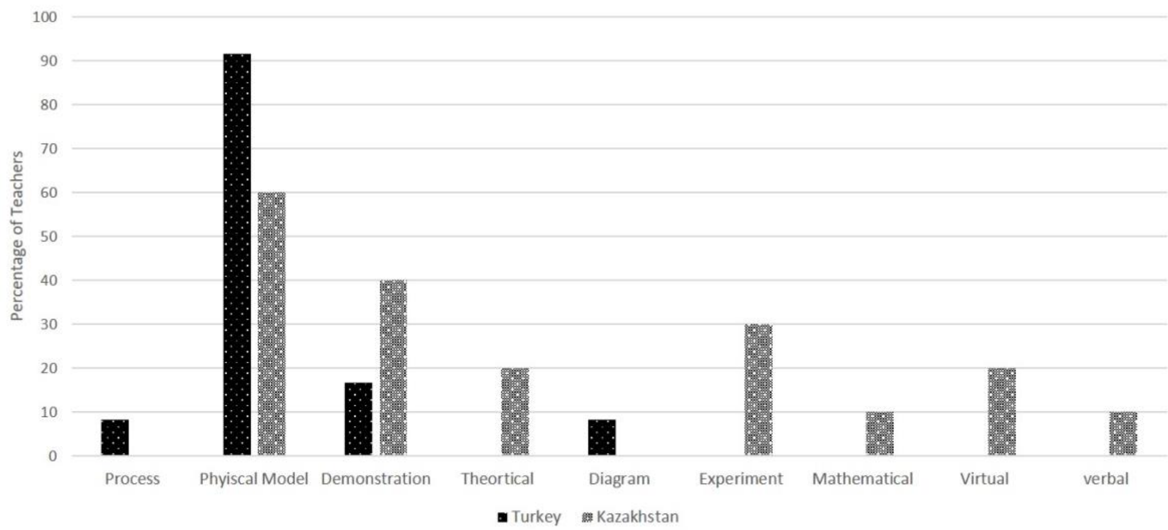

Figure 3. Scientific Model Coding Themes by country

When the transcripts were reviewed in terms of scientific modelling, seven separate codes were discovered (see Figure 4). An eighth code called, scientific modelling, was a predetermined code based upon how scientific modelling is defined in the research community. None of the teacher participants, no matter nationality, had a concise, well-defined understanding of modelling thus that code was not utilized (refer to Figure 4). Many of the codes and their descriptions overlap between the concept of science models and modelling. Thus, the majority of the teachers did not distinguish the difference between models and modelling thus interpreting the terms as synonymous. It seemed that teachers were not making the observation that a model is a noun and modelling is a verb but "seeing" these two science terms as identical in usage and definition. None of the teachers from either nationality spoke about modeling in terms of a cycle as shown in Figure 2.

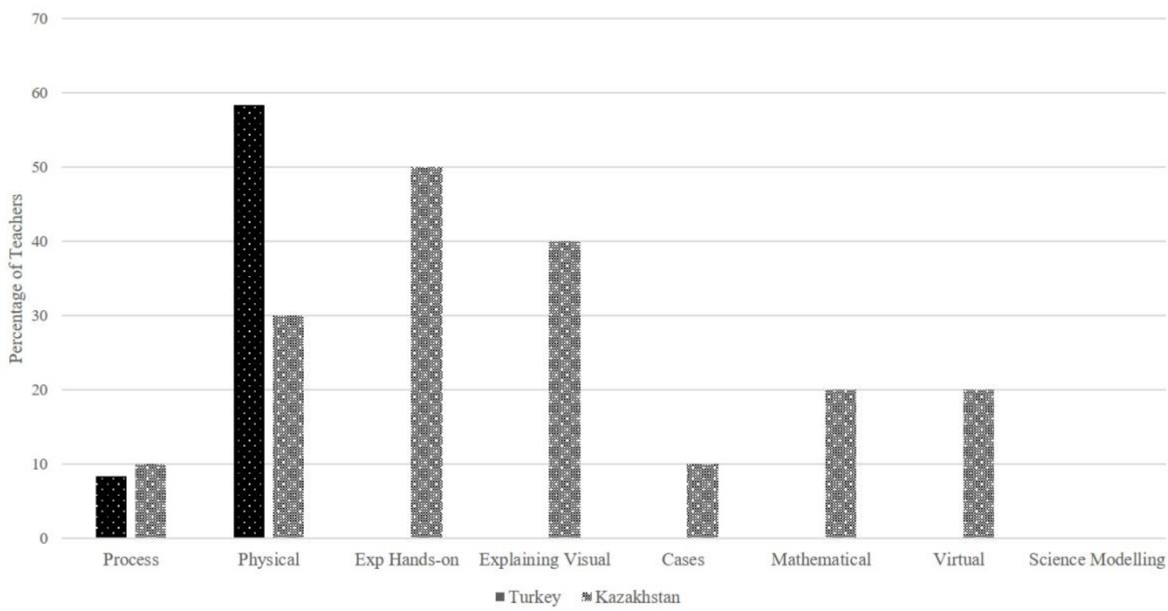

Figure 4. Scientific Modelling Coding Themes by country

Another finding worth mentioning is that both Turkish and Kazakhstani teachers did not seem to have chances to upgrade their skills in teaching their disciplines during their teaching careers via targeted professional development. This can be seen in the transcripts when teachers are asked about their attendance at workshops that focused on scientific modelling. None of the teachers in either country had participated in workshops focused on science models and modelling.

DISCUSSION AND CONCLUSIONS

The results of this exploratory study demonstrate that the in-service science teachers in this study do not have a clear understanding of the authentic practice of using science models and scientific modelling in science classrooms. There is no conception that the multiple representations in a model are linked thus supporting and enriching student understanding. The data suggest that while many teachers may use one or more multiple representations in their classes, they seem to consider them as separate entities. In addition, it is unclear whether teachers use them in a predictive sense during modelling activities. In other words, this study seems to point out that the in-service teachers of Kazakhstan and Turkey do not use scientific modeling in its true sense.

According to this study, another difference in understanding of science models could be connected with the gender. By way of illustration, the Turkish in-service STEM teachers, predominantly females conceptualized both science models and modeling as a physical entity and a process. While their Kazakhstani counterparts, who were predominantly male also did not seem to have a conceptual understanding of the differences between science models and modelling but intellectualized them in a different fashion. The Kazakhstani teachers also thought of models as physical entities but did not consider it a process. The male Kazakhstani teachers considered a science model to be either a demonstration or an experiment. As this study posits, males have different attitudes towards the new phenomenon than females and they seem to conceptualize modelling as more hands-on and experimental in nature. In addition, only the Kazakhstani teachers identified modelling as being connected to mathematical representations. This means it is possible that Kazakh teachers may use more experiments that require predictions or the gathering of some initial data. However, further evaluation and data needs to be explored in the future to determine if there really is a difference in its use in the classroom. The inability to apply modeling for predictions can lead to insufficient application of science models in the classroom with in-service teachers underestimating the importance of various representations or science models during modelling activities. This means that teachers could be neglecting to use a range of possible science models with their students in both of these two selected countries. Thus, the idea that a scientific model consists of multiple representations does not seem to be an understanding shared by in-service teachers, whether they are located in Turkey or Kazakhstan.

These misconceptions of scientific models and scientific modelling that are shared by teachers seems to point to a failure ultimately in both countries in terms of science education at the university level. Changes in science education methods courses as well as general science courses at the university level in both countries are not supporting teachers in reaching an understanding of the authentic practice of scientific modelling. Curricular updates need to be made at the university level that allow pre-service science to embed using science models and modelling in both general science and science methods courses.

Another suggestion to improve students' reasoning skills is to further promote the application of modeling by in-service teachers in both Turkey and Kazakhstan. In-service teachers need to have additional support via targeted PD to shift their practice towards the use of scientific modelling in their classes, so it becomes a natural part of their teaching practice. The models should be diverse including not only physical or demonstration ones but also those consisting of multiple representations. Moreover, there could be solutions such as the requirement for the in-service teachers of the selected countries to allocate a special time slot for the use of scientific modeling during lessons as an integral part of the study and instruction. In other words, the policies should require incorporating science models and scientific modeling as an integral part of each lesson in the preparation of in-service teachers at the university levels. Such initiatives could be articulated in the policy documents both at the country and institutional levels then they could underpin the whole learning process of students. Raising the awareness about science models and scientific modeling through PD to teachers complemented with the policy initiatives could be a solution to improving students' reasoning skills in the selected countries.

ACKNOWLEDGEMENT

This research was partially funded by a grant under the Nazarbayev University Social Policy Grant System and by Chevron Corporation. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the funding organizations

REFERENCES

Bridges, D. (Ed.). (2014). *Education reform and internationalisation: The case of school reform in Kazakhstan*. Cambridge University Press.

Gilbert, J. K., & Justi, R. (2016). *Modelling-based teaching in science education* (Vol. 9). Cham, Switzerland: Springer International Publishing.

Henze, I., Van Driel, J., & Verloop, N. (2007). The change of science teachers' personal knowledge about teaching models and modeling in the context of science education reform. *International Journal of Science Education*, *15*(3), 1819-1846.

Hestenes, D. (2010). Modeling theory for math and science education. In R. Lesh, C. R. Haines, P. L. Galbraith & A. Harford (Eds.), *Modeling Students' Mathematical Modeling Competencies* (pp. 13-41). CITY: Springer U.S,.

Justi, R., & Gilbert, J. (2003). Teachers' views on the nature of models. *International Journal of Science Education*, *25*(11), 1369-1386.

Krell, M., & Krüger, D. (2016). Testing models: A key aspect to promote teaching activities related to models and modelling in biology lessons? *Journal of Biological Education*, *50*(2), 160-173.

Liang L.L., Fulmer, G.W., Majerich, D.M., Clevenstine. R., Howanski, R. (2012). The effects of a model-based physics curriculum program with a physics first approach: A causal-comparative study. *Journal of Science Education and Technology*, *21*(1), 114–124.

Malone, K.L., Schuchardt A.M. & Sabree, Z. (2019). Models and Modeling in Evolution. In Ute Harms and Michael J Reiss (Eds), *Evolution Education Re-considered: Understanding What Works (pp. 207-226).* Switzerland: Springer International Publishing. doi: 10.1007/978-3-030-14698-6

McHugh, M. L. (2012). Interrater reliability: The kappa statistic. *Biochemia medica*, *22*(3), 276-282.

Miller, A. R., & Kastens, K. A. (2017). Investigating the impacts of targeted professional development around models and modeling on teachers' instructional practice and student learning. *Journal of Research in Science Teaching*, 55*(*5), 641-663. Retrieved from: https://doi.org/10.1002/tea.21434

Mullis, I. V. S., Martin, M. O., Goh, S., & Cotter, K. (Eds.) (2016). *TIMSS 2015 Encyclopedia: Education Policy and Curriculum in Mathematics and Science.* Retrieved from Boston College, TIMSS & PIRLS International Study Center website: http://timssandpirls.bc.edu/timss2015/encyclopedia/

OECD (2014). *Reviews of National Policies for Education: Secondary Education in Kazakhstan*. OECD Publishing: Paris.

OECD (2015). PISA 2015 Country Overview. Retrieved from http://www.compareyourcountry.org/pisa/country/tur?lg=en

OECD (2016*), Low-Performing Students: Why they fall behind and how to help them succeed, PISA*, OECD Publishing, Paris, http://dx.doi.org/10.1787/9789264250246-en.

Şentürk, C., & Aydogmus, M. (2017). Comparison of Turkish Elementary School Science Curriculum: 2005-2013-2017. *International Journal of Modern Education Studies*, *1*(1), 46-57.

Stammen, A., Malone, K.L, & Irving, K.E. (2018). Effects of Modeling Instruction professional development on biology teachers' scientific reasoning skills. *Education Sciences, 8* (3),119. https://doi.org/10.3390/educsci8030119

Ware, T., Malone, K.L., Irving, K., & Mollohan, K. (2017, January). Models and Modeling: An evaluation of teacher knowledge. *Proceedings from HICE 2017: The 15th Annual Hawaii International Conference on Education*. Honolulu, HI.

World Bank (2012) . World Bank – Kazakhstan partnership program snapshot, April 2012, World Bank, Washington, DC.

THE ROLE OF REPRESENTATIONS IN CHEMISTRY TEACHING: AN EXPERIENCE WITH PRE-SERVICE TEACHERS

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Meaning making in Science classes has been related to multimodal representations and multimodality. The communication of many science phenomena demands a complex combination of verbal language with images, formulas, symbols, gestures etc. In this sense, the orchestration of multiple representations and different forms of communication is an important aspect of the teacher's performance and of the meaning making process. The main purpose of this paper is to analyze the understanding of teachers in training relative to the role of representation in Science/Chemistry teaching. A limited understanding was perceived, which evolves with the use of an approach based on the multimodal representations.

Keywords: pre-service teacher, representation, multimodal representation.

INTRODUCTION

According to studies conducted by Halliday (1978; 1985) on Systemic Functional Grammar (SFG), language is a system of meanings, with which an individual interactively codes and decodes expressions, developing communicative competence.

Kress and van Leeuwen (1996) expanded Halliday's studies (1978; 1985) by incorporating imaging and developed 'The Grammar of Visual Design.' Other modes of communication were incorporated into research involving language, creating the concept of multimodality. So, efficient communication involves going beyond the interpretation of language and its meanings, requiring other modes of representation and communication (Jewitt, 2006; 2008; 2009; Kress, 2009; 2010; Norris, 2004) and leading to the development of a 'Multimodality' field (Adami, 2016).

Since communication is multimodal by nature, it is necessary to specify what semiotic modes are and which of them are used to communicate something. According to Kress (2010) and Jewitt (2008), mode is defined as a communication channel that a culture recognizes. A ball-and-stick model, for example, is an important mode of communication for chemists. However, for an individual with little knowledge of chemistry, it may be just a toy or something unimportant. This ball-and-stick model only acts as a semiotic mode in a context where it is culturally recognized.

Kress (2010) states semiotic modes often used in the classroom refer to words, images, colors, shapes, typographic features, proxemics, gestures, prosody, sounds, music, speech, among others that depend on the context. Norris (2004) classifies these modes as audio (speech, music, sound, sound effects, etc.), visual (look, impression, image, etc.), action (gestures, posture, movement, facial expression, contact, handling of objects/models, screen projection, etc.), and environmental modes (proxemics, layout, etc.).

However, these modes must be brought together, organized, and planned to be useful for those who want to produce meanings according to what they are communicating, a process reported by Kress (2010) as 'multimodal orchestration'. Based on that, using different modes is not enough, they should be correlated to produce meanings and for learning.

Multimodality is associated with communication and representations. Considering science teaching/learning or, more specifically, chemistry, communication and modes of representation are critical, as it involves an understanding of chemical 'entities' that cannot be seen, for instance, atoms, electrons, ions, molecules and other submicroscopic entities that constitute the group of entities used to explain the formation of matter, its properties and transformation process.

One of the approaches for science teaching in the classroom is based on multimodality and the wide use of representations, called 'multimodal representations,' which will be discussed below.

Multimodal representations

Representations have been widely used for thinking about and communicating concepts and explanations in the field of natural sciences. This study is focused on how these representations are used, and not on the representations themselves.

Lemke (1998, p. 87) suggests that "to do science, to talk science, to read and write science, it is necessary to juggle and combine in canonical ways verbal discourse, mathematical expression, graphical-visual representations, and motor operations in the natural world." Lemke (1998, p. 89) adds that scientists "combine, interconnect, and integrate verbal text with mathematical expressions, quantitative graphs, information tables, abstract diagrams, maps, drawings, photographs, and a host of unique specialized visual genres seen nowhere else". Latour (1986) argues that this reasoning practice using visualization and inscription, involving material and symbolic instruments, was crucial for understanding scientific origins and some special characteristics. According to him, it attracted the interest of science educators in the role of representations in science teaching and learning.

Kozma (2003, p. 205), when analyzing the work of chemistry experts, noted that, regarding their research, they made different representations based on the characteristics of the material, and when negotiating/sharing understandings, they manipulated these representations, correlating them. Then, Kozma (2003) argued that students could develop this ability to build representations and communicate them in a suitable way to the teacher, constructing and correlating different representations. When investigating the use of representations with students, Kozma and Russell (2005, p. 129-130) argued that students learn science effectively when they participate in activities "in which representations are used in the formulation and evaluation of conjectures, examples, applications, hypotheses, evidence, conclusions, and arguments."

Tytler (2003) argues that students have to deal with two aspects present in scientific discourse: representations and multimodality. The perception of science built from multimodal and representational reasoning associated with active involvement of students in class and respect for the individual learning needs and preferences of students becomes the basis of the approach based on multimodal representations. Therefore, this approach is focused on the negotiation process for understanding representations. Quadros and Giordan (2019) analyzed the class of a teacher who used the representation proposed by the students to begin the studies of chemistry present in a given phenomenon.

Prain and Tytler (2013) argue that representational competence plays a crucial role in learning science and that developing this competence implies student involvement in the interpretation and construction of relations of an object, its representation and meaning. For these authors, representation becomes a sign for the student when it means something (an idea or explanation) in relation to the object of study. For students to understand or explain concepts in science, they must use their cognitive and representational resources and then learn new concepts while learning how to represent them. With the approach of multimodal representations, learning scientific concepts involves switching between representational modes (verbal, written, visual and mathematical), coordinating them to generate consistent explanations.

For Prain, Tytler, Hubber and Waldrip (2013), quality learning involves building and coordinating representations to solve problems and develop explanations. Therefore, learning is a more active process. Knowledge is built through representational practices involving generation/proposition, refining/negotiation, justification and judgment of explanations, processes and methods in science. Throughout this process, students will be challenged to represent and argue around representations in an attempt to place the student's representations closer to canonical representations.

Therefore, multimodal representations involve the integration of methods to communicate ideas related to science through different representations. As an approach in science classes, students are involved in proposition, justification/negotiation, reformulation of representations.

METHODOLOGY

The classes analyzed in this study took place in an optional course offered to students from the Chemistry teacher training course (didactic-pedagogical classes) at the Universidade Federal de Minas Gerais, Brazil, in the second semester of 2018. Twelve students from the fifth to the eighth semester of the training course participated in this optional course.

From an experiment involving the presence of air in a syringe, the students (teachers in training) were asked to represent the air particles at three different moments: with syringe plunger in the normal position, with syringe pushed in, and syringe pushed out, keeping the air outlet closed in these last two cases (Figure 1). The air particles were under normal pressure in the first moment, higher pressure in the second, and lower pressure in the third.

A B C

Figure 1 - Experiment with a syringe at three different moments. A) plunger in normal position; B) plunger pushed in, and C) plunger pushed out.

Once the students produced the three representations (five pairs and two individual students), the course teacher invited them to draw such representations on the board. After the seven groups of representations were drawn on the board, they discussed about these representations for 28 minutes and 30 seconds. The class was fully videotaped and, for this study, the discussion about representations built by the students was analyzed to identify possible contributions of this discussion for the understanding of the role of representation in science classes.

The episode was transcribed to facilitate the analysis. This analysis considered the multiple representations and multimodality involved in the construction of meanings, and the analysis categories were defined according to resulting data.

RESULTS AND DISCUSSION

With the experiment involving the presence of air in a syringe, the students were invited to represent the air particles at three moments (Figure 1). After the students produced the three representations, the teacher asked them to draw these representations on the board. Figure 2 shows a picture of the board with the representations drawn by the students.

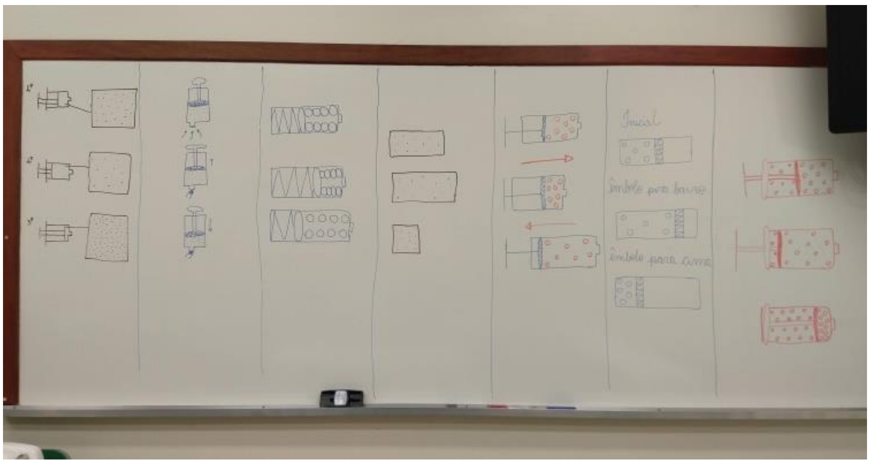


Figure 2 – Picture of the board with the representations drawn by the students.

The representations had similar features among them, but also many different aspects. The first group to the left showed a zoomed-in section of the syringe while the fourth group had a box without many details; all other groups represented the internal part of the syringe. Air particles were represented as both dots and balls. Some used arrows to indicate the force exerted on the syringe and one had notes with the drawing. After the students explained their representations, the teacher made questions that were essential to help understand them in their aspects of particle size, amount of particles drawn and distance between them, as explained below.

Particle size

In four of the seven groups, the particles were drawn as a small ball, with an empty space inside each one. The teacher questioned these shapes and several justifications were produced, most of them reporting easy visualization. With the teacher's persistence, student Patricia said: '... it's just a representation, it's not the particle itself!' The teacher insisted on the use of the ball and asked the students to put themselves in the place of a student who does not know chemistry and is still learning, and reminded them that alternative conceptions can also be constructed in school, as they had already studied.

Then the discussion involved possible alternative conceptions that could be built if they represented the particles as small balls, or empty spaces inside them. The students agreed that dots would be the best way to represent air particles to avoid alternative conceptions.

For Prain and Waldrip (2010), the act of representing is an important skill for an individual to become scientifically literate, and not just a peripheral resource. When Patricia said it was just a representation and not the particle itself, she seems to use the representation as a peripheral resource. For the authors of this study, the act of representing is a method to organize our own ideas and, therefore, it helps learning as it builds meanings. Tang, Delgado and Moge (2014) also consider representations as artifacts that symbolize an idea or concept in science and, for this reason, they are an integral part of the language of science. In teacher training, the need to value the role of representation in the construction of meanings is already evident in the beginning of this discussion.

Amount of air particles

Considering all representations drawn on the board, only Milena's drawing clearly used the zoom resource to represent air particles (Figure 6); the other students represented the internal part of the syringe (Figure 7). The teacher highlighted this difference and asked them to explain why this difference happened between their representations. The following dialogue took place.

Table 1 – Dialog involving types of representations

Narrator	Transcription of speech
Teacher	*What is the advantage of yours when comparing them to Milena's?*
Pedro	*I liked it because of the zoom.*
Juliana	*But it shows only a small part.*
Natália	*In fact, it does not have only 12 particles in a syringe.*
Teacher	*How many air particles do you think a syringe can have?*

Natália, when comparing her representation with the representation highlighted by the teacher (Milena's), realizes the number of particles drawn on the board does not match their knowledge of chemistry. This discussion was more consensual when compared to the others, since the students agreed with Milena's proposal. Tytler et al. (2013) discuss about explanatory representations, that is, representations that help understand a phenomenon. These students were aware that a space like that inside a syringe could contain thousands of particles. But, when they represented the particles, they drew a very limited number of particles, not paying attention to this mistake. The teacher had to question these representations so Natália could express her understanding, which seemed to be the understanding of all other students.

Figure 6 – Representation with zoom in section of the syringe

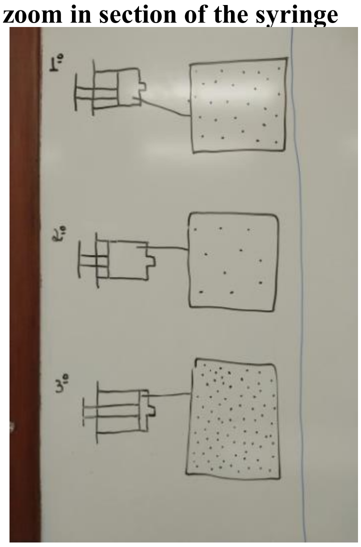
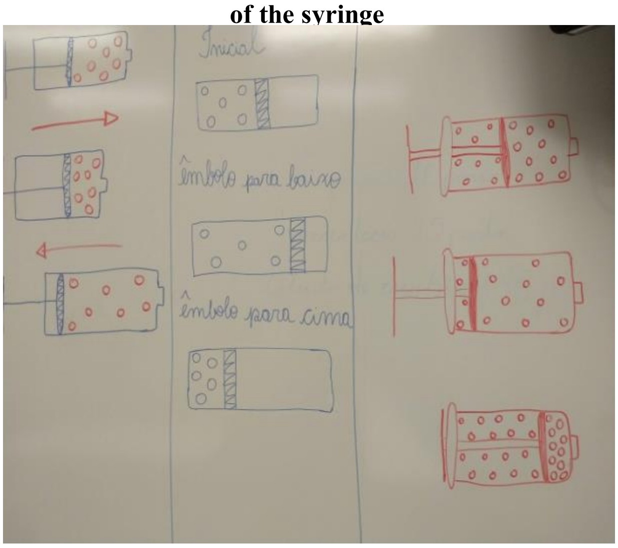


Figure 7 – Representation of internal part of the syringe



Distance between air particles

The representations showed different spacing between air particles, even in the same group. The particles were subjected to different pressure, but all three cases referred to gas. Since the students did not notice any problem regarding the distance between the particles in the representations they had drawn on the board, the teacher talked about a subject that apparently was not part of the lesson: representations of different physical states of the matter. The teacher drew on the board three boxes and identified them as zoom-in substances in the solid, liquid and gas states, respectively. She asked the students to represent the particles in these three states. Augusto went to the board and drew the representations, ensuring proper distance between the particles – the particles in the gas box were far from each other, and those in the solid box were much closer to each other (Figure 3).

gas

liquid

solid

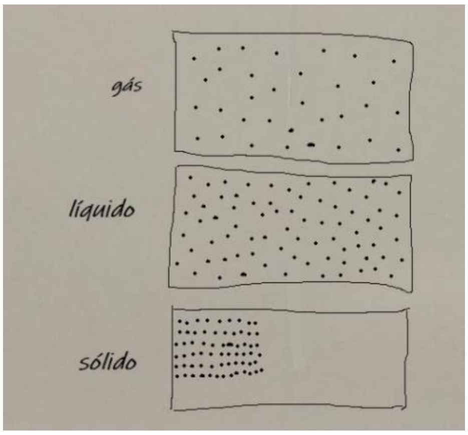


Figure 3 – Representations of states of matter drawn by one student

In the case of solid state representation, the student did not use the whole box, stating that all space would be occupied in the same way, with particles organized in lines. The teacher asked the support from the other students in the analysis of the drawing made by Augusto. Apparently no one disagreed with the drawing. However, the teacher's silence promoted another discussion.

The presence of lines was justified by the fact that, in the solid state, the particles are more organized. As a strategy to show the limitation of these representations and advance in the discussions, the teacher asked everyone to stand up and pretend they were particles of a substance in the gas state. One student started to move around the room, followed by the others, who also started to walk randomly around the room. The movement of vibration was also used by one student. The teacher highlighted the challenge of inserting movement in a static representation like a drawing, and argued that embodied representation favors the understanding of movement. Two students, when in contact, questioned if such closeness is possible, and another student answered that 'the particles are always in contact, not always producing a reaction.'

After that, the teacher asked the students to pretend they were particles of a liquid substance, and the group immediately gathered to one side of the room, moving in a more limited area. As there was no question regarding this representation, the teacher then asked the students to pretend they were solid particles. They were closer to one another, but leaving an empty space in the center of the group. When questioned about the meaning of that space, they moved and assumed a more standardized distance between them. Some of them kept doing the vibratory movement. The teacher then asked if they were sure that it was the most suitable representation of solid particles, which was confirmed by all students.

The next task consisted in comparing the embodied representations made by the students to the drawings on the board. The fact that the movement cannot be represented in the drawing was emphasized by most students and some suggestions were made but not materialized in the drawing. The teacher highlighted the solid state representation by saying: 'Here (pointing to the drawing on the board – Figure 8), the particles are lined up, but you didn't get in line when you represented the solid state in the corner (pointing to the corner of the room). You assumed more random positions.' The students understood the inconsistency between the two representations and said the drawing should be different. The teacher asked one student to go to the board and reformulate the drawing.

gas

liquid

solid

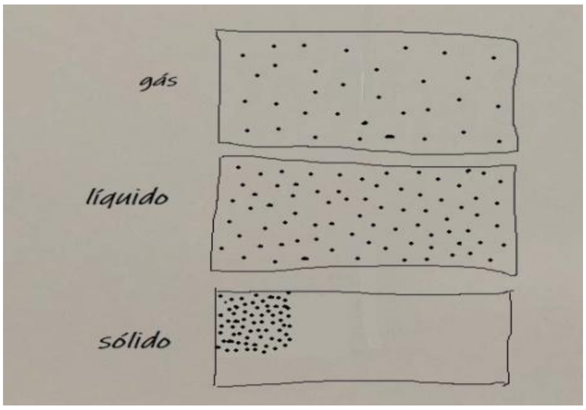


Figure 4 – Representations of states of matter drawn on the board after embodied representation

For being two representations of the same phenomenon, they are expected to be similar. Prain and Tytler (2013) point out the importance of students to have multiple opportunities to represent and reconfigure their understandings through discussion with their peers and the teacher. By using a different representation from what they had initially drawn on the board, the students ended up changing the representation, placing the particles that represented the solid state more randomly. Then, the authors agree with Prain and Tytler (2013), considering that, by providing students with an opportunity to represent the same phenomenon using different semiotic modes – first the drawing on the board and then their own bodies – the students compared the representations and reformulated the drawing on the board.

Once a consensus was created for the representations of solid particle, the teacher asked the students to observe the distance between air particles represented in the first activity, that is, the representation of air present in the syringe at three different moments. Milena, who correctly used the zoom resource, laughed at her own representation and said: ‘This is not gas!’ She went to the board and drew the particles again, keeping proper distance between them, that is, keeping the distance of particles in the gas state, but with a small difference between them due to higher or lower pressure to which they were subjected.

FINAL CONSIDERATIONS

To ensure a meaning to the representations, the students had the opportunity to construct, justify, negotiate and reformulate their own representations, placing them closer to canonical representations. Although they were teachers in training, there was no consistent understanding of the role of representation in chemistry teaching.

Regarding the distance between gas particles subjected to different pressures, representations through drawings on the board were not enough. When using embodied representations, the students understood the incoherence in the distribution of particles representing the solid state. Then, they were able to advance their knowledge by returning to the initial representation of the phenomenon that occurred inside the syringe and reformulating their representations. This way they placed their representations closer to canonical representations. Multimodality and multimodal representation were, therefore, essential for the construction of meanings.

Based on the initial speeches present in the discussion of episode 2, these teachers in training did not use representation as a form of knowledge construction. After the activities of classes 1 and 2, the teacher used the meaning of representations in chemistry teaching, exploring the possibility of creating alternative conceptions and using representation to help organize ideas and, therefore, construct knowledge. Understanding the role of representation proved to be essential for teachers, and in this sense, this topic should be widely explored in science teacher education courses. Students from teacher education courses who will soon become chemistry teachers, need to recognize the role of representations in conceptual learning.

ACKNOWLEDGEMENT

The authors would like to thank Fapemig and CAPES for their support.

REFERENCES

Adami, E. (2016). Multimodality. In O. Garcìa, N. Flores and M. Spotti (Eds). pp. Oxford Handbook of Language and Society. Oxford: Oxford University Press. Doi: 10.1093/oxfordhb/9780190212896.013.23

Halliday, M. A. K. (1978). Language as social semiotic: the social interpretation of language and meaning. London: Edward Arnold.

Halliday, M. A. K. (1985). An introduction to functional grammar. London: Baltimore.

Jewitt, C. (2008). Multimodality and Literacy in School Classrooms. Review of Research in Education, 32, 241–267.

Jewitt, C. (2006). Technology, Literacy, Learning: A Multimodality Approach, London: Routledge.

Jewitt, C. (2009). The routledge handbook of multimodal analysis. London: Routledge.

Kozma, R. (2003). The material features of multiple representations and their cognitive and social affordances for science understanding. Learning and Instruction, 13, 205–226.

Kozma, R. & Russell, J. (2005). Students becoming chemists: Developing representational competence. In J. Gilbert (Ed.). Visualization in Science Education (pp. 121-145). Springer, Dordrecht.

Kress, G. & Van Leerwen, T. (1996). Reading Images: the grammar of visual design. London & New York: Routledge.

Kress, G. What is Mode? (2009). In J. Carey (ed.). The Routledge Handbook of Multimodal Analysis (pp. 54-67). New York: Routledge.

Kress, G. (2010). Multimodality: a social semiotic approach to contemporary communication. New York: Routledge.

Latour, B. (1986). Visualization and cognition: Drawing things together. Knowledge and Society, 6, 1-40.

Lemke, J. (1998). Multiplying meaning: Visual and verbal semiotics in scientific text. In J. Martin & R. Veel (Eds.), Reading science: Critical and functional perspectives on discourses of science (pp. 87–113). London: Routledge.

Norris, S. (2004). Analyzing multimodal interaction: A methodological framework. New York: Routledge.

Prain, V. & Waldrip, B. (2010). Representing Science Literacies: An Introduction. Research in Science Education, 40(1), 1-3.

Prain, V., Tytler, R., Hubber, P. & Waldrip, B. (2013). Implications for the Future. In R. Tytler, V. Prain, P. Hubber, & B. Waldrip (Eds.). Constructing Representations to Learn in Science (pp. 183-192). Rotterdam, Netherlands: Sense Publishers.

Prain, V. & Tytler, R. (2013). Learning Through the Affordances of Representation Construction. In R. Tytler; V. Prain; P. Hubber; B. Waldrip (Eds.), Constructing Representations to Learn in Science (pp. 66-82). Holanda: Sense Publishers.

Quadros, A. L. & Giordan, M. (2019). Rotas de Transição Modal e o ensino de Representações envolvidas no Modelo Cinético Molecular. Investigações em Ensino de Ciências, 24(3), pp. 74-100.

Tang, K., Delgado, C. & Moje, E. B. (2014). An Integrative Framework for the Analysis of Multiple and Multimodal Representations for Meaning-Making in Science Education. Science Education, 98(2), 305-326.

Tytler, R., Prain, V., Hubber, P. & Waldrip, B. (2013). Constructing Representations to Learn in Science. Rotterdam, Netherlands: Sense Publishers.

Tytler, R. (2003). A window for a purpose: Developing a framework for describing effective science teaching and learning. Research in Science Education, 30(3), 273-298.

PRE-SERVICE TEACHERS' EXPLANATIONS OF PHYSICAL PHENOMENA USING A SELF-CONSTRUCTED PARTICLE MODEL OF MATTER

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This paper analyses pre-service teachers' explanations of physical phenomena and their ability to improve them using a self-constructed particle model of matter. The investigation was conducted in an undergraduate double degree teachers' course where student teachers were introduced to a model-based learning and teaching approach. Data was collected from the written material produced by students explaining different experiments in two moments of a lesson. Explanations were analyzed in order to understand the characteristics of the model of matter being used to produce such explanations and the characteristics of the explanation itself. Results suggest that student teachers did not have a consistent model to explain physical phenomena but a context-dependent model, and they improved the sophistication of their explanations during the instruction.

Keywords: Teacher Professional Development, Explanation Construction, Modeling-based learning.

INTRODUCTION

This study compares prior and after instruction pre-service teachers' explanations using a self-constructed particle model of matter as a tool to gain access to the development of their abilities related to causal explanations for natural phenomena. The study is framed in a pre-service science teaching course of a primary and kindergarten teaching double degree which main goal is to change students' views of science and science teaching, while being immersed in a Model Based Learning approach. During the course, students were engaged in modelling practices regarding the kinetic theory of matter over a four-week lesson period, in order to: (i) offer a new learning experience useful to work on their teaching views; (ii) work on their content knowledge, which is important as the vast majority of them gave up studying science subjects at the age of 16.

THEORETHICAL FRAMEWORK

Current research in science education emphasizes engaging students in the scientific practices in order to learn core scientific ideas (Oh & Oh, 2011). Although scientific activity involves many different practices (i.e. posing investigable questions, argumentation, analysing data, etc.), all of them must be developed in an intricate way in order to achieve the broad purpose of the scientific endeavour: developing evidence-based, explanatory models of natural phenomena to make sense of the world (Passmore et al., 2014). Thus, constructing scientific explanations for natural phenomena appears to be a key scientific practice ~~and~~ providing students with the competence to construct explanations scientifically resulting in their learning new ways of thinking about science education (National Research Council, 2007).

Characterizing scientific explanations and their nature has been at the centre of philosophical attention and debate throughout history and five major philosophical models of scientific explanations have been identified as relevant to research and practice in science education (Braaten & Windschitl, 2011). However, for the purposes of this study, we focus on causal (also referred to as mechanistic) explanations (Braaten & Windschitl, 2011; Russ et al. 2008), being understood as explicit applications of theory that go beyond description to reveal the causal relationship or model the mechanism for a specific situation or phenomenon (Braaten & Windschitl, 2011).

Even though mechanistic reasoning seems to arise quite intuitively when trying to explain certain natural phenomena (Russ et al., 2008), research underlines the persistence of difficulties in constructing proper scientific explanations, even after years of instruction (McNeill et al. 2006). To foster students' competence in constructing scientific explanation calls, therefore, for explicit guidance (McNeill et al. 2006; Braaten & Windschitl, 2011).

The kinetic theory of matter (particle theory) is used by scientist to give mechanistic explanations about a vast array of biological, chemical and physical phenomena. Several studies explore how students of different ages use particle models to give an account of natural phenomena (Harrison & Treagust, 2002). However, little is known about how pre-service teachers construct such knowledge to further support students in this sort of practice.

To address this issue, the present study analyses pre-service teachers' explanations of physical phenomena and their ability to use a self-constructed particle model of matter to build them.

METHOD

Data was gathered from 23 student teachers' written explanations of physical phenomena in two moments: (i) prior to instruction, when student teachers had to work in small groups following the Prediction-Observation- Explanation structure in relation to six experiments regarding air pressure, condensation or solutions; (ii) after four weeks of instruction where student teachers engaged in modelling practices (thus constructing, evaluating, reviewing and using models) to learn about the kinetic theory of matter. In this moment, working in the same groups, student teachers were encouraged to revisit some of their initial explanations and to explain some of the same phenomena. The explanations given were analysed in terms of: (i) characteristics of explanations and the mechanistic reasoning within them (based on Russ et al approach (2008), see table 1) and; (ii) characteristics of the subjacent model being used (based on Harrison & Treagust, 2002, see table 2).

Table 1. Categories within analysis of explanations (based on Russ et al., 2008)

Type	Description
Type A	Entities; the organization, activities, and properties of the entities which are needed to explain the phenomenon identified and which are appropriate to explain the observed phenomenon. Chaining occurs.
Type B.1	The components identified are adequate to explain the observed phenomenon, but not all components are identified. Chaining occurs.
Type B.2	The components identified are adequate to explain the observed phenomenon, but not all components are identified. Chaining does not occur.

Type C.1	The components identified are not adequate to explain the observed phenomenon. Chaining occurs.
Type C.2	The components identified are not adequate to explain the observed phenomenon. Chaining does not occur.
Type D	Non-explanation, a description of an observation.

Table 2. Categories within subjacent models (based on Harrison & Treagust, 2002)

Type	Description
Type 0. No model	No model is being used
Type 1. Macroscopic	The phenomenon is described using a macroscopic model of matter
Type 2. Non-kinetic particulate model	The model being used considers microscopic particles, but they do not have any sort of movement
Type 3. Partial kinetic particulate model	The model being used considers microscopic particles, but they have any sort of movement

RESULTS

In this paper, results come from the detailed analysis of two experiments. These experiments have been chosen because they describe the most common situations found in the complete results.

In the first experiment, students were required to place a drop of dye into three beakers containing the same amount of water at different temperatures. Students had to explain why an increase in temperature causes an increase of liquid solubility. The aim was to focus on the relationship between temperature and the movement of molecules in a liquid, thus relating the observed phenomena to the molecular-kinetic theory and neglecting other theories (i.e. thermodynamics) that could also be used to explain it.

Prior to instruction, the subjacent models used to explain this phenomenon were, as shown in Fig. 1, the non-kinetic particulate model (33% in grey, type 2) and the kinetic particulate model (39%, in yellow, type 3). However, it is also worthwhile to notice that, in 28% of the initial accounts no kind of matter representation was used (in blue colour, type 0 in fig. 1).

Regarding the sophistication of the explanations, and as it is also shown in figure 1, 33% of the students made a mere description of what was happening (type D). For example, student 1 wrote: "*In warm water the drop of dye dissolves faster*". Furthermore, 32% of the students gave unchained explanations (types B.2 and C.2) for the phenomena. There was not a single explanation Type A in this stage.

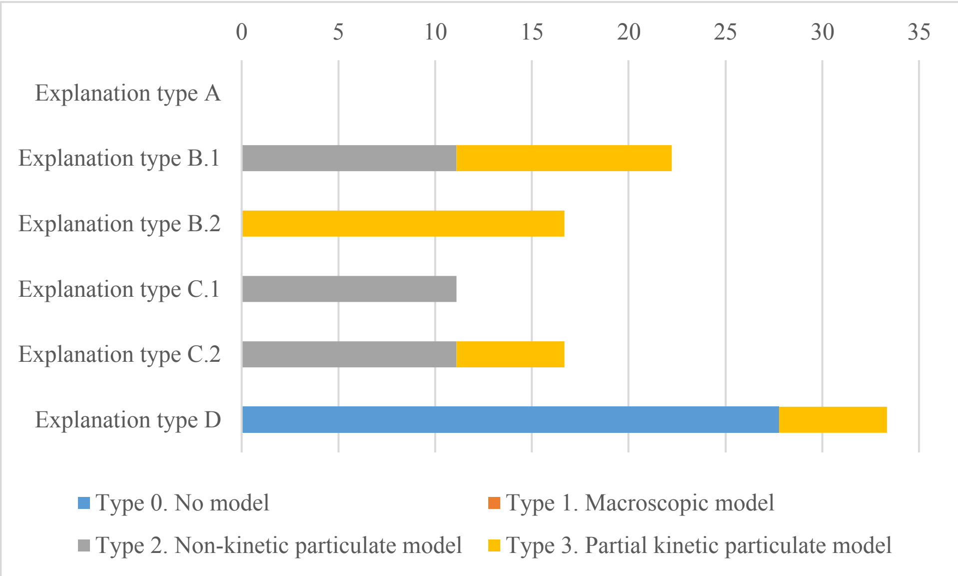

Figure 1. Results of initial explanations in the first experiment

Through instruction, student teachers not only improved their representations of matter, but also their explanations of the phenomenon became more sophisticated. As it can be seen in Fig. 2, the vast majority of students used the kinetic particulate model (58%, type 3 in yellow) and the non-kinetic particulate model (32% type 2 in grey). Regarding their explanations, it is possible to see that mere descriptions (type D, fig.2) were only given by 5% of the student teachers. Unchained events explanation, types B.2 and C.2 in fig. 2, decreased to 0% and the most sophisticated ways of explaining (type A explanations, fig. 2) represented 21% of the sample.

For instance, and in order to show a sophisticated way of explaining (Type A) in which chaining occurs and the components of the explanations are adequate to explain the phenomenon, we see that student 2 wrote: "*The drop of dye descends more vertically in the* *cold water, because in warm temperatures, dye and water particles move faster and, therefore, the drop of dye dissolves better in the warm water*".

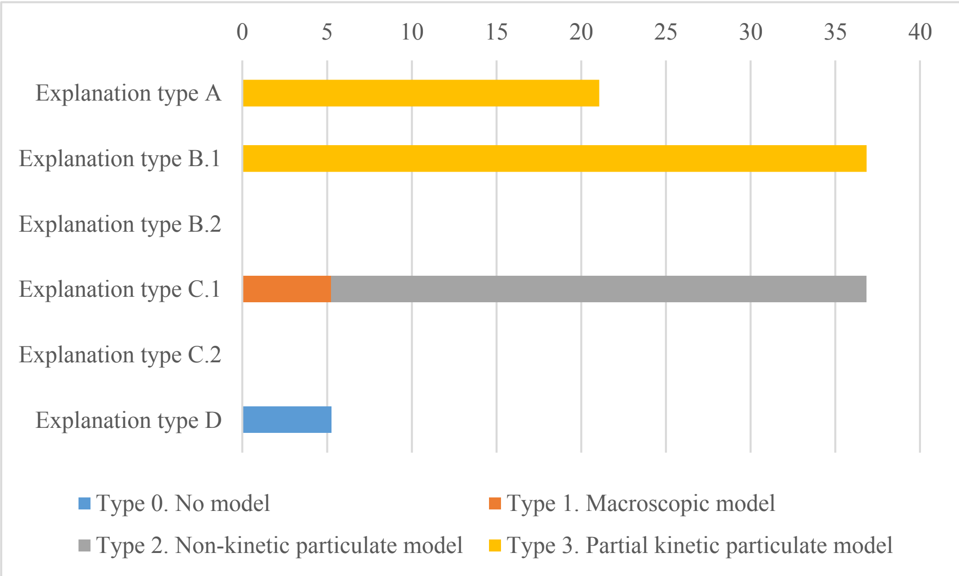

Figure 2. Results of final explanations of the first experiment

The second experiment referred to the effects of air pressure. In this case, students had to explain why a tied balloon expands after pumping the air out using a vacuum apparatus.

At initial stages and as shown in Fig. 3, students used a macroscopic model (52%, orange, type 1) and a non-kinetic particular model (29%, grey colour, type 2). As far as the sophistication of explanations is concerned, we can see that 19% of them were classified as mere descriptions (type D explanations). Moreover, 38% of the students produced unchained explanations, types B.2 and C.2. There was not a single explanation Type A in this stage.

In order to show how they use a macroscopic model we can see, for example, how student 3 wrote: *"The air inside the balloon wants to take up the maximum space, but is stopped by the balloon's elastic wall, which is deformed, and the balloon blows up. The particles inside the balloon push up to take up space"*. This example is also useful to show how students were able to chain events, even though the components of the explanation were not adequate to explain the phenomenon.

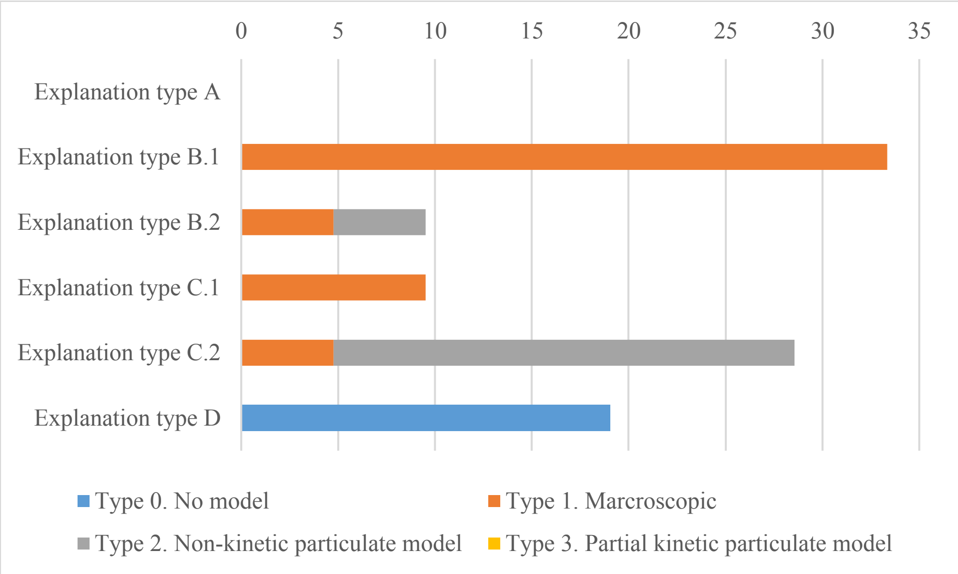

Figure 3. Results of initial explanations in the second experiment

After instruction, as is shown in Fig. 4, 26% of students continued using a macroscopic model (type 1, orange). However, most of them used particulate models: non-kinetic particulate model (60%, grey, type 2) and kinetic particulate model (9%, yellow, type 3). Explanations also increased in sophistication. Mere descriptions (type D) only represented the 13% during the final stage, while chained explanations types A, B.1 and C.1 increased from 42% to 82%, through instruction.

The following example shows a sophisticated explanation using a non-kinetic particulate model. In this case, student 4 wrote: "*First of all, the particles of air inside the vacuum apparatus take up a space that the particles inside the balloon are not able to take up. The air particles outside the balloon push against the balloon, the air particles inside the balloon push outwards. When we pump the air out, in other words, when the vacuum is made, the pressure exerted by the particles outside the balloon disappeared. So, the pressure exerted by the air particles inside the balloon has no opposition. The air particles inside the balloon take up this space, and the volume of the balloon increases*". Even though this explanation could not be considered scientifically adequate due to the macroscopic model used by students, from the point of view of the structure of the explanation, the components and the chaining of the events could be considered fully adequate.

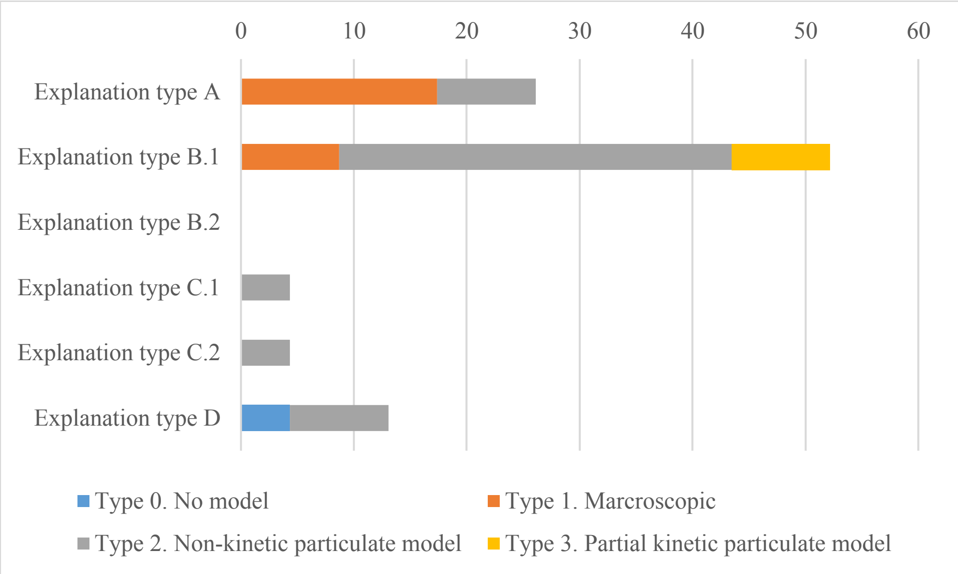

Figure 4. Results of final explanations in the second experiment

CONCLUSIONS

Mechanistic reasoning is fundamental for predicting and explaining the behaviour of many natural phenomena and, accordingly, is necessary for the knowledge construction in science (Nersessian, 2008). Models are also central to the process of understanding, doing and communicating about science, being used as tools to make predictions and construct explanations for how and why natural phenomena occur (Passmore et al., 2017). This study contributes to think about the relation between construction of models and its use to give explanations about natural phenomena.

Overall, the results suggest a lack of consistency using a self-constructed model of matter while explaining different phenomena. For example, some students would use a particulate model to explain why an increase in temperature causes an increase of liquid solubility while using a macroscopic model to explain why a balloon expands in a vacuum apparatus. In this sense, using one model or another seems to be context dependent.

Furthermore, it is possible to conclude that instruction increases the sophistication of causal explanations mainly facilitating chaining reasoning strategies. These results are in consonance with other studies that show that, although the potential of reasoning about causes and effects emerges very early, its mastery is not an all-or-nothing accomplishment and, therefore requires for explicit guidance (McNeill et al. 2006; Braaten & Windschitl, 2011).

Finally, results show that causal explanations given by students are not always consistent with those accepted by scientists as the components of the explanation differs from those considered in scientific explanations. According to theories on responsive teaching in science classrooms (Hammer et al., 2005), these results may have important implications for undergraduate classes. Pre-service teachers in this study were engaged in modelling practices to learn concepts within science while learning about the kinds of epistemic activity that constitutes science. Therefore, the recognition of productive explanations beyond their scientific correctness, could help pre-service teachers to recognise them.

REFERENCES

Braaten, M., & Windschitl, M. (2011). Working toward a stronger conceptualization of scientific explanation for science education. *Science education*, *95*(4), 639-669.

Hammer, D., Elby, A., Scherr, R. E. & Redish, E. F. (2005). Resources, framing, and transfer. In: *Transfer of learning from a modern multidisciplinary perspective (pp* . 89-119). Greenwich, CT.

Harrison, A. G., & Treagust, D. F. (2002). The particulate nature of matter: Challenges in understanding the submicroscopic world. In *Chemical education: Towards research-based practice* (pp. 189-212). Springer, Dordrecht.

McNeill, K. L. et al. (2006). Supporting students' construction of scientific explanations by fading scaffolds in instructional materials. *The Journal of the Learning Sciences*, *15*(2), 153-191.

National Research Council. (2007). *Taking science to school: Learning and teaching science in grades K-8*. National Academies Press.

Nersessian, N. (2008). *Creating scientific concepts*. Cambridge, MA: MIT Press.

Oh, P. S., & Oh, S. J. (2011). What teachers of science need to know about models: An overview. *International Journal of Science Education*, *33*(8), 1109-1130.

Passmore, C., Gouvea, J. S., & Giere, R. (2014). Models in science and in learning science: Focusing scientific practice on sense-making. In *International handbook of research in history, philosophy and science teaching* (pp. 1171-1202). Springer, Dordrecht.

Passmore, C., Schwarz, C., Mankowski, J. (2017). Developing and Using Models. In *Helping students make sense of the world using next generation science and engineering practices* (pp.109-135). NSTA Press.

Russ, R. S., Scherr, R. E., Hammer, D., & Mikeska, J. (2008). Recognizing mechanistic reasoning in student scientific inquiry: A framework for Discourse Analysis Developed From Philosophy of Science. *Science Education, 92*(3), 499-525.

THE DESIGN OF AN INNOVATIVE SCIENTIFIC INTERDISCIPLINARY LAB FOR PRE-SERVICE PRIMARY TEACHERS

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Teaching science is a crucial issue in early childhood and primary school, as it greatly influences the future attitude of pupils (and, thus, of future citizens) towards scientific knowledge. However, an effective training in teaching science cannot rely solely on isolated, well-curated courses. In this paper, we describe a widescale proposal of innovation for the academic scientific curriculum of pre-service pre-primary and primary teachers. Our aim is to improve scientific knowledge of students, as well as their related teaching skills. The major foci of our proposal are: (i) making a "scientific environment" available, i.e. a term fully devoted to science during the five years of the academic curriculum; (ii) planning interdisciplinary lab classes connected to a central topic of keynote importance (which was chosen to be water); (iii) allowing students to actively work on the topic through hands-on activities. The combination of these factors is expected to circumvent many flaws in the traditional academic teaching of science, which are exaggerated in the context of the education of pre-service teachers, who actually did not select a scientific course for their academic career. In a nutshell, a stimulating scientific context and more engaging, cutting-edge classes will hopefully turn motivated students into effective teachers of tomorrow.

Keywords: Primary School, Teacher Preparation, Interdisciplinarity

INTRODUCTION

Because of the quick changes of our world, the development of STEM (Science, Technology, Engineering, and Mathematics) knowledge and skills to deal with complex issues and wicked problems is becoming more and more important since the beginning of the educational path. As stated in the Netherland report (Adams et al., 2018), "Science [STEM] education, which cuts across the persistent divide of natural sciences and social science, is potentially uniquely positioned to support new generations' understanding and engagement and address the social, economic and environmental dimensions of these global challenges."

Although recent educational reforms emphasize the importance of teaching STEM from the lower educational level, it still remains a difficult domain. Indeed, many elementary teachers feel less knowledgeable about STEM content and less comfortable teaching STEM than other subjects.

One of the most accurate statistics on science learning from the United States clearly pinpoints flaws in science teaching: roughly 60% of students enrolling in a STEM field leave for non-STEM courses or drop out. The percentage can reach 80% for women and for some minority groups (President's Council of Advisors on Science and Technology, 2012). This issue is amplificated in university courses for pre-service pre-primary and primary school teachers, who did not enrol in STEM university courses at all and should anyway follow science courses. Recently, in the US, STEM education has been placed in the spotlight because of mediocre achievement in these disciplines (NCES, 2009; OECD, 2013). Indeed, across US, many teacher education programmes are now becoming more focused on ways to improve pre-service teachers' preparation for teaching and integrating STEM disciplines (Lederman & Lederman, 2013).

Many claims have risen in recent years in favour of two long-known, but not long-applied ways of teaching, notwithstanding a large amount of skepticism (Waldrop, 2015; Wieman & Gilbert, 2015b). First, active teaching methodologies are persistently found to be more effective and more engaging (e.g., Šorgo, 2010; Freeman et al., 2014; Waldrop, 2015; Wieman & Gilbert, 2015a, 2015b); moreover, the importance of interdisciplinarity is repeatedly underlined (Huber & Hutchings, 2004; Huber, Hutchings, Gale, Miller, & Bree, 2007; Woods, 2007; Šorgo, 2010). Again, the multidisciplinary, relevant, and experiential character of place-based education is said to increase students' engagement, understanding, and academic achievement (Semken & Freeman, 2008). Many universities are fostering opportunities for integrative learnings (Association of American Colleges and Universities, 2002), but these experiences still involve limited numbers of students (Huber & Hutchings, 2004).

Integrate learning across contexts and time is one of the greatest challenges in education (Huber & Hutchings, 2004): accordingly, the integrative learning approach should be a "campus-wide concern" (Huber et al., 2007). The idea that teaching STEM needs to be grounded on inter-multi-disciplinary knowledge organization poses challenges to teacher preparation and teaching practices. As stated by Woods (2007), inter-multi-disciplinary learning is expected to effectively improve knowledge and skills if three mandatory elements are kept: the interdisciplinary collaboration needs to be set up some months before the lab classes; the lab classes must offer a real opportunity for interdisciplinary collaboration; time and space for reflection and assessment should be envisaged (Woods 2007; Wieman & Gilbert, 2015b).

Given this literature background, the Single Cycle Degree of Primary Teacher Education at the University of Bologna, proposed an institutional and educational reform concerning the scientific disciplines, with the specific aim of engaging more and more the students towards science and improving scientific knowledge of students, as well as their related teaching skills.

This paper aims at presenting the architecture and the main features of a new scientific inter-multi-disciplinary laboratory designed to combine active learning and inter-multi-disciplinarity for pre-service pre-primary and primary teachers. The lab classes devised by our group for pre-service teachers were conceived as a first step towards the scenario we introduced above, with active teaching and learning interwoven in an inter-multi-disciplinary framework spanning over biology, chemistry, ecology, and physics as well as crossing boundaries between STEM and humanities in order to address more complex societal issues. In this paper, we describe the architecture of the lab, followed by a preliminary analysis of students' reactions to the inputs of this innovative inter-multi-disciplinary lab.

THE ARCHITECTURE

The institutional and educational context

The context of our study is the Single Cycle Degree of Primary Teacher Education of the University of Bologna (Italy), aiming to the training of future primary and pre-primary teachers. The access to the degree course is restricted and every year a cohort of about 300 students is enrolled.

According with the institutional reform started in the 2016/2017 academic year, from the 2018/2019 a.y., all the third-year courses carried out during the second term are totally devoted to science and science education, which sets up the interdisciplinary collaboration (following Woods, 2007). This institutional choice followed up a process of reflection at institutional level that took into account both the results within the literature, concerning the difficulties illustrated in the framework above (e.g., OECD, 2013), as well as the data collected in the previous years from student evaluation questionnaires concerning the degree course and its structure.

Specifically, three scientific courses have been assembled in the same term: Elements of Biology, Elements of Chemistry and Ecology, Elements of Physics and Physics Teaching. All courses span over the foundations of the discipline and its teaching/learning methods, where the educational reconstruction of the basic concepts together with educational reflections and phenomenological experiences are used to elaborate the acquired knowledge and to turn it into teaching knowledge.

The institutional reform concerns not only the organisation of the scientific courses, but also the laboratory courses related to them. Indeed, along with the theoretical disciplinary courses, the program foresees disciplinary laboratories, which are strictly interconnected with the topics addressed in the courses. Each student can choose to attend the laboratory courses of one discipline among Biology, Chemistry and Ecology, or Physics: the specific purpose of the disciplinary laboratory is to elaborate on some of the course's topics, observing and carrying out scientific experiments, that can be easily reproduced in early childhood and primary schools. Together with the disciplinary laboratory, all the students are required to attend an inter-multi-disciplinary laboratory, spanning over Biology, Chemistry and Ecology, and Physics. This innovative laboratory has been designed and introduced to achieve several purposes: (i) investigating a topic underlying all the aforementioned scientific disciplines; (ii) discovering that a topic can be studied in detail and better understood if it is analysed under different perspectives, each related to a different discipline; (iii) highlighting the ethic and social impact of science and technology, that cannot be neglected. Moreover, an inter- and trans-disciplinary approach allows to face natural and anthropic phenomena, along with problems associated to everyday life, which are not easily understandable with a purely disciplinary approach.

The choice of introducing a mandatory inter-multi-disciplinary laboratory for all the students represented a real innovation within the degree courses and it represented a real experimental context that needed to be shaped from the very beginning.

In order to answer this need, a group of experts was established for designing such new and innovative lab. The group was comprised by researchers in the specific disciplinary domains, researchers in science education, a researcher in methodology of educational research (who is also the Director of Single Cycle Degree of Primary Teacher Education) together with school teachers.

The group of experts met up for one year and cared about the whole process: from the reflection on the existing literature on the topic to the design of the course, from the preparation of all the materials (e.g., slide, worksheet, home tasks, evaluation questionnaire) to the setting up of the experimental equipment. The lab was hosted in a science centre in Bologna (Opificio Golinelli), that provided adequate spaces and structures in order to realise the lab.

The first implementation of the inter-multi-disciplinary lab was carried out on May and July 2019 and was repeated 9 times with 9 different groups of students, for a total amount of 238 students. The teachers of the lab were two of the experts of the designing group, with the occasional co-participation of other experts of the group.

The inter-multi-disciplinary lab

As introduced before, the inter-multi-disciplinary laboratory aims at investigating a topic under different frameworks, each one related to a different discipline, in order to obtain an overall picture by integrating all its different aspects. Water was considered to be a suitable theme since it is a very transdisciplinary topic from a scientific standpoint, but also an open-ended multifaceted social issue.

Each implementation consists of a full-day lab class of 8 hours. Briefly, the trail of the laboratory begins with a phenomenological analysis of the behaviour of different objects put in water to build a macroscopic physical model that can explain this phenomenon. Then, a microscopic chemical model is introduced to explain other peculiar properties of water, highlighting some of their ecological consequences. Finally, the relation between these properties of water and the origin and adaptations of life is explored.

The first part of the laboratory follows a classical physical approach. The students start from observation of phenomenological evidence. Then, through a group discussion, students start to compare ideas and preconceptions about the features of a floating object, formulating hypotheses and designing experiments to verify their validity. A free exploration phase immediately follows: using a wide range of common objects and materials, including ice, students can test the validity of their hypotheses in large and medium-sized water tanks. In this way, they recognize that mass and volume individually do not justify the property of an object to float. The new concept of density must be built at this point, allowing the macroscopic explanation of the phenomenon of flotation.

In the second part of this laboratory, a microscopic chemical model is introduced: water molecule and hydrogen bridge bonds. This microscopic structure can explain many other water anomalies: the presence of all the three aggregation states under commonly encountered temperatures and pressures conditions, the high surface tension, the phenomenon of capillarity, the high solvent power. For each of these peculiarities, students carry out laboratory activities in small groups, like chromatography on paper, solubility tests, preparation of crystals. Also, the ecological consequences of these characteristics are highlighted: the relevance of ice floating on water for life development and maintenance on Earth, the role of capillarity in vascular plants, the karst environments.

Finally, biological consequences of water properties are investigated. Water high solvent power has played a crucial role in the processes that led to the origin of life on our planet. This peculiarity is also a decisive key for all metabolic reactions occurring in a single cell. As a take-home message from this section of the lab, students are faced with the idea that life was in its origin and still is an essentially aquatic phenomenon. Students experience and elaborate on the disparity of aquatic animals and their different forms of adaptation through (i) placing various animals in a salty water ecospace and (ii) observing the diverse microorganisms present in a single drop of steady water.

METHODS AND DATA ANALYSIS

Materials and Methods

Interdisciplinary laboratory classes were carried out in May and July 2019 for a total of 238 students. Teachers were two of the authors, namely CB (4 classes) and FP (5 classes). After the laboratory, students were assigned to hand a three-page report about the didactic value of the experience, discussing its strengths and weaknesses from the teacher's point of view, and eventual improving feedbacks as well. The assignment was mandatory for the students and they were graded by lab teachers with −1, 0, or +1 (on a 30 scale). The obtained grade contributed to the final mark of their semester examination. The assignment is reported in Table 1, while the assessment criteria are shown in Table 2.

Table 1. The assignment of the reports used for text mining

	Item
1	Strength of the approach presented in the lab (both methodology and contents)
2	Weaknesses and suggested improvements
3	Inter- and trans-disciplinary links
4	Suitability and plasticity for pre-primary school
5	Suggested connection with local resources (field trips, museums, natural parks,…)

Table 2. Assessment criteria

	Item
1	Mastering of disciplinary contents and of inter- and trans-disciplinary connections
2	Logic of the adaptation to the pre-primary school and of the use of local resources
3	Soundness of the use of the disciplinary lexicon and jargon
4	Originality of the proposals

At the conclusion of the semester, a total of 226 reports have been handed in and assessed. Overall, 164 out of 226 reports (72.57%) were scored +1.

Custom bash scripts were written to convert all reports in plain text files, which were cleaned and filtered using the package tm (Feinerer et al., 2008) of the software R (R Core Team, 2019). Stemming was carried out with the R package SnowballC (Bouchet-Valat, 2019). Words between 4 and 20 characters were retained if present in at least 20 texts and at most 222; empty words ("to be", "to can", "many", "some", "through", "when", "first", "second", "moreover", "allow", "during", "therefore", "to do", "point", "strength", "relative", and "weakness") among the most used terms were manually removed. Associations between words were looked for, setting 0.40 as the threshold level to retain an association.

Differences in text composition might be due to the two different hosts of the lab classes. In order to investigate this issue, we used the Principal Component Analysis (PCA) on the final term matrix. Given the sparsity of the matrix, it was not possible to use the log-transformed frequencies and, for the sake of clarity, only the 34 top-occurring terms were investigated, provided that results using all terms are not different. The PCA biplot was depicted using the R package ggbiplot (available at https://github.com/vqv/ggbiplot).

Results

The initial term matrix was comprised by 6,824 vocabulary items for a total of 1,542,224 words after cleaning typos, removing punctuation and filtering out Italian stop words. Expectedly, the most used word is "water" (3,542 occurrences), followed by "child", "active", "lab", and "school" (2,519, 1,725, 1,430, and 1,350 occurrences, respectively). Generally speaking, our corpus is in good agreement with the Zipf's law ($r = -0.98$, $R^2 = 0.95$, $P = 0$) and 183 vocabulary items account for half the corpus.

After removal of empty words and of poorly informative words present in more than 222 texts ("water", "child", "lab", and "school"), we obtained a matrix with 880 terms with a maximum length of 16 characters. The sparsity of the matrix was 72.97% (53,760 non-sparse entries). The words which were found in more texts were "active", "experiment" (216 texts each), "childhood", "to use" (215 texts each), and "possible" (214 texts). Similarly, the five most used words in terms of total occurrence are "active", "experiment", "to use", "possible", and "to observe": all top-occurring words (i.e., those words with more than 400 occurrences) are shown in Figure 1.

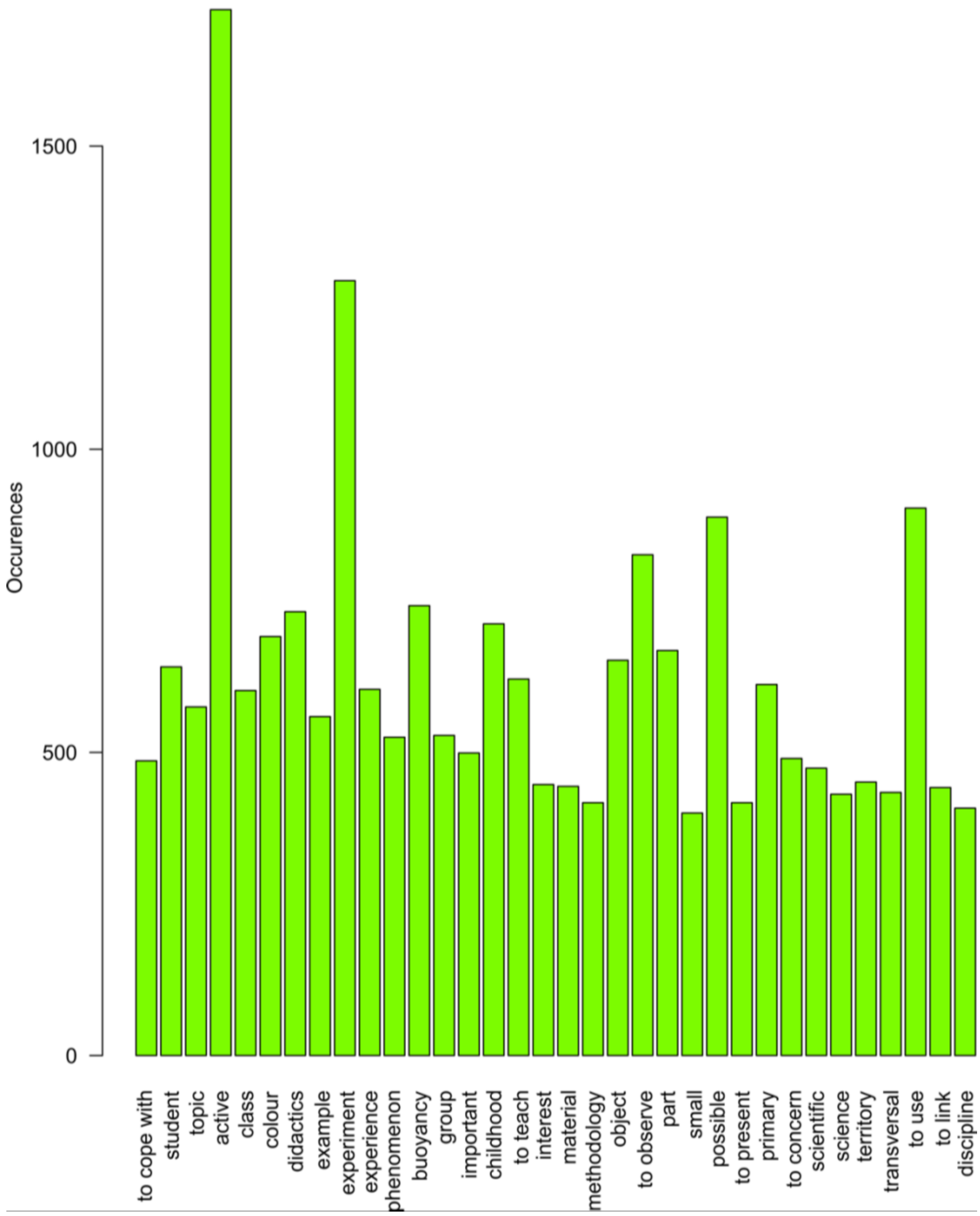

Figure 1. Top-occurring words. Word with at least 400 occurrences are shown.

Intermediate to moderately high levels of associations were evidenced within the corpus, in that only two term pairs scored an association level greater than 0.60; interestingly, both are connected to the flotation experience: "object"/ "to float" (0.69) and "object"/ "to sink" (0.65). Many pairs are connected to concrete, hands-on experience that were carried out during the lab (e.g., "object"/"to float", "colour"/"glass"); other pairs are connected to the scientific approach (e.g., "phenomenon"/"to observe") as well as to science teaching and learning (e.g., "to teach"/"to ask"). Notably, "methodology" and "content" are associated with an association level equal to 0.57, which means that an effective, multifaceted figure of science teaching and learning has been achieved by most students. Interestingly, all the three disciplines which are involved in the present lab are connected with the term "to present" to a similar extent (0.44 for "chemistry", 0.42 for "physics", and 0.40 for "biology"). The term "to teach" is more common in the corpus, with 621 occurrences in 186 texts against 417 occurrences in 162 texts for "to present"; recall that it shares the same stem with "teacher", the latter is probably the most used meaning of this stem, while the need of a fascinating way to deliver (to "present") science to pupils is retrieved from our corpus.

The first two principal components evidenced by the PCA approach jointly explain the 31.07% variance in the use of words in the filtered corpus (Fig. 2). There is apparently no structure in the corpus, i.e. no sub-groupings or cluster are evident. Interestingly, this holds for the lab hosts as well: the 95% ellipse computed on texts written by students who carried out the lab class with CB is perfectly superimposed with that computed on texts written by those who carried out it with FP. This suggests that the lab architecture and its outcome in terms of knowledge and effectiveness in science teaching and learning are largely independent from the actual host of the lab, which indicates that the inter-multi-disciplinary lab is robust to personal teaching idiosyncrasies of single lab teachers.

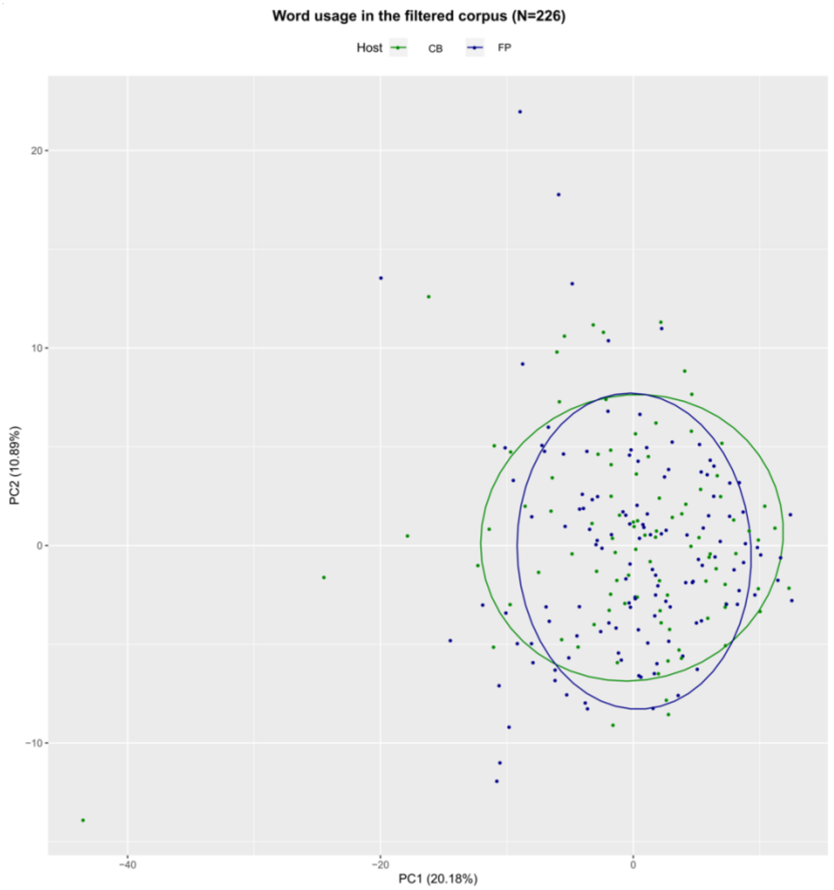

Figure 2. Word usage in the filtered corpus. Only the 34 top-occurring words shown in Fig. 1 are used.

DISCUSSION AND PERSPECTIVES

The inter-multi-disciplinary lab described in this paper is an experimental implementation of the current leading framework about STEM teaching and learning: active teaching methodologies (Šorgo, 2010; Freeman et al., 2014; Waldrop, 2015; Wieman & Gilbert, 2015a, 2015b); interdisciplinarity (Huber & Hutchings, 2004; Woods, 2007; Šorgo, 2010), even at a whole-curriculum scale (Huber et al., 2007); long-lasting interdisciplinary collaboration that does not run out with the lab class (Woods 2007); reflection and assessment opportunities (Wieman & Gilbert, 2015b).

The set up of a term which is explicitly devoted to natural sciences (biology, chemistry, ecology, and physics) is a precise line of the graduation degree board, and it represented a powerful introduction towards an effective interdisciplinary learning and thinking as well (Huber et al., 2007; Woods, 2007). The three courses are held together, and links and overlaps are highlighted, with special reference to the biology-chemistry, biology-ecology, and chemistry-physics boundaries. Within this framework, it seemed natural for students the hands-on experience to be focused on a topic, such as water, and not on single disciplines.

Therefore, the full-day lab class is naturally intended to play a pivotal role in the three courses and in the scientific education of pre-service pre-primary and primary teachers itself. Still, the aim of the lab would have not been pursued without a proper and sound opportunity of (self-)assessment (Woods, 2007; Wieman & Gilbert, 2015b), and this is the point of the brief reports that were requested to students: offering an opportunity of processing on the experience, a process which would have not been spontaneous in many cases.

The inter-multi-disciplinary lab has been put into practice with students for the first time in the a.y. 2018-2019. Thus, aim of the present paper is not a thorough evaluation of its effectiveness, rather a discussion of preliminary results about students' reaction to the novelty, reporting about the first impact on students' engagement and improvement in scientific knowledge related to the lab itself and independently from the lab teachers. Interestingly, the lab appears to be relatively robust with respect to the host, at least considering the word usage of the students' reports (Fig. 2). Conversely, observation and experiment are two faces of the scientific method, and these words and their relatives were retrieved among the most used in the students' reports (Fig. 1), meaning that the architecture of the lab class hit the students' attention more than the actual host.

Concerning the disciplinary contents, some misconceptions were found in the reports: e.g., the use of the word "heavy" associated to "object", while the concept of "dense" has been demonstrated to be preferable. Moreover, some experiences of the lab are more common in students' reports with respect to others – this is the case, for example, of flotation and capillarity. However, the main purposes of the lab class appear to have been fulfilled: (i) the association of "methodology" and "content" suggests a pursuit of an effective STEM teaching, resulting in active learning sequences, and (ii) the present lab class constitutes a possibility of integration of different scientific realms.

Notably, words and ideas connected to biology and ecology are more sparse and less common with respect to chemistry and physics. Whether this indicates a minor interest of students towards these disciplines or a greater difficulty to integrate these concepts within a written report is beyond the scope of the present paper. Our results suggest the validity and effectiveness of the inter-multidisciplinary approach in STEM education; a rigorous and thorough evaluation and characterization of the inter-multi-disciplinary lab deserves careful investigation in the following cohorts, in order to obtain an affordable amount of information.

ACKNOWLEDGEMENT

We are deeply grateful to Professor Ira Vannini, Director of Single Cycle Degree of Primary

Teacher Education, whose invaluable support was essential for the introduction of the innovative curriculum which is described in the present paper. We also wish to thank the Marino Golinelli Foundation, that provided spaces, materials and assistance for the lab.

REFERENCES

Adams, J., Avraamidou, L., Bayram-Jacobs, D., Boujaoude, S., Bryan, L., Christodoulou, A., ... Zembal-Saul, C. (2018). *The Role of Science Education in a Changing World.* Lorentz Center, Netherlands.

Association of American Colleges and Universities. (2002). *Greater expectations: A new vision for learning as a nation goes to college*. Washington, DC: Association of American Colleges and Universities.

Bouchet-Valat, M. (2019). *SnowballC: Snowball Stemmers Based on the C 'libstemmer' UTF-8 Library. R package version 0.6.0*. URL: https://CRAN.R-project.org/package=SnowballC

Feinerer, I., Hornik, K. & Meyer, D. (2008). Text Mining Infrastructure in R. *Journal of Statistical Software, 25,* 1–54.

Freeman, S., Eddy, S.L., McDonough, M., Smith, M.K., Okoroafor, N., Jordt, H., & Wenderoth, M.P. (2014). Active learning increases student performance in science, engineering, and mathematics. *PNAS, 111*, 8410-8415.

Huber, M.T., & Hutchings, P. (2004). *Integrative Learning. Mapping the Terrain*. Washington, DC: Association of American Colleges and Universities.

Huber, M.T., Hutchings, P., Gale, R., Miller, R., & Bree, M. (2007). Leading Initiatives for Integrative Learning. *Liberal Education, 2007*, 46-51.

Lederman, N. G., & Lederman, J. S. (2013). Is it STEM or "S & M" that we truly love? Journal of Science Teacher Education, *24*, 1237-1240.

National Center for Economic Statistics (NCES) (2009). NAEP 2008: Trends in Academic Progress. NCES 2009-479. Washington, DC: NCES.

Organization for Economic Co-operation and Development. (OECD). PISA 2012 Results in focus: What 15-year-olds know and what they can do with what they know. Paris: OECD, 2013.

President's Council of Advisors on Science and Technology. (2012). *Engage to Excel: Producing One Million Additional College Graduates with Degrees in Science, Technology, Engineering, and Mathematics*. Washington, DC: White House.

R Core Team (2019). *R: A language and environment for statistical computing*. R Foundation for Statistical Computing, Vienna, Austria. URL: https://www.R-project.org/.

Semken, S., & Freeman, C. B. (2008). Sense of place in the practice and assessment of place-based science teaching. *Science Education*, *92*, 1042-1057.

Šorgo, A. (2010). Connecting Biology and Mathematics: First Prepare the Teachers. *CBE Life Science Education, 9*, 196-200.

Waldrop, M.M. (2015). The science of teaching science. *Nature, 523*, 272-274.

Wieman, C., & Gilbert, S. (2015a). Taking a Scientific Approach to Science Education, Part I–Research. *Microbe, 10*, 152-156.

Wieman, C., & Gilbert, S. (2015b). Taking a Scientific Approach to Science Education, Part II—Changing Teaching. *Microbe, 10*, 203-207.

Woods, C. (2007). Researching and developing interdisciplinary teaching: towards a conceptual framework for classroom communication. *Higher Education, 54*, 853-866.

INITIAL SKILLS IN DRAWING OF THE PRE-SERVICE BIOLOGY TEACHERS

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Observations of biological objects accompanied by their description are natural parts of biology and biology teaching and learning. According to Dempsey & Betz (2001) the drawing is an excellent way to describe an object and it helps to develop change from simple mental models to focus on the identity of specific object. Whilst biologists use drawings in their studies, labs or field research, these drawings have different purpose in the school science. Many research studies support an idea that drawing is the key element in science education. It enables visualization in scientific thinking, helps to organize students' knowledge, students are more motivated and their understanding and communication competencies are better developed etc. These reasons speak in favour of the use of biological drawing in education. This article deals with the problems of use drawing in teacher training. Initial drawing skills of pre-service primary biology teachers were investigated in this empirical study. Fifty-seven pre-service teachers were asked for making the sketches of selected biological specimens (tick, woodlouse, spider, feather, fish scale) using the microscope and stereomicroscope. Research questions: (1) Are standard rules of biological drawing used by future teachers at the beginning of their studies?; (2) Are students able to visualize typical attributes of specimens?; (3) Are there any typical mistakes in drawings or some attributes preferred in drawing?, and (4) Are there any misconceptions in biological knowledge recognizable from the sketches? Sketches of the pre-service teachers were analysed using the coding tool with respect to the RQs. The tool enabled to follow the individual characteristics of sketches and the data were analysed with basic statistical methods afterwards. The findings show better quality of sketches of the objects prepared in microscope slides in comparison to the objects observed with stereomicroscope. There are many offences against rules and many mistakes in representation of observed reality.

Keywords: Science Education, Teacher Preparation, Training and Development

INTRODUCTION

Biological drawing is an important skill for biologists and biology teachers. Despite of almost excellent quality of the current imaging technologies and their increasing variety, the drawing is still important tool for the recording of outcomes the biological observation and documentation of specimens and objects (in several branches, for example in animal morphology and anatomy – for example Schneider, Kovac, Steck & Freidberg, 2018). Whilst biologists use the drawing in their research studies and labs or field research, from point of view of science education drawing is considered as very useful and important tool for visualization in scientific thinking and for conceptual understanding of the subject (Merkle, 2015; Bartoszeck &Tunniclife, 2017). Ainsworth, Prain & Tytler (2011) promote following five reasons why students' drawing should be considered alongside writing, reading, and talking as a key element in science education: (1) drawing enhances students' engagement, (2) drawing develops visual literacy and helps creating new and supporting current knowledge, (3) understanding is joined often with visual models and enables visual model-based reasoning (also Quilin & Thomas, 2015), (4) drawing can be effective learning strategy and helps organize students' knowledge or understanding and (5) it provides opportunities to exchange and clarify meanings between peers and science communication (also Watson & Lom, 2007). Therefore, drawing should be developed in teacher training, especially in science (biology) teacher education.

There are many definitions of drawing in the literature. Quilin &Thomas (2015, p. 2) formulated very important but quite extensive definition: *"By learner-generated external visual representation depicting any type of content, whether structure, relationship, or process, created in static two dimensions in any medium"*. We were focused on visual model of biological structures and specimens in our study. The biology drawing has specific parameters or principles in comparison with common drawings and cartoons. It is necessary to adhere respected principles of biological sketches, for example use sharp and no coloured pencil, draw continuous lines, sketch without shading, keep accuracy, enough size and correct labelling (OCR, 2015). The accuracy is very important for the record of specimens. The understanding and knowledge are necessary as well as for accuracy in drawing (drawing what is visible, not what author should see, elimination of disruptive artefacts etc.).

Biology and biology education contain typical specific subjects, which require drawing skills related with nature of science. Therefore, this research was aimed to the identify state of initial pre-service biology teachers' drawing skills at the beginning of their study at university. Outcomes can be useful for development and innovation of teacher educational programmes.

OBJECTIVES OF THE STUDY AND RESEARCH QUESTIONS:

(1) Are standard rules of biological drawing used by future teachers at start of their studies?

(2) Are students able to visualize typical attributes of specimens?

(3) Are there some typical and repeated mistakes in drawings or are some attributes preferred in drawing?

(4) Are there any misconceptions in biological knowledge recognizable from the sketches?

METHODS

Pre-service teachers (n = 57) were asked to make the sketches of selected biological specimens (feather, fish scale or arthropods such as tick, woodlouse, spider and dragonfly larva, all fixed using 70% ethanol) using the microscope and stereomicroscope (Olympus CX31, Olympus SZ51). Each pre-service teacher received the worksheets with adequate space for recording of observed objects without suggestions to biological drawing (to allow identifying the basic skills in drawing and basic knowledge of drawing rules from previous study of respondents at secondary school).

Sketches of the pre-service teachers were analysed with the coding tool with respect to the RQs (Table. 1.). The tool enabled to assess the individual characteristics of sketches and afterwards the data were analysed with basic statistical methods.

The assessment of sketches followed five basic characteristics: (1) quality of lines – purity and continuity; (2) drawing correctness – overlap, half-done lines, unclosed contours; (3) objective correctness – recording of essential characteristics of specimens, recording of artefacts; (4) large; (5) occurrence of misconceptions.

Table 1. Coding table for the assessment of sketches.

	1	2	3	4
quality of lines	very poor	poor	satisfactory	correct
drawing correctness	very poor	poor	satisfactory	correct
objective correctness	very poor	poor	satisfactory	correct
large	very poor (very small)	poor (small)	satisfactory	correct (adequate large)
occurrence of misconceptions	principal	considerable	petty	without

RESULTS

Results showed mistakes in all observed parameters. (Fig. 1)

(1) Quality of lines: On average about 31 % of respondents used very negligent drawing style and unsuitable lines characterized by interrupting, undulation and irregular thickness. There is unequal representation of mistakes at several specimens. The pictures of fish scales were the poorest sketches (very poor quality at 51 % examples). When draw this specimen it is necessary to use many small and thick lines and possibility of error is relative higher than in the case of uncomplicated specimens.

(2) Overlap and connected imperfections, as half-done or slack lines: There were found mistakes in up to 33 % of sketches, especially in case of drawing objects with many small and repeated structures (e.g. feather). The sketches of bigger objects and structures (e.g. whole body of arthropods) showed better quality, but there were found the same mistakes as mentioned above in details of these sketches.

(3) Objective correctness: This is the major parameter in relation to the demands on biology drawing. It is connected with visualisation of scientific thinking. In general, we can say that drawn objects were identifiable, but about 53 % of sketches corresponded with the reality only remotely (32 %) or not at all (21%). There is very small representation of correct sketches (about 7 % in all specimens). Usually sketches have average quality with larger or smaller mistakes and recognizable defects. Drawing of the arthropods specimens was shown as very difficult for respondents. (Figs. 2, 3, 4, 5, 6, 8)

(4) Size of the sketch: In this case the respondents' sketches were large enough with exception of few sketches. (Fig. 7)

(5) Misconceptions: Some observed structures were recorded with errors (mainly in the case of arthropods body). For example, there was absence of segmentation of body, legs or antennae or whole parts of body. The segmentation of body or legs absented relatively often. Crossing of contours and false visibility of body parts was frequent problem as well. Lack of experience with the use of stereomicroscope can be the reason for it. In the specimens and microscopy slides respondents identified some artefacts (bubbles, dust, rift, fibres) incorrectly and they identified them as common structures. They drew these structures without consideration of their origin. Described problems can show vague knowledge of some parts of curriculum and in this case biological drawing can provide valuable information about knowledge or competencies of students (pre-service teachers as well). (Fig. 2)

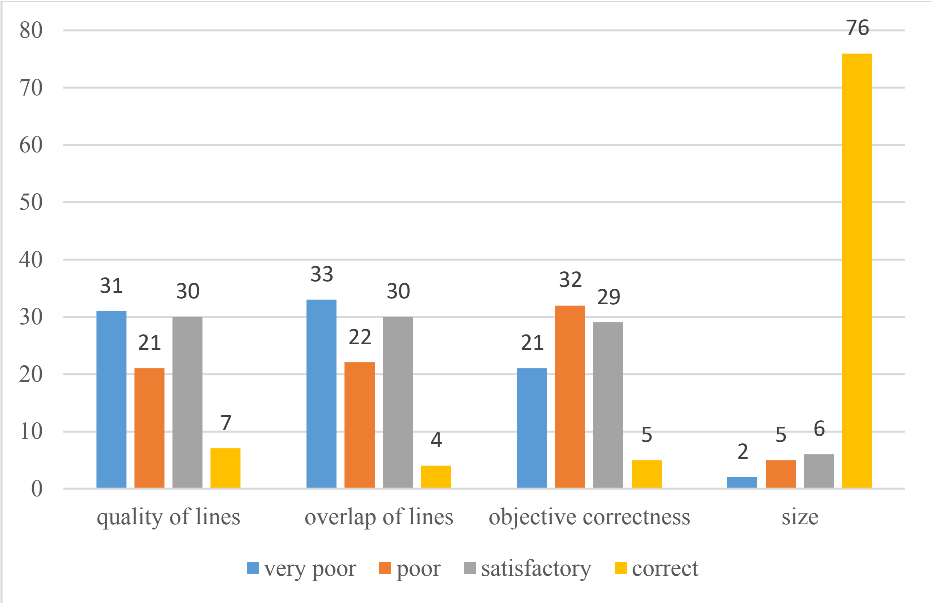

Figure 1. Quality of the sketches with regards to typical mistakes and offences against drawing rules (%).

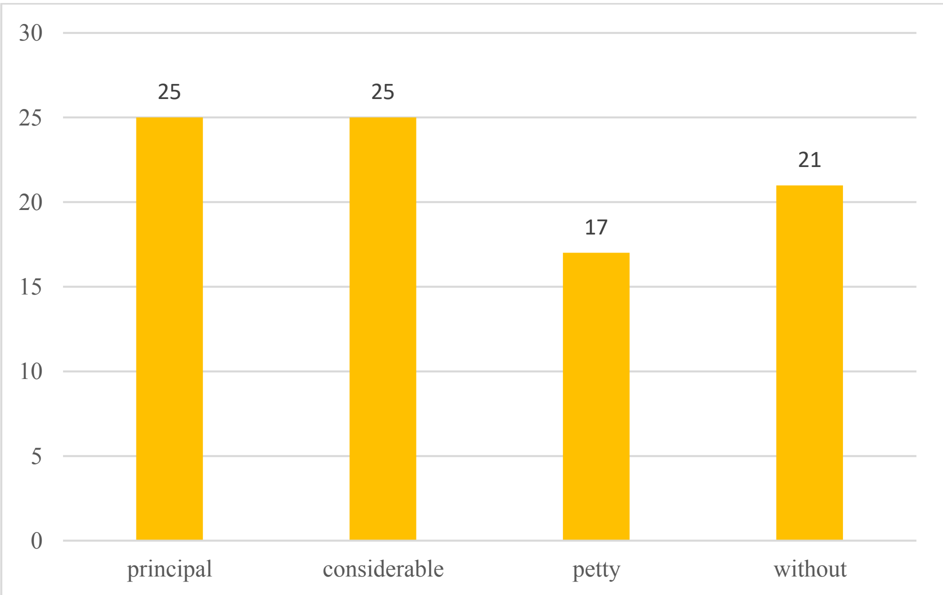

Figure 2. Frequency of misconceptions in the sketches (%). (Principal – e.g. missing segmentation in the pictures of arthropod body or legs; considerable – e.g. incorrect shape or position of details; petty – e.g. some artefacts considered as part of specimen, other objects were drew correctly; without – whole picture corresponds to the reality).

Figures 3. The microphotography made from microscopy slide of tick (*Ixodes ricinus*)**.** (Photo J. Petr);

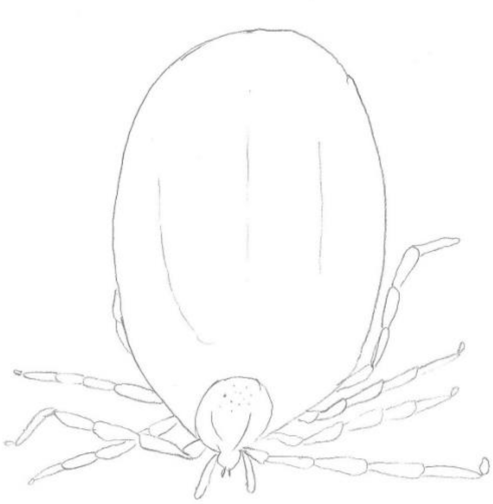

Figure 4. Relatively right sketch of the specimen. (Physical proportions of the body, segmentation of the legs and some structures on the surface of body are right captured; some minor mistakes in quality of lines are visible)

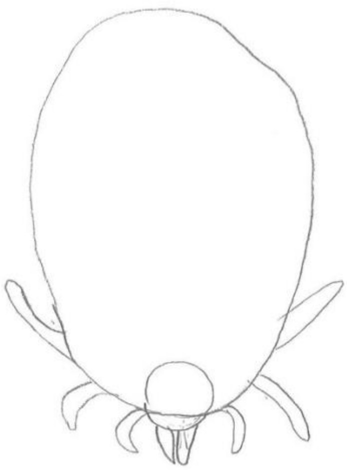

Figure 5. Wrong sketch with visible principal misconceptions. (Absent segmentation of the legs which are similar to undefined lobes, vague mouth apparatus, incorrect number of legs)

Figure 6. Evident effort to record all details of the ventral side of tick body. (There are technical mistakes in comparison with rules of biological drawing – overlapping and crossing of lines, poor quality of some lines – double or thick lines).

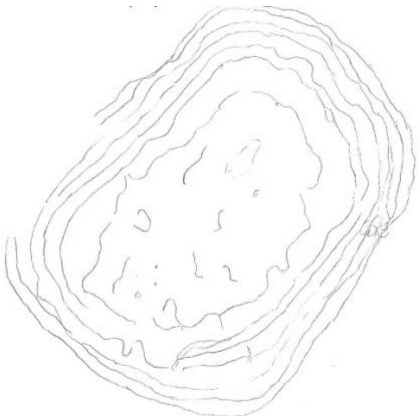

Figure 7. Sketch of fish scale. (There are technical mistakes in comparison with rules of biological drawing – repeated half-done lines, absented details like pigment cells).

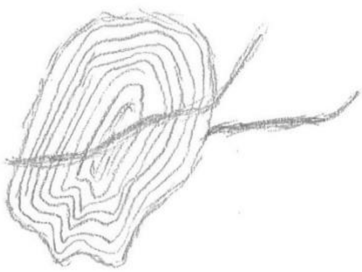

Figure 7. Sketch of fish scale. (Very small picture – original size about 3 cm, visible artefacts – cross lines – probably fibre from a cloth).

Figure 8. Sketches of two fish scales. (Unclear shape and position of some structures, crossing and double lines with their poor quality).

DISCUSSION AND CONCLUSIONS

Pre-service biology teachers had often poor skills connected to the biological drawing. The repeated mistakes were frequent in every domain characterized by each individual rule for appropriate biological drawing.

(RQ1) The pre-service teachers followed standard rules of biological drawing only particularly. It is challenge for next steps in teacher preparation not only in didactics but also in special/specific subjects and labs.

(RQ2) Pre-service teachers were not able to record all attributes of specimens correctly without deeper knowledge in appropriate subject or topic. All students or pre-service teachers do not have to draw pictures in artistic quality or quality created by experts in biology drawing but basic documentary skills are needed for future teacher practice.

(RQ3) Typical mistakes were found in the most of students' sketches.

(RQ4) It was possible to recognize some misconceptions in sketches. The question is whether it is caused by lack of knowledge or imperfection in drawing. If mistakes in biological drawing are caused by misconceptions, we can use drawing in evaluation of quality of education. For example this method was mentioned by Köse (2008).

The preparation of special course focused on the rules and principles of biology drawing could be very useful in pre-service biology teacher education. It is also necessary to develop their drawing skills during all labs courses in their study. Methodology described by Watson & Lom (2007) presents very useful tool for development of pre-service teachers' drawing skills within their professional training/preparation.

ACKNOWLEDGEMENT

Publication of this article was supported by grant GAJU 123/2019/S

REFERENCES

Ainsworth, S., Prain, V., & Tytler, R. (2011). Drawing to Learn in Science. Science, 333 (6046), 1096-1097. doi: 10.1126/science.1204153

Bartoszeck, A. B., & Tunnicliffe, S. D. (2017). Development of Biological Literacy through Drawing Organisms. Drawing For Science Education, 55–65. doi: 10.1007/978-94-6300-875-4_5

Dempsey, B. C., & Betz, B. J. (2001). Biological Drawing: A Scientific Tool for Learning. The American Biology Teacher, 63(4), 271-279. doi: 10.2307/4451099

Köse, S. (2008). Diagnosing Student Misconceptions: Using Drawings as a Research Method. *World Applied Sciences Journal* 3 (2), 283–293.

Merkle, B.G. (2015). *Why Scientists (even non-artists) should draw*. Crastina.se. Retrieved from https://crastina.se/the-crastina-column-july-scientific-sketching/

OCR (2015). *A Level Biology and A Level Biology B (Advancing Biology) Biological drawing*. Oxford Cambridge and RSA. Retrieved from https://www.ocr.org.uk/Images/251799-biology-drawing-skills-handbook.pdf

Quillin, K., & Thomas, S. (2015). Drawing-to-Learn: A Framework for Using Drawings to Promote Model-Based Reasoning in Biology. *CBE–Life Sciences Education*, 14, 1–16. doi: 10.1187/cbe.14-08-0128

Watson, F. L., & Lom, B. (2005). More than a Picture: Helping Undergraduates Learn to Communicate through Scientific Images. *CBE–Life Sciences Education*, 7, 27–35. doi: 10.1187/cbe.07–07–0045

Schneider, A., Kovac, D., Steck, G. J., & Freidberg, A. (2018). Larval descriptions of five Oriental bamboo-inhabiting Acroceratitis species (Diptera: Tephritidae). *European Journal Of Entomology (1)*, 115, 535-561. https://doi.org/10.14411/eje.2018.053

CELL BIOLOGY ANALOGIES IN BRAZILIAN BIOLOGY TEXTBOOKS: A TEACHER GUIDE BASED ON FAR MODEL

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From a well-established model for the use of analogies in science teaching (Focus, Action, Reflection – FAR Guide) this research aimed to develop a teacher support resource (teacher guide) based on the four most frequent cell analogies in Brazilian biology textbooks which were: DNA as a spiral staircase, complex substrate enzyme as a key and lock, ATP as currency and mitochondria as a power plant. This teacher guide was evaluated by pre-service biology teachers from a Brazilian public university. Perceptions and recommendations were collected by questionnaires, participant speeches' recording and a field notebook. Students' responses were tabulated and analyzed, and these results were evaluated for a current version of the teacher guide. The comprehension of the content was perceptible by the majority of participants, however some of them showed doubts about analogies' limits. FAR Guide was considered a good way to plan use of analogies to a cell biology class and a viable didactic resource to be used in the Brazilian educational context.

Keywords: Classroom Discourse, Higher Education, Biology Education

INTRODUCTION

Analogies are used in different ways, contributing to science learning and teaching, teacher training, and even as research tools (Aubusson, Harrison, & Ritche, 2006). Analogies and metaphors are ways of comparing structures or processes from two different domains, from their similarities, with the intention of expressing something unknown or unfamiliar through something known or familiar (Duit, 1991; Aubusson et al., 2006). The familiar domain is called an analogy and the unfamiliar domain is called a target and, through analogical reasoning, the similarity relationships between these two domains are traced, giving rise to an analogical model (Duit, 1991).

Analogies can benefit the learning of new concepts allowing the student to build relationships between their previous knowledge (analogies) and scientific knowledge (targets) (Glynn, 1991). They also play an important role in the interpretation of scientific complex models by providing mental models from familiar analogies that, although limited, clarify natural phenomena until to learn more complex models (Glynn & Takahashi, 1998). The use of analogies allows an easier and more concrete perception of abstract concepts and structures that are not very tangible to students (Duit, 1991; Treagust, Harrison, & Venville, 1998), as is the case of content related to cell biology.

With regard to cell content, simple analogies are recurrent in Brazilian biology textbooks (Araujo & Guimarães, 2017) and teaching material to assist a systematic presentation of analogies is practically absent in these textbooks. In this way, we see an opportunity to produce support material for biology teacher. To this end, despite the popularity of Teaching With Analogies - TWA (Glynn, 1991) in Brazil, our research team chose Focus-Action-Reflection (FAR) Guide for Teaching with Analogies and Models (Treagust et al., 1998; Aubusson et al., 2006; Harrison and Treagust, 2006; Harrison and Coll, 2008) for being a pedagogical process that includes not only in-class actions, but also "two important aspects of effective teaching, namely, lesson planning and post-class reflection. A model was sought that would encourage teachers to think about and their presentation before, during, and following lessons in which analogies were used." (Treagust et al., 1998, p. 88).

In this article we report results of a qualitative research on perceptions of Brazilian pre-service biology teachers from a public university about a teacher guide developed according to Focus-Action-Reflection (FAR) Guide for Teaching with Analogies and Models (Treagust et al., 1998). This teacher guide was designed for the most frequent cell analogies in Brazilian biology textbooks. The research took place in a broader context (Oliveira, 2019) also involving biology textbooks analysis, selection and mapping of cell analogies, as well as the collect and analysis of students' prior knowledge about analogies. These results were not included in this article.

METHODS

From the well-established Focus-Action-Reflection (FAR) Guide for Teaching with Analogies and Models (Treagust et al., 1998), a teacher guide was developed for the four most frequent cell biology analogies in Brazilian biology textbooks according to Araujo & Guimarães (2017) and Oliveira (2019). The teacher guide was based on Duit (1991), Treagust et al. (1998), Aubusson et al. (2006), Harrison and Treagust (2006), Harrison and Coll (2008). Our major goal was to develop a teacher guide which could assist Brazilian in-service biology teachers when using biology textbooks in public high schools in their classes about cells.

In concern to teacher guide design, it was formatted in two parts. The first part was concerned to explain, in a general way, the role of analogies in science teaching and how they work in this context. For these purposes, a definition of the theme and an example of a cell analogy was presented: the comparison between the structure of a eukaryotic cell with a city, in a similar way to Venville (2008). Also included in the first part of this teacher guide are the positive and negative points from the use of analogy in science teaching, a historical example of the use of an analogy by a scientist, and a brief explanation of the FAR Guide phases. The second part of the teacher guide had as objective, based on the FAR Guide, to help biology teacher to use the four most frequent cell analogies in Brazilian biology textbooks which are regularly distributed by Brazilian government to public schools through the National Textbook Program. These most frequent analogies were: adenosine triphosphate (ATP) as currency, DNA structure as a spiral staircase, mitochondria as a power plant and the specificity between enzymes and substrates compared to a key and lock.

The structure of the FAR Guide was maintained with the "three stages for the systematic presentation of analogies and resembles the planning phases of expert teaching and the action research model" (Harrison & Treagust, 2006, p. 20). For each analogy, a text was prepared for the Focus and Reflection phase according to the contents of the target and analog domains adopted. In Focus phase, Concept, Students and Experience parts were inferences related to our team-teaching experience. The Action stage was presented through similarities and differences between each specific domain resulting in mappings. In addition to the steps of the FAR Guide, some parts of textbooks with the respective analogy were transcribed. Similar to what was done in FAR Guide publications (Treagust et al., 1998; Harrison & Coll, 2008), images of each target and analogy were also included in order to illustrate the two different domains.

The teacher guide was evaluated by 54 Brazilian pre-service biology teachers from the University of Brasília (Brasília, Federal District, Brazil). For its analysis, interventions were made during the 2018 second academic semester in different courses in which these students were enrolled. After oral presentations about general aspects of the use of analogies in teaching biology, carried out by our team, students organized themselves into small groups and received the teacher guide for analysis. Each small group has received a specific analogy to consider.

The results of this research are concerned about the second part of the teacher guide which was based on FAR Guide. Students' perceptions and recommendations were collected by questionnaires, participant speeches' recording and a field notebook in a qualitative research approach (Bogdan & Biklen, 1994). Each student answered, according to a specific analogy, five questions regarding the clarity and functionality of each phase of the FAR Guide being possible to make comments and suggestions. Data were tabulated and analyzed in Gibbs' perspective (2009), and results were considered for the current version of teacher guide.

RESULTS AND DISCUSSION

Overall, the teacher guide was evaluated positively by the 54 participants. The FAR Guide developed for the "ATP as currency" analogy was also positively evaluated in all aspects by 17 students. Despite this, some students commented that this analogy should be used with caution to avoid alternative conceptions of the target. One of the students pointed out that the domains are very different, maybe creating some difficulties in the learning process of the target. In face of this observation, it was clear that teacher guide did not allow the understanding of the analogy, which is even presented in Alberts et al. (2017), a reference for pre-service biology teachers during their cell biology courses. Probably, the participant's perception was due to the image chosen to illustrate this analog - a stack of coins - and may imply that the analogy - ATP as currency - would be structural, rather than functional. It is noteworthy that the inappropriate image selection also did not help the student to understand the analogy that is presented in textbooks as follows: "ATP is like energy currency" without any complementary explanation. In current version of teacher guide, a new image was chosen which illustrate a shopping transaction, which is the essence of the analogy in question.

In the other hand, another research participant argued that this analogy is only functional maybe being not efficient to the scientific concept's understanding. As pointed out by Duit (1991), all analogies, by definition, are limited. Venville (2008) stressed about some consideration to be taken in the first two steps, Focus and Action, of the FAR Guide to be sure to explain about analogy and target's attributes. Therefore, recognizing the limits of an analogy is a fundamental factor to stimulate the use of analogical reasoning properly. Because this discussion appeared in other occasions during this research, an additional information related to analogical relationship, as pointed by Curtis and Reigeluth (1984), was included in the current version of teacher guide.

The part of the teacher guide related to the "DNA/spiral staircase", in general, was well evaluated by 15 students. However, some students did not agree with certain parts of the teacher guide, reporting their dissatisfactions with the fact this analogy only serves to explain the structure and does not allow the explanation of the function of the DNA molecule. As in the ATP analogy as currency, these pre-service teachers had difficulties in recognizing the limits of the DNA/spiral staircase analogy that is, in fact, exclusively structural according to Curtis and Reigeluth (1984). A student stressed that she understood the analogical model but recommended the inclusion, in the teacher guide, a greater emphasis on the fact that this analogy is exclusively structural. Another student clearly questioned whether the analog (spiral staircase) is part of her daily life and proposed a school activity to explore the analogy more efficiently. It is emphasized that, in every analogical model, the analog needs to be recognized by the receptor, therefore, the participant's point of view is relevant in the school context (Venville, 2008). As the analogy was assessed using and instructional material prepared by our team and not by a classroom dynamics, as the FAR-Action step assumes to be (Treagust et al., 1998), research participants' familiarity with the analog was not checked and the above student soon realized the need for check receptor's familiarity when using any analogy in the classroom.

During the analysis of the teacher guide's FAR-Reflection phase, one of the students asked: "Would it be interesting to bring another analogy for students to explain the function of DNA, such as an analogy between DNA and the alphabet?", realizing that this analogy also needed for further explanation. The alphabet analogy was included in the teacher guide as inference elaborated by our team when developing the activities of the FAR Post-Lesson Reflection phase, specifically regarding to Improvements. This part was planned to encourage teacher to reflect on the following questions: "What changes are needed for the following lesson? "and "What changes are needed next time I use this analogy?" (Harrison & Treagust, 2006, p. 21). It was noticeable that the insertion of a new analogy in no way helped the FAR-Reflection phase and do not answer these questions. In the current version of teacher guide the alphabet analogy was removed from Improvements.

The students also emphasized that the image adopted to exemplify the spiral staircase could cause confusion for not illustrating a staircase with two handrails, which would be more suitable for comparison with the molecular structure of DNA model. With this perception and that one related to ATP analogy, a more careful image selection had to be done by our research team, also taking in account that in the Brazilian biology textbooks, with regard to the cell content, there are few pictorial-verbal analogies as emphasized by Araujo and Guimarães (2017).

In the teacher guide, the concept of mitochondria was explained in an analogous way by comparing organelle functions to that of a power plant. From the total of 13 student who analyzed this analogy, one of them suggested that in the FAR-Focus of teacher guide, the explanation of the analog should be close to that of the target concept and not interspersed with the projections of possible students' conceptions in relation to the target concept. Such change, in the participant's point of view, could facilitate the reader's understanding about the analogy. However, the FAR Guide is systematically presented with information from Pre-Lesson Focus in the following order: Concepts, Students and Analog (or Experience) (Treagust et al.1998; Harrison & Treagust, 2006; Venville, 2008). According to cited authors, first teacher reflects on the concept: “Is the concept difficult, single-family or abstract?” (Harrison & Treagust, 2006, p. 21). Then, the concept is analyzed from the students' perspective: “What ideas do the students already have about the concept?” (Harrison & Treagust, 2006, p. 21). Finally, teacher thinks about analogies “What familiar experiences do students have that I can use?” (Harrison & Treagust, 2006, p. 21). The teacher guide was modified following the student's recommendation. But, in future applications of the FAR Guide, we will return to the original sequence verifying, using data from further research, whether such a change is, in fact, really necessary over the logical sequence established in the FAR Guide.

Several students questioned the feasibility of using the mitochondria / power plant analogy considering that it is an analog difficult to understand: the operation of a power plant that produces energy. Such perception is related to a fundamental aspect in the use of analogy in the classroom: analogies facilitate learning when comparing something unknown with something known (Aubusson et al., 2006). According to Araujo and Guimarães (2017) and Oliveira (2019), the analogy in question is presented, in general, in biology textbooks as simple analogy (“mitochondria is a power plant”), usually without complementary explanations and leaving the responsibility for the textbook reader to understand it. In addition, the analogy refers to a specific aspect of mitochondria functioning explored in detail by Alberts et al. (2017), a reference used by Brazilian biology textbooks’ authors, and is related to the ATP synthase. In Brazilian biology textbooks, such an analogy is rarely put as follows: “At certain points in the membrane, however, protons can return to the mitochondrial matrix, and in doing so, similarly to what happens in a generator of hydroelectric plant, but in much smaller proportions, they literally spin a molecular rotor. This process, which generates ATP and is called chemiosmosis” (Bizzo, 2016, p. 143). As the main objective of the teacher guide is to assist the teacher who is faced with such an analogy in Brazilian biology textbooks, it will be up to the professional to decide whether or not to explore it in the classroom, ascertaining the student familiarity with the analog. However, it is considered that the most salutary in this research was the perception of participants of the need to establish student familiarity with the analog, as highlighted by Treagust et al. (1998, p. 85): “When using an analogy in science teaching, teachers should select an appropriate student world analog to assist in explaining the science concept.”

A student wrote the following: "In the textbook section, it was not clear to me whether it is considered a good or bad use of the analogy". This perception came from the Bizzo excerpt (2016, p. 143) shared above and which stands out, in relation to other biology textbooks, for being an enriched analogy according to Curtis & Reigetluth (1984). Therefore, we must still continue to test if insertion of excerpts from textbooks helps or not the teacher guide user, even if in current version the textbooks’ excerpts have been maintained.

The key and lock analogy had the least number of analysis (9), with participants evaluating it positively and being readily recognized as a familiar analogy. The main point highlighted by the participants was the presence of five marked differences between the domains, a higher number than that presented in the mapping of the other analogies. But it is also important to highlight that even in the face of the obsolescence of this analogy, this aspect was not accentuated by the students who analyzed it. Nelson and Cox (2014) reported that Emil Fischer in 1984, from his findings, postulated that the structures of enzymes would be complementary to their substrates, such as a key and lock. Subsequently, with advances and discoveries in the area, it is now understood that this analogy does not explain perfectly this molecular interaction. However, this analogy still remains in the Brazilian biology textbooks. This perpetuation is due to the fact that the National Textbook Program took into account, in the biology area, the understanding and recognition of the history of science as something beneficial for biology teaching, allowing the presence of this analogy in the biology textbooks with the purpose to stimulate discussions about how scientific knowledge is constructed (Ministério da Educação, 2017). However, none systematic presentation of this analogy is found in biology textbooks, leaving it up to the biology in-service teacher how to use and explore this analogy, not exactly in the perspective intended by the National Textbook Program.

In general, the second part of teacher guide that incorporated the FAR Guide for certain analogies of cell biology was positively evaluated by the participants. Even with the sharing of some criticisms and reservations, 52 students stated that they would use the teacher guide, making recommendations regarding its format and content. Only two students answered that they would not use the teacher guide, claiming that they did not like the analogy they received to carry out the analysis or because they did not feel comfortable using analogies as teaching resources. One of the questions in this research addressed whether the teacher guide would assist in conducting a cell biology class with analogies, and all responses were positive without any reservations. A total of 35 participants wrote that they would explain the contents about the cell with the teacher guide. Of this total, 24 participants would adopt the analogies to start explaining cellular concepts, as one of the students explained: “Just in the situation of explaining about this subject in biology, because I think it is much clearer and easier to learn if you compare something you have already know with something you would like to learn”. The other 11 participants, on the other hand, would also adopt analogies to explain scientific concepts, but as a second option and after a previous explanation of the target concept, a situation exemplified in the response of another student: “I would use it to consolidate the concept of DNA structure after an expository class on each of the elements”. It is noted in these considerations that the participants of this research would choose to use the analogy in the perspective of Glynn (1991) and Glynn and Takahashi (1998). And, mainly, these Brazilian pre-service biology teachers had the opportunity to analyze an instructional material based on the FAR Guide for Teaching and Learning With Analogies (Treagust et al., 1998; Harrison & Treagust, 2006; Harrison & Coll, 2008), a valuable systematic presentation of analogies still not well-known in Brazil.

CONCLUSIONS

To develop, by FAR Guide, and to test a teacher guide to help the use of cell analogies presented in the Brazilian biology textbooks allowed us to verify that Brazilian pre-service biology teachers are interested in an instructional resource which help to plan the use of analogies.

Most of the analogies related to the cell biology content were presented in the Brazilian biology textbooks without additional explanations (for example, their limits) when compared to the scientific concepts and the participants of this research demonstrated difficulties in realizing that any analogy, by its nature, has such limitations.

Brazilian pre-service biology teachers realized the need to be cautious in the use of analogies in the classroom to avoid alternative conceptions of scientific concepts by students and also the need to establish student familiarity with the analog.

The pre-service teachers' perceptions enabled us to verify that when choosing images to illustrate the analog and inserting it in an instructional material, a careful selection must be made, taking also into account that in the Brazilian biology textbooks, regarding the content of the cell, few analogies are pictorial-verbal.

FAR Guide can become an excellent instructional material complementary to biology textbooks distributed in the Brazilian territory, taking into account that, in the case of cell biology, scientific content is abstract, simple analogies are the most recurrent in these textbooks, with the absence of supplementary instructional material to assist teacher to present analogies in a systematic way.

REFERENCES

Alberts, B., Johnson, A., Lewis, J., Morgan, D., Raff, M., Roberts, K., Walter, P., Wilson, J., & Hunt, P. (2017). *Biologia molecular da célula*. Porto Alegre: Artmed. (Original work published 2017)

Araujo, C.M.Y, & Guimarães, Z. F. S. (2017). Analogias no ensino da célula: Análise de livros didáticos de biologia adotados pelo Plano Nacional do Livro Didático 2015 no Brasil. *Enseñanza de las Ciencias: revista de investigación y experiências didácticas*, *nº Extra*, 1295-1302. Retrieved from https://www.raco.cat/index.php/Ensenanza/article/view/336900

Aubusson, P.J., Harrison, A.G., & Ritchie, S.M. (2006). Metaphor and Analogy: Serious thought in science education. In Aubusson, P.J., Harrison, A.G. & Ritchie, S.M. (Eds.), *Metaphor and Analogy in Science Education* (pp. 1-9). Dordrecht: Springer.

Bizzo, N. (2016). *Biologia: Novas Bases* [Biology: New Grounds]. São Paulo: IBEP.

Bogdan, R., & Biklen, S. (1994). *Investigação qualitativa em* educação. (M.J. Alvarez, S.B. dos Santos & T.M. Baptista, Trans.). Porto: Porto Editora. (Original work published 1991)

Curtis, R. V., & Reigeluth, C. M. (1984). The use of analogies in written text. *Instructional Science*, *13*, 99-117. doi: https://doi.org/10.1007/BF00052380

Duit, R. (1991). On the role of analogies and metaphors in learning science. *Science Education*, *75*, 649–672. doi: https://doi.org/10.1002/sce.3730750606

Gibbs, G. (2009). *Análise de dados qualitativos*. (R.C. Costa, Trans). Porto Alegre: Artmed. (Original work published 2008)

Glynn, S. M. (1991). The Teaching with Analogies Model. In D. Muth, D. (Ed.), *Children's comprehension of text* (pp. 185-204). Newark: IRA.

Glynn, M. S., & Takahashi, T. (1998). Learning from Analogy-Enhanced Science Text. *Journal of Research in Science Teaching*, *35*, 1129-1149. doi: https://doi.org/10.1002/(SICI)1098-2736(199812)35:10<1129::AID-TEA5>3.0.CO;2-2

Harrison, A. G., & Treagust, D. F. (2006). Teaching and Leaning with Analogies: Friend or foe? In Aubusson, P.J., Harrison, A.G. & Ritchie, S.M. (Eds.), *Metaphor and Analogy in Science Education* (pp. 11-24). Dordrecht: Springer.

Harrison, A. G., & Coll, R. K. (2008). *Using Analogies in Middle and Secondary Science Classrooms*. Thousand Oaks: Corwin Press.

Ministério da Educação. (2017). Guia de livros didáticos: PNLD 2018. Biologia: ensino médio. Brasília, DF: Ministério da Educação, Secretaria de Educação Básica. Retrieved from https://www.fnde.gov.br/index.php/programas/programas-do-livro/pnld/guia-do-livro-didatico/item/11148-guia-pnld-2018

Nelson, D. L., & Cox, M. M. (2014). *Princípios de Bioquímica de Lehninger*. Porto Alegre: Artmed.

Oliveira, I.T. (2019). Analogias em biologia celular presentes nos livros de biologia do PNLD 2018: uma proposta de ação para o professor. (Master's thesis). Retrieved from https://bce.unb.br/bibliotecas-digitais/repositorio/teses-e-dissertacoes/

Treagust, F. D., Harrison, A. G., & Venville, G. J. (1998). Teaching Science Effectively With Analogies: an approach for preservice and in-service teacher education. *Journal of Science Teacher Education*, *9*, 85-101. doi: https://doi.org/10.1023/A:1009423030880

Venville, G. J. (2008). The Focus-Action-Reflection (FAR) Guide-Science Teaching Analogies. In A.G. Harrison & R.K. Coll (Eds.), *Using Analogies in Middle and Secondary Science Classrooms* (pp. 22-31). Thousand Oaks: Corwin Press.

MODELLING TEACHERS' CONTENT KNOWLEDGE IN PARTICLE PHYSICS

FINAL RESULTS FROM A DELPHI STUDY

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This project aimed at modelling the professional content knowledge teachers need to have in order to teach particle physics. We focussed on modelling subfacets of the knowledge dimension "content areas" by identifying relevant key concepts in particle physics and precisely describing them. The research design followed the Delphi method: During three consecutive survey rounds, a panel of experts from particle physics research, teaching and outreach were asked to name and characterise the key concepts in particle physics which are relevant for a secondary school physics teacher to know about. As result of the first two survey rounds, a content validated system of 10 knowledge categories and 35 subcategories could be established. In the third survey round, a definite consensus among the experts about the most relevant knowledge categories was reached. Additionally, the knowledge categories were also evaluated by teachers who have already taught particle physics in their classes. The common consensus of experts and teachers revealed the exceptional importance of 6 knowledge categories: Fundamental interactions, the structure of matter, particles in high energy physics, the role of particle physics in cosmology, types of experiments in high energy physics, and nuclear physics and radioactivity on particle level. Comparisons between the experts' and the teachers' opinions gave deeper insight into the way both groups argue when choosing the most important knowledge categories. The final results of the Delphi study – a well-structured and precisely described knowledge domain – can be regarded as normative target for teachers' content knowledge in particle physics and could function as a basis for the development of teacher training programmes.

Keywords: Teacher Content Knowledge, Particle Physics, Delphi Study

INTRODUCTION

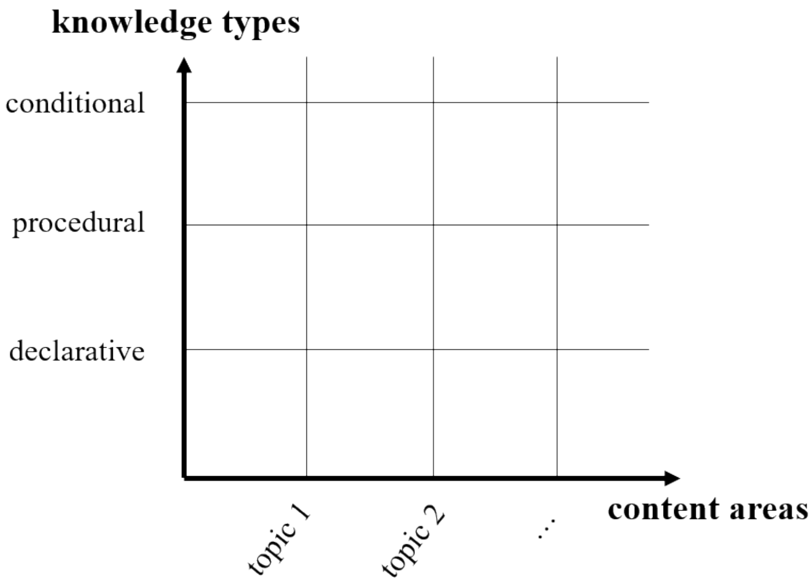
Motivation

Particle physics as a field of research addresses the investigation of subatomic structures such as the elementary constituents of matter and their interactions among each other. The rapidly evolving research in the field of modern particle physics along with the accompanying development of everyday applications and the media attention makes the topic intriguing for young people, i.e. school pupils. On the level of educational policies, the subject is in the progress of being included in scholar curricula. However, teaching particle physics can be challenging for teachers due to the complexity and the advanced level of the topic compared to other physical domains. Additionally, there is no consensus in science education research neither about the selection of particle physics issues to be taught in a secondary school physics class nor about the special knowledge that teachers need to have in order to teach this content. Here is where the project comes in: We aim at modelling teachers' content knowledge – as part of their professional knowledge - pertinent to the field of particle physics.

Theoretical Framework

Content knowledge is regarded as a central component of a teacher's professional knowledge (Shulman, 1986; Borko & Putnam, 1996). Modelling professional knowledge in general and in particular modelling content knowledge with the aim of working out a deeper knowledge structure is usually based on a conceptualization in different *knowledge dimensions,* each comprising in turn several *subfacets*. Research studies using the most elaborated and detailed model to structure the content knowledge especially in physics were mainly conducted in Germany: Following the findings from educational psychologists such as Paris et al. (1983), the project *ProwiN* (Tepner, et al., 2012), for example, focussed on the one hand on modelling the dimension of *knowledge types* (comprising the subfacets *declarative*, *procedural* and *conditional knowledge*). Simultaneously, *ProwiN* modelled the dimension of *content areas* (comprising different physical topics in mechanics). A schematic representation of a knowledge structure with two different dimensions, as for example modelled by *ProwiN,* can be found in Figure 1.

Figure 1. Schematic representation of a teacher's content knowledge as product of the dimensions content areas and knowledge types.



Comparing all such available models for teachers' content knowledge in physics reveals the importance of the dimension *content areas* which is used in all models as a frame of reference. The issue of modelling this important dimension especially for the domain of particle physics is addressed in the presented project.

METHOD

Research Questions

Modelling teachers' content knowledge in particle physics and focussing on the dimension of *content areas* needs to answer the following question: Which subfacets in terms of content can be identified and precisely described? In other words, we aim at gathering those key ideas in particle physics which are essential for a teacher to know about.

Research Design

The research design follows the Delphi method used in forecasting (Linstone & Turoff, 1975): A panel of experts from particle physics research, teaching, and outreach were asked to name and characterise the key ideas in particle physics relevant for a secondary school physics teacher to know about. The chosen Delphi design comprises three consecutive survey rounds and eventually strives for establishing a consensus among the participating experts about the most relevant key ideas. Each survey round was realized methodologically by means of an online survey containing open and closed questions. The survey rounds at a glance:

- *Round 1:* Open nomination of potentially relevant key ideas by the experts and development of a first model draft by assignment of the answers to a system of knowledge categories and subcategories
- *Round 2:* Content validation of the model draft using approvals, additions, and corrections to the draft given by the same panel of experts
- *Round 3:* Relevance rating of the remaining knowledge categories by the same experts as well as by experienced physics teachers to find a consensus about the most important topics for teachers' content knowledge.

ANALYSIS AND RESULTS

Survey Round 1

N=65 experts from 14 countries participated in the first survey round. The key ideas in particle physics named by the experts were assigned to 10 knowledge categories and 41 subcategories using a qualitative content analysis (Mayring, 2014). The overall interrater reliability between two raters assigning the answers to the categories was Cohen's $\kappa=.95$ showing excellent agreement. Additionally, the empirically established categories were triangulated with the literature by matching the categories to topics in standard text books for particle physics university courses. Besides the category titles, more detailed definitions in the form of a short summary for each subcategory could be derived from the experts' answers.

Survey Round 2

Proving the content validity of the categorical model from round 1 relies fundamentally on the question, if the derived system of categories covers the targeted content knowledge in all its facets - and only in that. For this purpose, in the second online survey, the experts were shown the system of categories derived from round 1 and were asked to evaluate it[1]. The following items were asked for each main category:

- 1 closed item: *How well do the shown subcategories cover the knowledge a teacher needs to have about the displayed main category?* (continuous rating with possible values between 0 and 100%)
- 2 open items: *Are any of the shown subcategories no part of the knowledge a teacher needs to have? Are there any fundamental aspects missing in the displayed list of subcategories?*

N=56 experts from 11 countries participated in the second survey round. Two thirds of the participants already contributed to survey round 1.

Concerning the closed rating item, the descriptive statistical parameters such as sample size *N*, mean, and standard deviation *SD* – rounded to integer numbers - are displayed for the ten main categories from round 1 in Table 1. The overall high values of the means show the experts' approval to the derived system of categories.

Table 1. Acceptance of the main categories derived from round 1 by the experts in round 2.

Main Category	N	MEAN [%]	SD [%]	D_{mn} (KS)	p (KS)
The Structure of Matter	12	92	9	0.72	< .001***
Particles in High Energy Physics	16	90	16	0.68	< .001***
Principles from SR and QM; QFT	10	80	24	0.49	.013*
Fundamental Interactions	15	85	21	0.59	< .001***
Symmetries & Conservations	13	93	11	0.69	< .001***
Particle Interactions & Decays	11	78	23	0.55	.003**
Higgs – Mechanism and Boson	15	91	16	0.62	< .001***
The Standard Model	14	85	13	0.62	< .001***
Cosmology	14	80	18	0.50	.002**
Open Questions	15	77	19	0.46	.003**

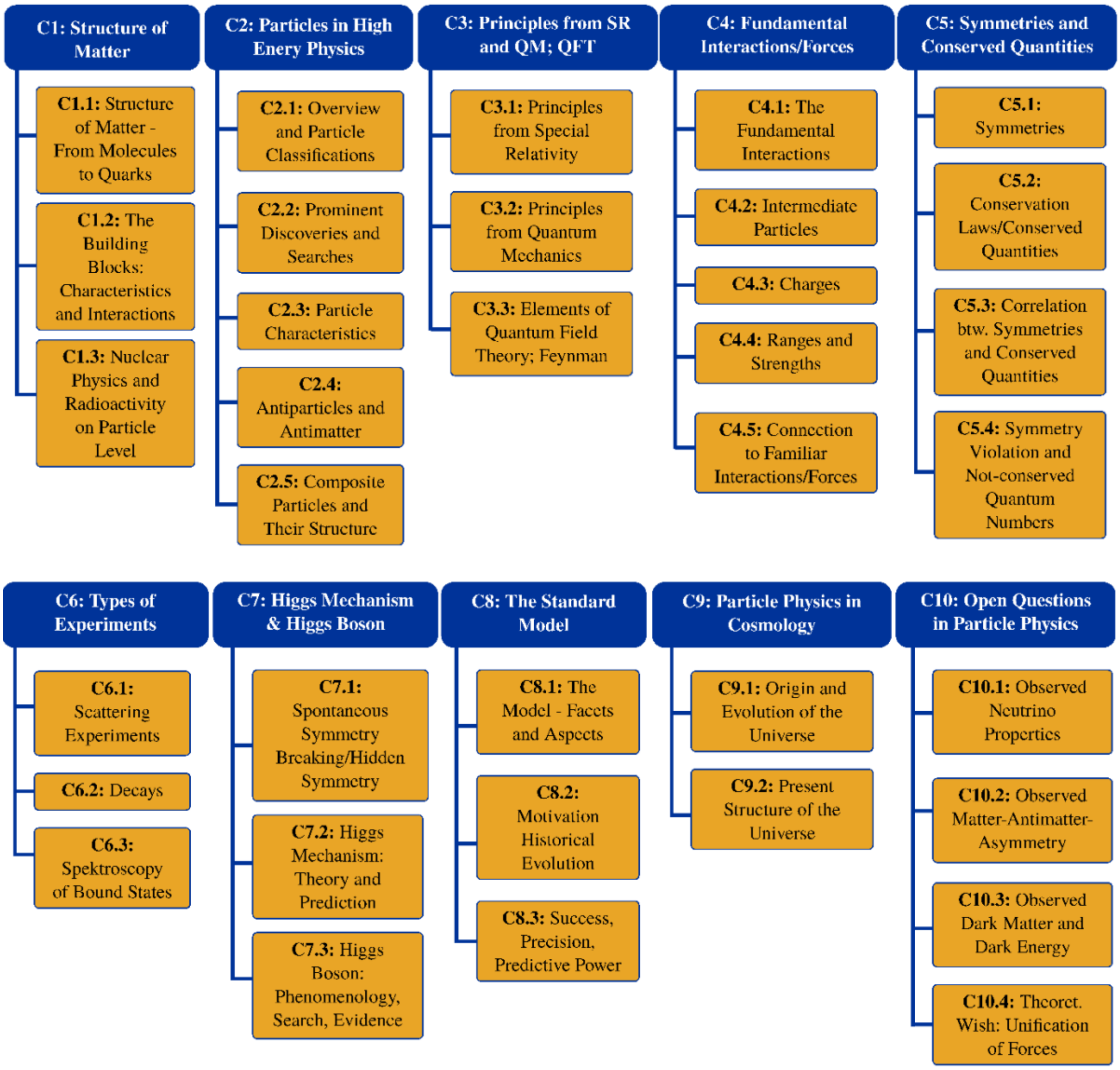
In order to assess the significance of the displayed results considering the small sample sizes for each category, we quantified how much the data deviates from a completely random rating behavior among the experts. For this purpose, the distribution of the measured data in each category was compared to the randomly expected uniform distribution using a *Kolmogorov-Smirnoff (KS) test* (see for example Daniel, 1990). The test statistic D_{mn} of the KS-test and the corresponding p-values are also listed in Table 1. These parameters show that the observed data deviates in each category significantly from a random rating by the experts.

The two open items in survey round 2 served to optimize the system of categories and subcategories derived from round 1. Using again a qualitative content analysis, we identified frequent proposals in the experts' open answers for removing or adding subcategories from or to the system. The interrater reliability for assigning the answers to an inductively derived system of proposals between two raters was Cohen's κ=.68 showing substantial agreement.

[1] Due to the large number of categories, each expert received for the evaluation only three out of the ten main categories as well as the corresponding subcategories and definitions.

The most frequently given proposals to change the system of categories were subsequently applied to the system. As result, the new system after round 2 comprised 10 knowledge categories with only 35 remaining subcategories. The content validated and optimized system resulting from survey round 2 is shown in Figure 2.

Figure 2. Content validated system of knowledge categories and subcategories as model of the content knowledge teachers need to possess in order to teach particle physics.



Survey Round 3

The following questions were central to the third and last survey round in the Delphi process:

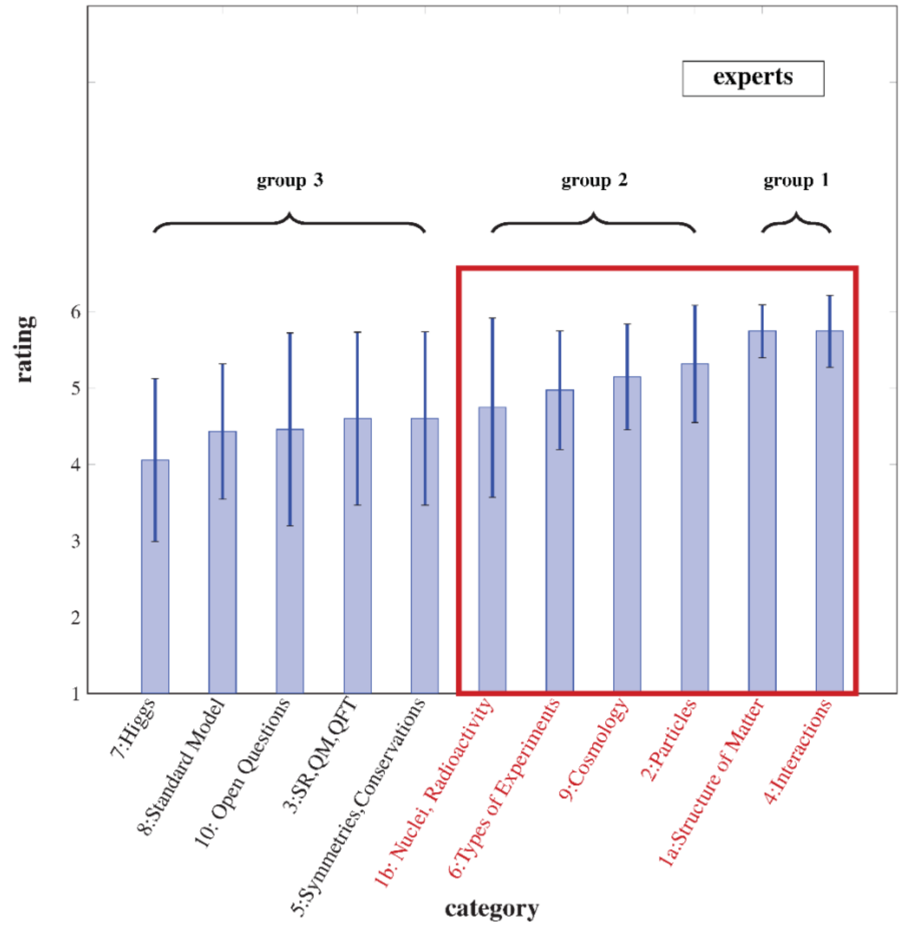
- Which of the knowledge categories determined in survey round 2 are particularly relevant for teachers' content knowledge?
- Which of the knowledge categories rated as particularly relevant by the experts can be validated from a practical point of view through similar ratings by teachers?

The first question aims to achieve a consensus among the participating experts about the fundamentally most important subject matter topics. Answering the second question involves a matching of the experts' ratings with the teachers' ratings who are regarded as practical experts.

The third survey round was again conducted by means of an online questionnaire. The participants were asked to rate all 35 knowledge subcategories from round 2 in terms of relevance for teachers' content knowledge. We used six-level Likert items with verbal anchors from "1=not at all relevant" until "6=very relevant". *N=35* experts from seven countries and *N=108* teachers from 32 countries participated in survey round 3. In order to facilitate the comparative analysis of the 35 rating items, we reduced the complexity by carrying out reliability analyses as well as exploratory factor analyses. Both types of statistical analyses showed that all subcategory ratings belonging to the same of the ten main categories are measuring the same underlying construct or factor. Therefore, the following analysis of the rating data can be conducted on the level of main categories instead of the subcategories. It should be noted that main category 1 forms an exception as there were the two factors "structure of matter" and "nuclear physics and radioactivity on particle level" that could be identified. Hence, the following analysis involves 11 new "main" categories instead of 10.

Analysing the rating data of the 11 categories solely for the panel of experts yields the bar chart in Figure 3 displaying the mean values and standard deviations of the categories sorted by mean values in ascending order.

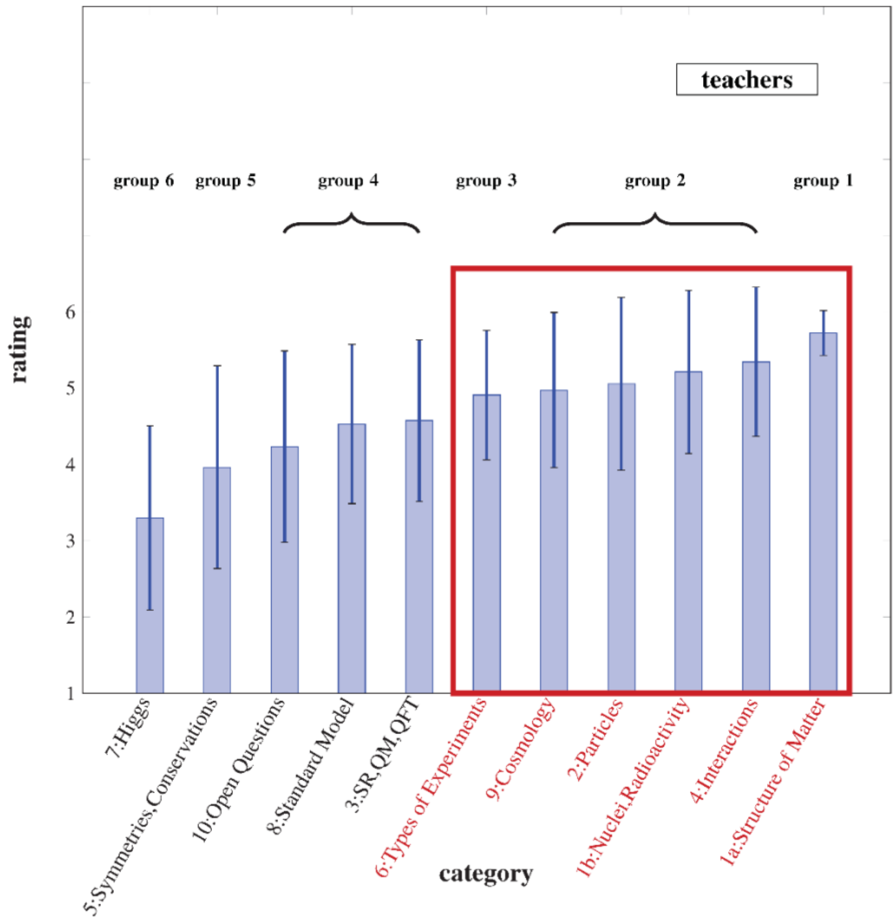
Figure 3. Mean values of the experts' relevance ratings for the 11 main knowledge categories.



Statistically significant differences in the mean values between categories were detected by means of a repeated measures ANOVA, whereby the parameters in the analysis of variance were estimated by linear mixed effect models. Adding the 11 categories as predictor to the model improved the fit to the data compared to the baseline model which only assumes the entity factor as predictor ($\chi^2(10)=135.17$, $p < .001$). Thus, the type of category affects the relevance ratings. Conducting suitable posthoc tests revealed where the differences are and which categories cannot be distinguished in term of relevance (see the three relevance groups in Figure 3). The groups of categories with highest and with second highest relevance constitute the answer to the question about the particularly important topics for a teachers' content knowledge. In the opinion of the experts, the categories about the structure of matter and about the fundamental interactions possess the greatest importance followed by the categories "particles in high energy physics", "particle physics in cosmology", "types of experiments in high energy physics" and "nuclear physics and radioactivity on particle level".

Establishing relevance groups among knowledge categories can be done in the same already described way for the rating data collected in the teacher sample. The groups of categories with non-distinguishable relevance are displayed in the bar chart in Figure 4.

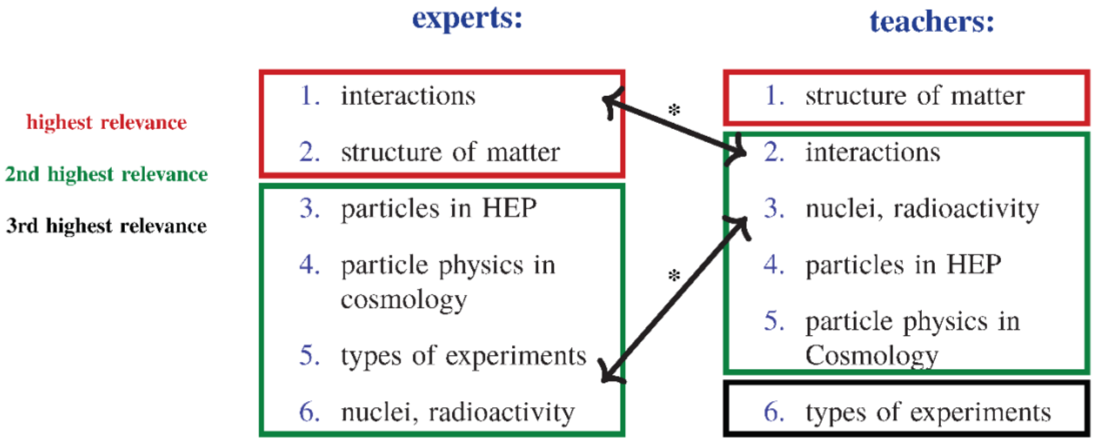
Figure 4. Mean values of the teachers' relevance ratings for the 11 main knowledge categories.



Comparing the results of the experts' and the teachers' sample in Figures 3 and 4, several differences can be detected as well as in the order of the categories as in the number of relevance groups. Nevertheless, both panels – experts and teachers – have rated the same six knowledge categories as being more relevant than the other five categories. The more relevant categories are highlighted in red in Figure 3 and 4. This answers the second questions asked in survey round 3 substantially. It can also be noted that the less relevant categories imply a higher level of mathematical modelling and abstractness (i.e. the standard model or quantum field theory) whereas the more relevant categories have a more conceptual and illustrative nature.

Directly contrasting the ranking of the six highest rated categories – as displayed in Figure 5 – yields further significant differences in the relevance ratings of the categories "interactions" and "nuclei, radioactivity" between the experts and the teachers. The significant differences were detected by conducting a factorial mixed ANOVA with appropriately chosen contrasts.

Figure 5. The most relevant content knowledge categories – TOP 6.



The differences give insight into the way experts and teachers reason. The experts rated the categories by taking into account the systematics of the subject matter domain which rely fundamentally on the standard model of particle physics and therefore to a great extent on the fundamental interactions. Teachers, on the other hand, assigned only "the structure of matter" the highest relevance and furthermore highlighted the role of "nuclei and radioactivity" compared to the experts. Thus, teachers argue from a curricular point of view since radioactivity and the structure of matter are already included in most curricula for high school level physics classes.

CONCLUSIONS AND RECOMMENDATIONS

This project aimed at modelling the dimension *content areas* of the content knowledge a secondary school physics teacher needs to have in order to teach particle physics. Conducting the Delphi study, 11 subject matter topics could be identified as being relevant for the teachers' content knowledge, six of which possess the highest relevance. The results could be used to fill the so far rather vague curricula with more details. Furthermore, the results can function as basis for the construction of future teacher training programmes in particle physics. We recommend a programme structure comprising 11 modules with an emphasis on the six most relevant topics. For the content of the modules, the definitions of the knowledge categories derived in survey round 2 should build the basis. If interested, all category definitions can be received from the authors.

REFERENCES

Borko, H., & Putnam, R. (1996). Learning to Teach. In D. Berliner, & R. Calfee, *Handbook of Educational Psychology* (673–708). New York: McMillan.

Daniel, W. (1990). *Applied nonparametric statistics.* Bosten (Mass.): PWS-KENT.

Linstone, H. A., & Turoff, M. (1975). *The Delphi Method: Techniques and Applications.* Reading, Mass.: Addison-Wesley.

Mayring, P. (2014). *Qualitative Content Analysis: Theoretical Foundation, Basic Procedures and Software Solution.* Klagenfurt: SSOAR.

Paris, S. G., Lipson, M. Y., & Wixson, K. K. (1983). Becoming a strategic reader. *Contemporary Educational Psychology, 8*(3), 293–316.

Shulman, L. (1986). Those Who Understand: Knowledge Growth in Teaching. *Educational Researcher, 15*(2), 4–14.

Tepner, O., Borowski, A., Dollny, S., Fischer, H. E., Jüttner, M., Kirschner, S., et al. (2012). Modell zur Entwicklung von Testitems zur Erfassung des Professionswissens von Lehrkräften in den Naturwissenschaften. *Zeitschrift für Didaktik der Naturwissenschaften, 18*, 9–30.

APPLYING ARGUMENTATION IN PRIMARY PRE-SERVICE TEACHER EDUCATION. A TEACHING-LEARNING SEQUENCE USING COLLABORATIVE VIDEO ANNOTATIONS

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Argumentation process not only helps to promote the construction of new knowledge but also gives the students the possibility of participating in socio-scientific debates, approaching real Science to the scholar environment. As related argumentation competences are therefore fundamental for the professional profile of science educators, in this study, we would like to introduce a short sequence addressed to improve the argumentative competence in primary pre-service teachers through the use of collaborative video annotations. Using Climate Change Education (CCE) as a scientific context, we have designed a work sequence through examples and practical work about the argumentative process. The analysis of the preliminary results of a sample of 80 primary pre-service teachers, both at the level of preconceptions and the quality of the argumentative discourse indicates an opportunity to change the perception of this methodology regarding the advantages and improvements that the online video annotations may offer. In a subsequent study, comparisons of the pre/post-test profiles together with the productions of the students will provide a complete view of the degree of argumentation at this educational level and the improvements that should be implemented.

Keywords: Initial Teacher Education (Pre-service), Instructional Strategies, Video Analysis

INTRODUCTION

In recent years, argumentation has played an essential role in the curriculum for developing scientific thinking and critical citizens, with an increasing number of publications focused on the analysis of the argumentation discourse in science learning contexts (Jiménez-Aleixandre & Erduran, 2008). From a practical point of view, argumentation also aims to promote knowledge about the nature of Science, approaching socio-scientific contexts to students and connecting social concerns with their everyday life (Simonneaux, 2008).

As argumentation is used by scientist to relate evidence and claims thought use of warrants and backings (Toulmin, 2003), it represents a central role in the construction of explanations, models and theories (Siegel, 1995), and it is, therefore, necessary to promote it in the science classroom.

The teaching profile demands both valuable initial training and continuous professional development, updated and related to the necessities of society, which requires investing in innovative teacher preparation programs and establishing the professional competences needed for good teaching practice (Schleicher, 2011). Furthermore, it is essential to consider the design of proposals that contribute to the teacher's vision as a professional reflective of their practice (Korthagen, 2001; Mellado, 2010).

To Lupión-Cobos & Blanco-López (2016), this formation should include not only factors such as guidance and training but also other aspects related to Science Education, as its epistemological nature, the importance of scientific literacy, the development of STEM relationships and the use of relevant contexts for students learning. Thus, in initial teacher education, it is essential to promote the ability to establish relationships, argumentation and to question reality and define problems (Escudero, Vallejo, & Botías, 2008) as well as the digital competence, understood as the knowledge of the impact of technologies in the digital world and the promote collaboration to integrate them effectively (Prendes-Espinosa, Gutiérrez-Porlán, & Martínez-Sánchez, 2018), among others.

To this aim, a broad range of technologies has lately arisen to facilitate and support the learning of argumentation, with the video annotations emerging as a useful tool to identify problems and unexpected situations that can be analysed in the science classroom.

Hence, in the literature related to the development of professional skills, we can usually find proposals that employ video analysis as a strategy for teachers to learn to look professionally at their practice (Kersting, Givvin, Sotelo, & Stigler, 2010; Llinares, 2013), also developing the scientific argumentation skills necessary in the secondary classroom (Ruiz-Ortega, Márquez, Badillo, & Rodas-Rodríguez, 2018).

METHODOLOGY

With the purpose of promoting scientific argumentation skills in pre-service primary teachers at the University of Málaga (Daniel Cebrián-Robles, Franco-Mariscal, & Blanco-López, 2018) we propose a teaching-learning sequence based on the use of the digital tool CoAnnotation (https://coannotation.com) (Cebrián-Robles, Blanco-López, & Noguera-Valdemar, 2016), that helps to create online collaborative annotations. As scientific context for the design, we have chosen Climate Change Education (CCE), which affects all components of the education system (policy, legislation and curricula, among others) and promotes problem-solving skills in a collaborative way from a multidisciplinary perspective (United Nations Institute for Training and Research, 2013).

Design proposal

The complete sequence comprises six sessions, structured as indicated in Figure 1. The first session includes the pre-test, involving two main goals: to detect students' preconceptions about argumentation and to analyse the initial level of practice as well as the identification of the principal terms of arguments (forms, strategies or goals). During the second session, a teaching explanation of the different elements of the argumentation process, including Toulmin's model of argument and some practical examples are shown. Sessions third and fourth commit to the practice and auto-evaluation of argumentation through online collaborative video annotation and rubrics. After explaining the main features of CoAnnotation, students visualise a video about climate change and proceed to register their arguments in the online programme, together with an individual and collective reflexion, answering the critical question*: what is the foundation of a good argumentative essay?* Finally, each student completes the auto-evaluation process through CoRubric (http://corubric.com), an online tool that allows to create and register collaborative rubrics and analyse the results. In the fifth session, teachers provide students with their feedback about the practical activity and invite them to create an argumentation activity in the teacher role, following their recent knowledge on the topic. Students will select a video related to CCE and design the activity using CoAnnotation. Finally, the last session is devoted to the completion of the post-test and a final review of the evaluation.

SI	PRE-TEST	Students' preconceptions about argumentation	SV	FEEDBACK	Teaching feedback about the application of the argumentation process
SII	EXPLANATION	Elements of argumentation / Toulmin's model		APPLICATION	Selection of CCE video and design of activity (teacher role)
SIII	APPLICATION	Online collaborative video annotation with Coannotation© / Reflexions	SVI	POST-TEST	Students' postconceptions about argumentation
SIV	AUTO-EVALUATION	Online collaborative auto-evaluation with Corubric©		EVALUATION	Final outcomes about the evaluation of the sequence

Figure 1. Main schedule of the teaching-learning argumentation sequence

PRELIMINARY RESULTS

Here we would like to present a short insight into pre-service teachers' perceptions about argumentation as well as the level and quality of its practice prior to their instruction, outlining the difficulties they found and giving a general impression of the challenge to face in pre-service education. The preliminary results were collected from a semi-structured pre-test adapted from García-Romano (2017) and García-Romano, Condat, Occelli, & Valeiras (2016). The sample was composed of 80 pre-service teachers in their third year of undergraduate studies for primary school teachers.

First results about students' preconceptions show that 31% of pre-service teachers consider that subjects or contents to promote argumentation in science class (Figure 2) should be related to the student environment, focusing on the importance of contextualised situations for efficient learning, while only 10% regard socio-scientific issues as suitable topics.

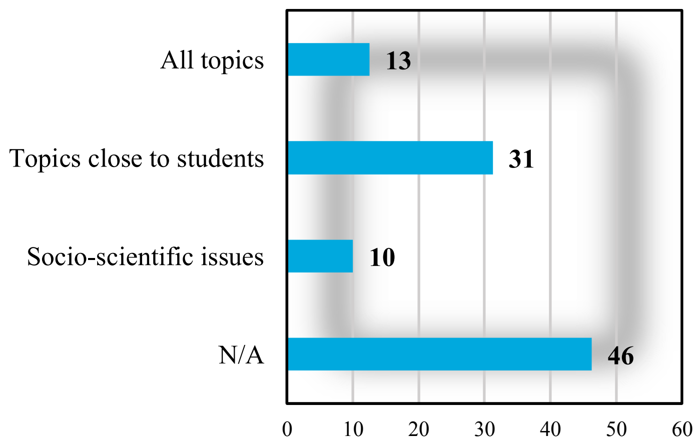


Figure 2. Subjects or contents to promote argumentation in science classroom (Data expressed in percentage of pre-service teachers)

Concerning the advantages of working argumentation (Figure 3), most pre-service teachers agree that it helps to promote critical thinking (53%), but also contributes to scientific literacy (13%). One of the main problems seems to be the low level of pre-service teachers to implement argumentation (55%), follow by other related problems such as the time required to practice it, the data management or the challenge for the teacher (Figure 3).

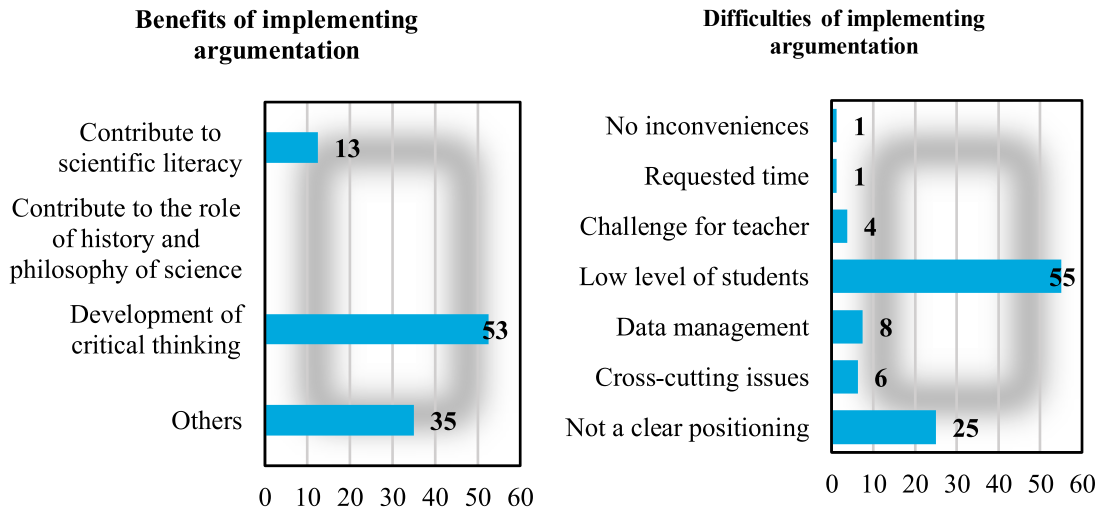


Figure 3. Preliminary results on pre-service teachers preconceptions about argumentation (Data expressed in percentage of pre-service teachers)

Moreover, up to 59% of future teachers indicated that defending a point of view in science is related to "presenting evidence to support it." To a lesser extent and in a similar proportion, the ideas of "justifying and trying to convince others that it is the right point of view" as well as "justifying without intentions to convince others" were chosen by 19% and 20% of the sample, respectively. Only 3% of students ran for the option of "justifying from what is known, without seeking information" (Figure 4).

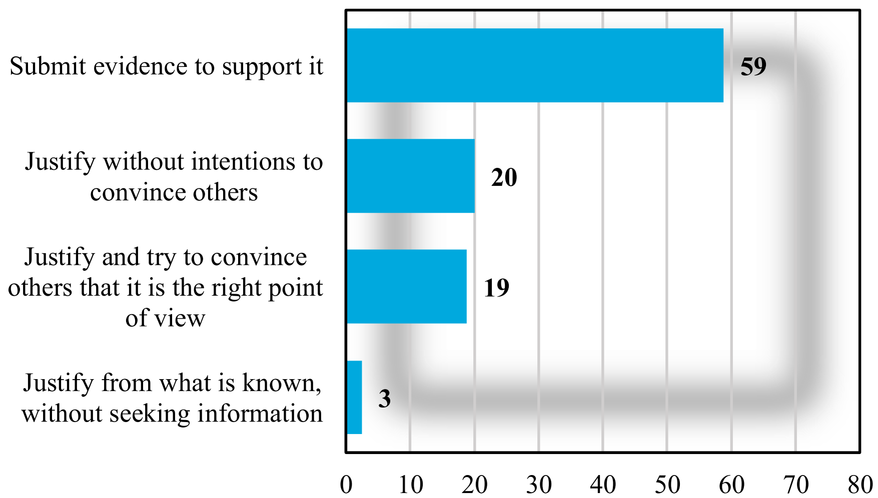


Figure 4. Notions linked to the idea of defending a point of view in science (Data expressed in percentage of pre-service teachers)

Regarding the future teaching practice and carrying out debate activities, about 99% of pre-service teachers considered as essential the participation of their students in debates where different points of view are discussed, while only 31% gave value to participation in debates in which a single argument is defended. About the use of materials for the search of information, up to 99% stressed the importance of using different sources of information. Additionally, 89% also consider the necessity to use the information that appears in books and notes (Figure 5).

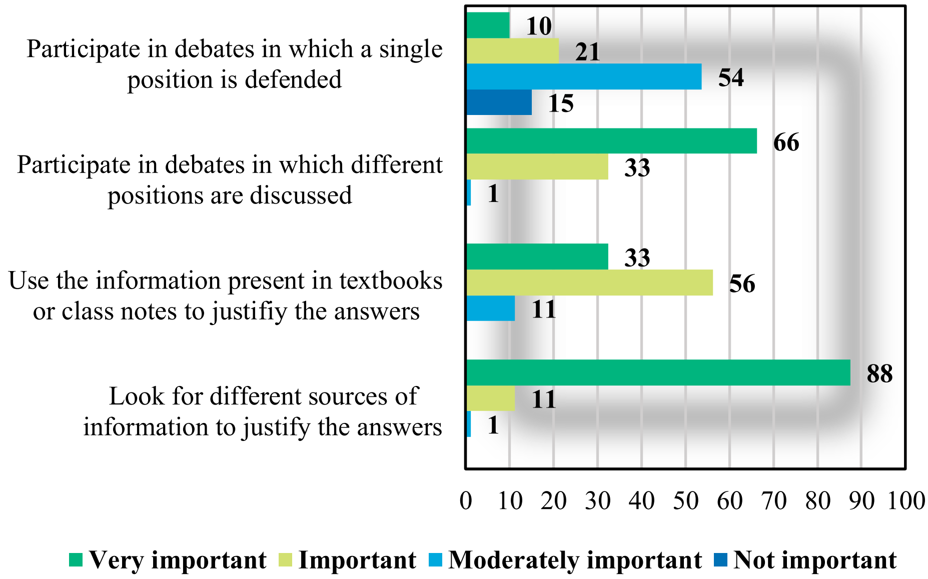


Figure 5. Importance granted by pre-service teachers to perform different tasks related to argumentation in science class (Data expressed in percentage of pre-service teachers)

Results about the quality of argumentative discourse (Figure 6) were evaluated through an environmental theme proposal based on energy sources, using the rubric published by Felton, García-Mila, & Gilabert (2009). While 68% of the students formulated a proposal for an energy source, establishing up to 50% the advantages of the selected source, only 25% listed the possible limitations of their choice. Although these results may be acceptable in a sample that has not yet worked on argumentative competence, the low percentages that have listed the advantages and limitations of the discarded energy sources (less than 5% in both cases) stand out negatively. More alarming may be the lack of coherence in the discourse, with only 6% making a reasoned conclusion. Regarding the contribution of relevant or additional information, the percentages are again low, with less than 10% of students in both cases.

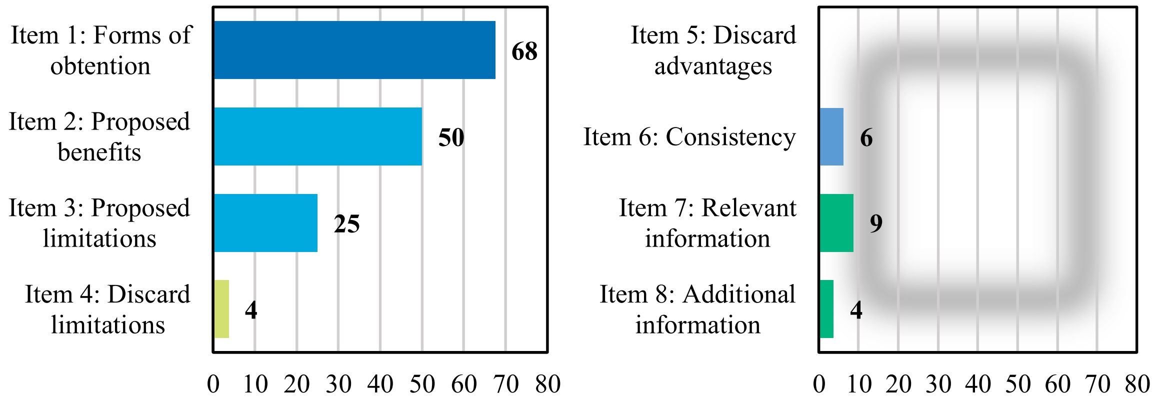


Figure 6. Preliminary results on the quality of pre-service teachers argumentative discourse (Data expressed in percentage of pre-service teachers)

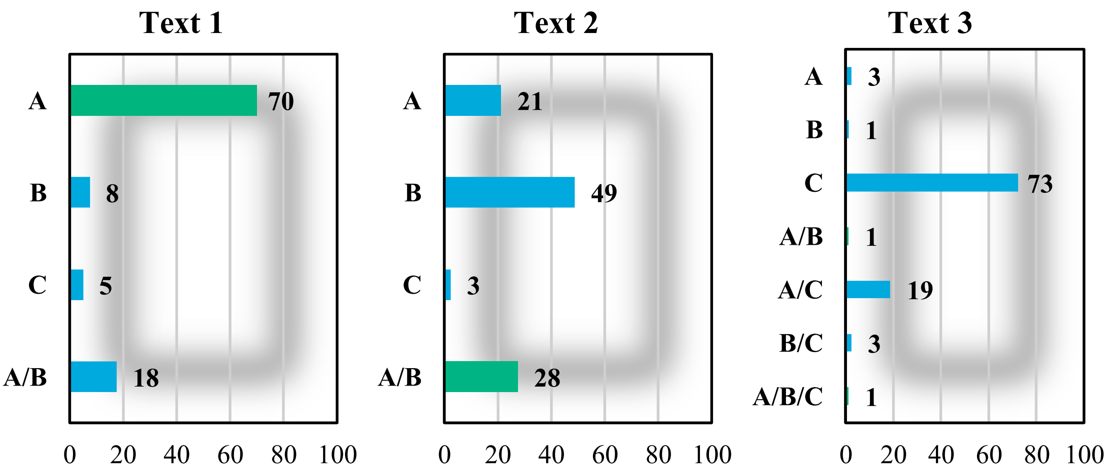
Finally, to know the degree of application of the argument, we adapted an activity related to CCE from the website http://leer.es,[1] a resource of the Spanish Ministry of Education. The objective of this activity was for pre-service teachers to critically analyse the information they receive, through an exhaustive analysis of the text and knowledge of the type of statements made in it. As climate change is a very new and current issue, it needs to be evident that this is a scientific problem where other political, economic and social issues are mixed. Likewise, since it remains unclear what the causes and consequences of warming are, therefore, it is still an open topic where many different opinions have a place. By doing so, we wanted pre-service teachers to recognize evidence and justifications within a text, to decide to what extent they accept or reject the information received and to become aware of their prejudices and their criteria of justification when they decide to believe or not a particular text. The closed-answers activity (Figure 7) consists of the correct classification of different texts (T1-T5) in facts (A), affirmations (B), hypotheses (C) or some combination of the three.

[1] Access to the activity: https://leer.es/documents/235507/242734/eso4_cn_cambioclimatico_prof_annagarrido.pdf/02a58087-46bb-429e-91e2-8004b633f974

T1	The hottest ten years ever recorded have all occurred since 1980 onwards.	Fact/Data	A
		Affirmation/Conclusion	B
		Hypothesis/Prediction	C
T2	During the last century, the level of carbon dioxide in the atmosphere has increased by 31%; the nitrous oxide level at 15%; and the level of methane at 100%. These are the three main gases causing global warming produced by the burning of fossil fuels.	Fact/Data	A
		Affirmation/Conclusion	B
		Hypothesis/Prediction	C
T3	Since 1900, the average temperature of the Earth's surface has risen between 0,3 and 0,6ºC. By the year 2100, it could have risen to 3,5°C, which constitutes a temperature change compared to what has occurred since the last ice age until today.	Fact/Data	A
		Affirmation/Conclusion	B
		Hypothesis/Prediction	C
T4	The melting of polar ice caps and glaciers could cause an increase in sea level of up to one meter by 2100. In this way, entire nations would be submerged, and the world map would be radically altered.	Fact/Data	A
		Affirmation/Conclusion	B
		Hypothesis/Prediction	C
T5	Scientists say that the world must reduce its emissions of global warming gases by 50% to 70% only to stabilize the current level of gases in the atmosphere. Nevertheless, projections indicate that the emissions of these gases will continue to increase in the coming decades.	Fact/Data	A
		Affirmation/Conclusion	B
		Hypothesis/Prediction	C

Figure 7. Translated texts and correct classification (in green)

Figure 8 shows the result set for each of the five texts presented, with the correct answer for each of them in green. While in sections 1 and 4 more than 70% of students choose the correct answer (fact and hypothesis, respectively), these success rates decrease considerably in sections 2 and 5, with less than 40% of successes in both cases. Finally, in section 3, a low 1% provided the correct answer (a combination of fact, statement and hypothesis), with the majority of pre-service teachers opting exclusively for the choice of hypotheses (73%).



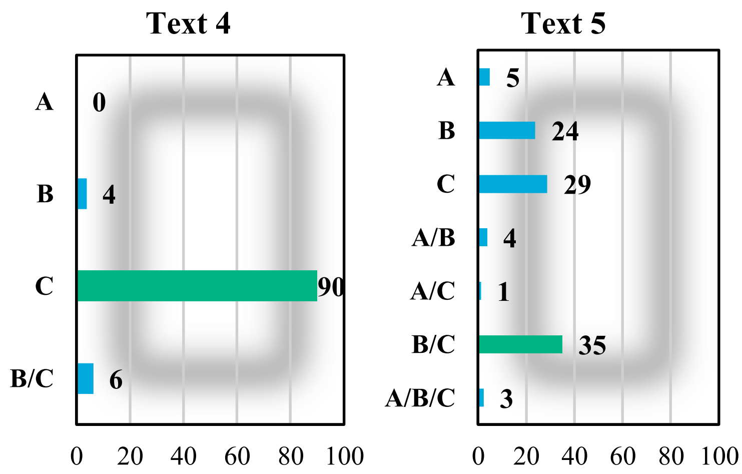


Figure 8. Results on application of the argumentative (correct answer in green) (Data expressed in percentage of pre-service teachers)

CONCLUSIONS

Preliminary results show a reasonable perception of the importance of contextualisation in the argumentative process, thus pointing out the relevance of using topics familiar to students. Nevertheless, socio-scientific issues were just taken into consideration for less than 10% of the sample, meaning that STEM relationships should be emphasised during this study.

As a major benefit of working with argumentation, the sample of pre-service teachers highlighted the development of critical thinking, one of the key milestones for scientific competence, which constitutes a solid starting point for this study. However, it should be noted that only a low percentage identifies the contribution of argumentation to scientific literacy (one of the fundamental objectives established by the OECD) or the contribution to the epistemology of science so that these aspects will be the goal of improvement in the teaching-learning programme proposed. More concerning are the decisions related to the higher difficulties to implement argumentation, with the focus set to the generally low level of students. This result will require the enhancing of learning environments to support students difficulties in argumentation, with the focus on work techniques such as the organisation of heterogeneous groups, the co-creation and sharing of intellectual artefacts or the acquisition of awareness tools, among others (Clark, Stegmann, Weinberger, Menekse, & Erkens, 2008).

The results regarding the quality of the argumentative discourse, both at the level of development and identification of the own elements, show that there is still a lack of coherence in it and a poor idea of the types of statements, being therefore necessary a more comprehensive formation in this regard to critically analyse the information received.

To sum up, the argumentative dimension analysed with the preliminary results of the pre-test points out the necessity of the application of learning opportunities in primary pre-service education in the context of argumentation, to improve the perception about the methodology and the quality itself. The next step in this research would be the implementation of the established innovation sequence, that we hope it will contribute to our purpose and will provide us with enough results to analyse and evaluate the relevance of the proposal regarding advantages and improvements of the online video annotations.

ACKNOWLEDGEMENT

This work is part of the R&D project entitled "Formación inicial del profesorado para el desarrollo de competencias científicas y profesionales mediante el uso de e-rúbricas, anotaciones sobre videos, realidad aumentada y herramientas de gamificación" (PIE17-062) supported by the University of Málaga and the Andalucía Tech - Campus de Excelencia Internacional.

REFERENCES

Cebrián-Robles, D, Blanco-López, A., & Noguera-Valdemar, J. (2016). El uso de anotaciones sobre vídeos en abierto como herramienta para analizar las concepciones de los estudiantes de pedagogía sobre un problema ambiental [The use of notes on open videos as a tool to analyse the conceptions of pedagogy students on an envi. *Indagatio Didactica*, *8*, 158–174.

Cebrián-Robles, Daniel, Franco-Mariscal, A. J., & Blanco-López, Á. (2018). Preservice elementary science teachers' argumentation competence: impact of a training programme. *Instructional Science*, *46*, 789–817. https://doi.org/10.1007/s11251-018-9446-4

Clark, D. B., Stegmann, K., Weinberger, A., Menekse, M., & Erkens, G. (2008). Technology-enhanced learning environments to support students' argumentation. In S. Erduran & M. P. Jiménez-Aleixandre (Eds.), *Argumentation in science education: perspectives from classroom-based research* (pp. 217–243). Dordrecht, Netherlands: Springer.

Escudero, J. M., Vallejo, M., & Botías, F. (2008). El asesoramiento en educación: ¿podrían ser las competencias profesionales una contribución positiva? [The advice in education: could the professional competitions be a positive contribution?]. *Profesorado: Revista de Curriculum y Formación Del Profesorado*, *12*(1), 1–22.

Felton, M., García-Mila, M., & Gilabert, S. (2009). Deliberation versus Dispute : The Impact of Argumentative Discourse Goals on Learning and Reasoning in the Science Classroom. *Informal Logic*, *29*(4), 417–446.

García-Romano, L. (2017). Concepciones sobre argumentación de futuros docentes de biología. In *X Congreso Internacional sobre Investigación en Didáctica de las Ciencias*.

García-Romano, L., Condat, M. E., Occelli, M., & Valeiras, N. (2016). La dimensión argumentativa y tecnológica en la formación de docentes de ciencias [Argumentative and technological dimensions in science teacher training]. *Ciência & Educaçâo*, *22*, 895–912.

Jiménez-Aleixandre, M. P., & Erduran, S. (2008). Argumentation in science education: an overview. In S. Erduran & M. P. Jiménez-Aleixandre (Eds.), *Argumentation in science education: perspectives from classroom-based research* (pp. 3–27). Dordrecht, Netherlands: Springer.

Kersting, N. B., Givvin, K. B., Sotelo, F. L., & Stigler, J. W. (2010). Teachers' analyses of classroom video predict student learning of mathematics: Further explorations of a novel measure of teacher knowledge. *Journal of Teacher Education*, *61*(1–2), 172–181. https://doi.org/10.1177/0022487109347875

Korthagen, F. A. J. (2001). *Linking Practice and Theory : The Pedagogy of Realistic Teacher Education*. London: Routledge.

Llinares, S. (2013). El desarrollo de la competencia docente 'mirar profesionalmente' la enseñanza-aprendizaje de las matemáticas [The development of the 'professional moticing' skill in teaching-learning mathematics]. *Educar Em Revista*, *50*, 117–133. https://doi.org/10.1590/s0104-40602013000400009

Lupión-Cobos, T., & Blanco-López, A. (2016). Reflexión sobre la práctica de profesorado de ciencias de secundaria en un programa formativo en torno a la competencia científica [Reflection on the practice of secondary science teachers in a training program about the scientific competence]. *Revista Electronica Intenruniversitaria de Formacion de Profesorado*, *19*, 195–206.

Mellado, V. (2010). Formación del profesorado de ciencias y buenas prácticas: el lugar de la innovación y la investigación didáctica. In *Biología y Geología. Investigación, Innovación y Buenas Prácticas* (pp. 9–24). https://doi.org/10.1055/s-2008-1040325

Prendes-Espinosa, M. P., Gutiérrez-Porlán, I., & Martínez-Sánchez, F. (2018). Competencia digital: una necesidad del profesorado universitario en el siglo XXI [Digital competence: a need for university teachers in the 21st century]. *Revista de Educación a Distancia (RED)*, *56*, 1–22. https://doi.org/10.1088/0022-3735/9/10/015

Ruiz-Ortega, F. J., Márquez, C., Badillo, E., & Rodas-Rodríguez, J. J. (2018). Desarrollo de la mirada profesional sobre la argumentación científica en el aula de secundaria [Development of professional noticing on scientific argumentation in the high school classroom]. *Revista Complutense de Educación*, *29*, 559–576. https://doi.org/10.5209/RCED.53452

Schleicher, A. (2011). *Building a high-quality teaching profession. Lessons from around the world*. OECD.

Siegel, H. (1995). Why should educators care about argumentation? *Informal Logic*, *17*, 159–176. https://doi.org/10.22329/il.v17i2.2405

Simonneaux, L. (2008). Argumentation in socio-scientific contexts. In S. Erduran & M. P. Jiménez-Aleixandre (Eds.), *Argumentation in science education: perspectives from classroom-based research* (pp. 179–199). Dordrecht, Netherlands: Springer.

Toulmin, S. E. (2003). *The uses of argument: Updated edition*. Cambridge, England: Cambridge University Press.

United Nations Institute for Training and Research [UNITAR]. (2013). *UN CC:Learn - Resource guide for advanced learning on integrating climate change in education at primary and secondary level*. Geneve, Switzerland. https://doi.org/10.1109/50.588673

ANALYSIS OF AN ARGUMENTATION ACTIVITY ON INVASIVE PLANTS IN PRE-SERVICE SCIENCE TEACHERS

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Scientific argumentation is considered a relevant practice in science education in general, and biology in particular. This work focuses on the importance of knowing the difficulties of pre-service science teachers (PSTs) to build and assess arguments within the framework of the learning progression raised by Osborne et al. (2016) facing a socio-scientific problem in the field of biology. An argumentation activity, adapted from those authors, was administered to 132 Spanish Pre-service Early Childhood Teachers (PSECT) and Pre-service Primary School Teachers (PSPST) of the University of Malaga (Malaga, Spain). The task presented different evidences on the extension of the purple loosestrife plant in wetlands of the United States to build different arguments and counter-arguments. The responses were categorized based on a rubric that was associated with the cited learning progression. The results show a decreasing progression in the percentage of PSTs both Early Childhood as Primary Education degrees who gave appropriate responses to advance at different levels of the learning progression (constructing a claim, providing evidence, constructing a one-sided or two-sided comparative argument), suggesting the need to continue working with them in new tasks that exclusively address the highest levels of progression. Finally, the Mann-Whitney U test detected statistically significant differences in the sense that PSPSTs provide better evidence than PSECTs, while these can provide a two-sided comparative argument better than those of PSPSTs.

Keywords: Initial Teacher Education (pre-service), Socio-scientific Issues, learning progressions

INTRODUCTION

One of the most important scientific practices in science education is argumentation as it allows learning of science and its culture (Pinochet, 2015). Furthermore, argumentation is one of the three main activities of scientific practice in science education along with inquiry and modelling (Jiménez-Aleixandre & Crujeiras, 2017). Proof of this is their importance in, among others, the educational frameworks such as K-12 in the American system (National Research Council, 2012) or the PISA international assessment tests (OECD, 2016).

The literature shows an effort to present learning progressions to guide how the learning of sequenced argumentative skills occurs (Bravo-Torija & Jiménez-Aleixandre, 2018; Lee et al., 2014; Osborne et al., 2016). The Osborne et al. (2016) learning progression, taken into account in this work, distinguishes between the construction of an argument, and the critical or evaluative part of it, which includes the counter-argumentation and counter-critique. These last levels in the progression constitute the most complex elements in the argumentation capacity and tend to be carried out to practice with discussion activities (Iordanou, 2013).

In the field of biology, the scientific argumentation has been raised through socio-scientific issues that pose decision-making based on evidence such as the choice of whether new zoos should be opened or not (Simon, Erduran & Osborne , 2006), the management of marine food resources (Bravo-Torija & Jiménez-Aleixandre, 2018) or the problem of invasive species (Berland & Reiser, 2009). The present study revisits this last problem from the analysis of the argumentation based on the learning progression of Osborne et al. (2016).

For this purpose, this work presents an argumentation activity with different questions that allow us to know the level of argumentation of pre-service science teachers (PSTs) within progressive learning. It is also focused on analysing whether the PSTs of two degrees of education (Early Childhood and Primary Education) have difficulties in initial capacity to construct and assess arguments, in this case, putting as context a biological problem.

ARGUMENTATION ACTIVITY ON INVASIVE PLANTS

PSTs responded to an argumentation activity presented as part of a broader questionnaire that included other socio-scientific issues, focusing, in this case, on biology and specifically on invasive plants. This activity was taken by Stanford University group of scientific argumentation[2]. It is a clear example of the different levels of complexity of the elements that must be coordinated as levels of progress concerning the competence of the argumentation in the science since it provided four elements used to inquire about the different levels of learning progression (Osborne et al., 2016).

The activity exposes that purple loosestrife, a wetland plant, imported from Europe to North America, spread to many wetland ecosystems in the country, and provides two images (figure 1) showing a wetland before and after purple loosestrife was introduced (evidence E0).

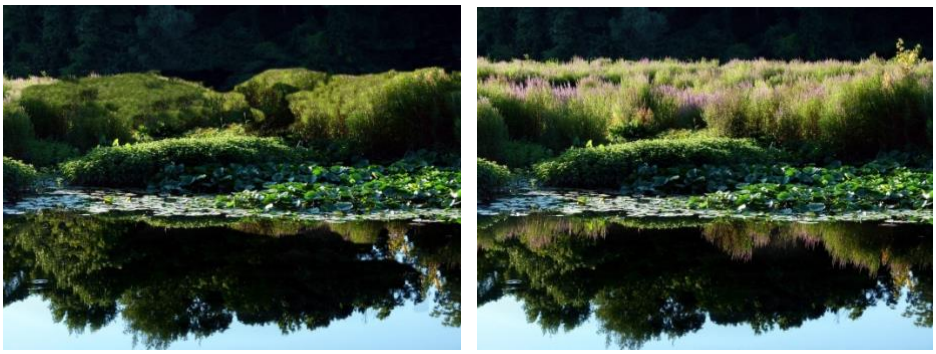

Figure 1. Images of the wetland before (left) and after (right) purple loosestrife.

[2] http://scientificargumentation.stanford.edu/assessments/loosestrife/

Three pieces of evidence are also provided by scientists who studied this specie in the United States:

(E1) The purple loosestrife grows twice as fast as the winged loosestrife (a native plant in these wetlands),

(E2) The winged loosestrife has ten different species of insects that eat its leaves,

(E3) The purple loosestrife has three different species of insects and two species of birds that eat its leaves.

The activity provides conclusions of two students (Sophie and Tina) following the election of if the invasive purple loosestrife is a successful invader and the evidence on which they are based:

(1) Sophie says: "I think the purple loosestrife is a successful invader because there are very few herbivores that eat it. Only five different species eat the purple loosestrife. Since it was so few things that eat it, it can just keep growing, and it can take over the ecosystem".

(2) Tina says: "I think the purple loosestrife is a successful invader because it grows much faster than other plants. The purple loosestrife grows twice as fast as a native plant. If the purple loosestrife grows faster than other species, then it can compete better for light, nutrients, and space".

This activity requires that PSTs rely on scientific data to elaborate and critique the relationships between arguments and scientific evidence. To help PSTs in the construction of the arguments, five questions were included in the task:

(A) Do you consider that the purple loosestrife is a successful invader in this ecosystem: yes or no?

(B) On what evidence do you base this assertion?

(C) On what argument are you in favour: Sophie or Tina?

(D) Why do you agree more with the argument selected in C?

(E) Why do not you agree with the other argument?

A, B, D and E are strictly questions linked to the levels of learning progression of Osborne et al. (2016) and question C is an opinion question, but related to D and E. Thus, in question A, PSTs must make a claim (level 0a); in B they must provide an evidence used to establish the conclusion in A (level 0c); in D they must construct a bilateral (level 2c) or unilateral (level 2b) comparative argument, and finally in E they must provide a counter-critique (level 2a).

METHOD

132 PSTs participated in this research: 56 Pre-service Early Childhood Teachers (PSECTs) and 76 Pre-service Primary School Teachers (PSPSTs) of the University of Malaga (Spain) during the course 2017-2018. They were all in a science education course in the third year of their

grade. 79.4% were women, and 20.6% were men, with an average age of 23. PSTs completed the online activity.

The answers of the PSTs were analysed through a rubric agreed by the researchers (Table 1) that relates the established categories with the different levels proposed by Osborne et al. (2016).

Table 1. Rubric to assess the argumentation activity on the purple loosestrife.

Rubric (established by researchers)			Levels (Osborne et al. 2016)
Question	Level and criteria		
A	No (inadequate)	0	
	Yes	0a	Constructing a claim
B	It does not provide any evidence or provides evidence E2, or provides E2 accompanied by other evidence (E0, E1 or E3) (inadequate).	0	--
	It contributes with 1, 2 or 3 different evidence of E2.	0c	Providing evidence
C	Opinion question	--	--
D & E	It does not construct any comparative argument (inadequate).	0	
	It agrees with one of the arguments of Tina or Sophie but does not justify or justify one.	2b	Constructing a one-sided comparative argument
	It elaborates a critique justifying the contributions of Tina and Sophie.	2c	Providing a two-sided comparative argument

An example of a response of a PST for the level 0 in question B was: "I guess the evidence is the changes that are being made in the ecosystem" (PSECT14) because he does not provide evidence in his argument. However, the following answer given for another PST “It grows faster than the winged loosestrife. Five different species eat loosestrife instead of ten” (PSECT22) was categorized in the level 0c since he can provide adequate evidence.

In the case of question D, an inadequate response (level 0) was “…because it grows faster.” (PSPST07). In this example of response, this PST does not provide a critique but repeats what was said. The PSPST11, for instance, had an adequate response in level 2b: “Because as it grows faster it can get more room to expand, better light, nutrients…”.

The possible statistically significant differences between groups were analysed with the SPSS 21.0 software using the Mann-Whitney U test.

RESULTS

Table 2 shows the results obtained from frequencies and percentages of PSTs for each level and question of the task, while figure 2 shows the evolution of the progression of the capacity of argumentation representing the most appropriate levels in each question of the task.

The results show a decrease in the performance of the PSTs in both degrees and their appropriate responses as progress is made in the levels of the learning progression (level 0a for question A, level 0c for question B and level 2c for questions D and E).

Table 2. Frequencies (f) and percentages (%) of PSTs for each level and question.

	f / %		f / %		f / %		f / %	
Question	PSECT	PSPST	PSECT	PSPST	PSECT	PSPST	PSECT	PSPST
	Level 0		Level 0a					
A	7 / 12.5	6 / 7.9	49 / 87.5	70 / 92.1				
	Level 0		Level 0c (1 evidence)		Level 0c (2 evidence)		Level 0c (3 evidence)	
B	4 / 14.3	4 / 10.6	3 / 42.9	0 / 25	1 / 41.0	4 / 55.3	24 / 1.8	19 / 9.2
	Level 0		Level 2b		Level 2c			
D	30 / 53.6	42 / 55.3	24 / 42.9	32 / 42.1	2 / 3.6	2 / 2.6		
E	23 / 41.0	47 / 61.8	32 / 57.1	27 / 35.5	1 / 1.8	0 / 0		

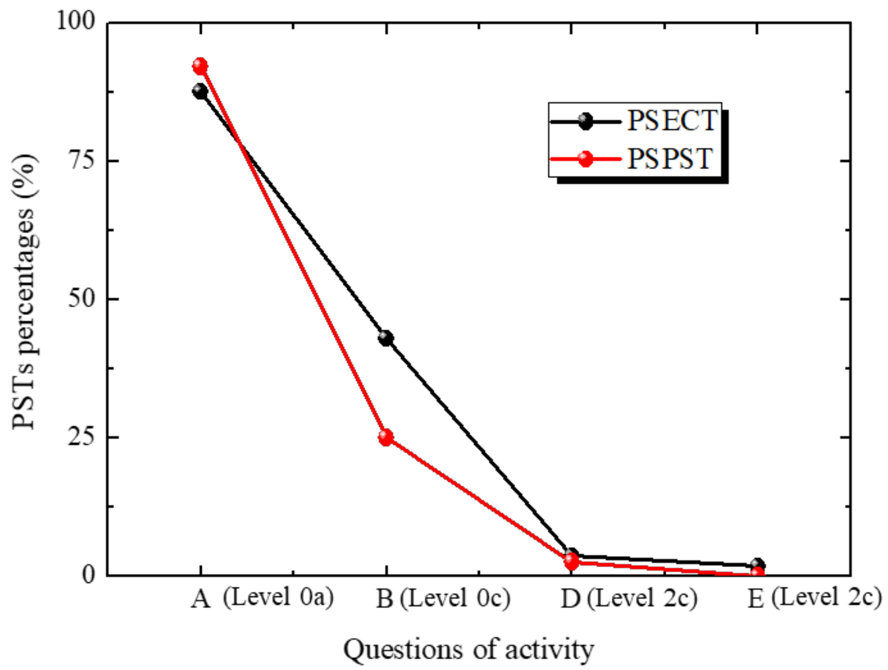

Figure 2. Evolution in the progress of the argumentative capacity of PSECTs and PSPSTs.

The Mann-Whitney U test (table 3) indicated that there were no significant differences between the two groups for questions A and D, showing that both PSECTs and PSPSTs presented similar results in their prior knowledge. In the case of questions B and E, statistically significant differences were detected being in question B in favour of the PSPSTs and question E in favour of the PSECTs.

Table 3. Results for the Mann-Whitney U test.

	Mean (median)		Mann-Whitney U test	
Question	**PSECT**	**PSPST**	**U**	**p**
A	1.9 (2.0)	1.9 (2.0)	2030.0	NS
B	4.1 (4.0)	4,5 (5.0)	1622.5	0.011*
D	1.5(1.0)	1.5 (1.0)	2084.0	NS
E	1.6 (2.0)	1.4 (1.0)	1671.5	0.015*

CONCLUSIONS

These results highlight the need to train the PSTs in constructing a one-sided and two-sided comparative arguments (levels 2b and 2c in the learning progression). For this purpose, we are developing a training programme for the PSTs to learn how to discuss about science.

We are also working on new biology contexts to try to justify the significant differences detected between PSPSTs and PSECTs in questions B and E.

ACKNOWLEDGEMENT

This work was supported by the Spanish government through its 2017 research calls [EDU2017-82197-P, R&D Project].

REFERENCES

Berland, L. K., & Reiser, B. J. (2009). Making sense of argumentation and explanation. *Science Education*, *93*, 26-55.

Bravo-Torija, B., & Jiménez-Aleixandre, M. P. (2018). Developing an Initial Learning Progression for the Use of Evidence in Decision-Making Contexts. *International Journal of Science and Mathematics Education*, *16*(4), 619–638.

Iordanou, K. (2013). Developing Face-to-Face Argumentation Skills: Does Arguing on the Computer Help? *Journal of Cognition and Development: Official Journal of the Cognitive Development Society*, *14*(2), 292–320.

Jiménez-Aleixandre, M. P., & Crujeiras, B. (2017). Epistemic Practices and Scientific Practices in Science Education. In K. S. Taber & B. Akpan (Eds.), *Science Education. New Directions in Mathematics and Science Education* (pp. 69-80). Rotterdam: SensePublishers.

Lee, H.-S., Liu, O. L., Pallant, A., Roohr, K. C., Pryputniewicz, S., & Buck, Z. E. (2014). Assessment of uncertainty-infused scientific argumentation. *Journal of Research in Science Teaching*, *51*(5), 581–605.

National Research Council (2012). *A Framework for K-12 Science Education: Practices, Crosscutting*

Concepts, and Core Ideas. Washington, DC: The National Academies Press.

OECD (2016). *The Organisation for Economic Co-operation and Development*. Brussels: The Organisation for Economic Co-Operation and Development. http://www.oecd.org/

Osborne, J., Henderson, J. B., MacPherson, A., Szu, E., Wild, A., & Yao, S. (2016). The development and validation of a learning progression for argumentation in science. *Journal of Research in Science Teaching*, *53*(6), 821–846.

Pinochet, J. (2015). El modelo argumentativo de Toulmin y la educación en ciencias: una revisión argumentada. *Ciência & Educação (Bauru)*, *21*(2), 307-327.

Simon, S., Erduran, S., & Osborne, J. (2006). Learning to Teach Argumentation: Research and development in the science classroom. *International Journal of Science Education*, *28*(2-3), 235–260.

FUTURE CHEMISTRY TEACHERS' PERCEPTIONS OF VOCATIONALLY RELEVANT LEARNING METHODS

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The lack of relevance is a major challenge in chemistry education. In the last two decades, a lot of research and development projects for increasing the relevancy have been conducted in all educational levels, expect in chemistry teacher education. This research is filling this knowledge gap by investigating what kind of learning methods in pre-service chemistry teacher education have high and low vocational relevance. The relevance of different learning methods included in chemistry teacher education courses are analysed by studying future chemistry teachers' perceptions. Research was carried out as a case study utilising a mixed methods approach. Data was collected via an online questionnaire. The total number of respondents was 72. According to this research, laboratory activities, teaching exercises (e.g. teaching for peers or pupils in a non-formal learning environment study visit) and discussions (e.g. group discussions) were experienced the most vocationally relevant. Writing exercises were experienced the least relevant. All highly relevant learning methods stimulated high-order thinking skills and supported collaborative learning. The level of experienced relevance was mostly intrinsic (skills and knowledge for career) and it had both present and future focus. These results can be used for developing vocationally high relevance learning methods for pre-service chemistry teacher education.

Keywords: learning method, pre-service chemistry teacher education, relevance

INTRODUCTION

The term "relevance" is often mentioned as a goal for developing educational programs, courses and learning materials. It has interested scholars over many decades, because the lack of relevance is a major challenge in science education. For example, students don't experience science relevant for their everyday lives and therefore, they don't choose a science-related career (Osborne et al., 2003; Osborne & Dillon, 2008; Sjøberg & Schreiner, 2010).

Depending on the definition, relevance has been used e.g. as a synonym for interest, describing students' perception of meaningfulness or their learning needs or a mixture of all these. (Stuckey et al., 2013) One highly citated model for defining the concept of relevance has been published by Stuckey et al. in 2013. They made a broad literature review of how the term "relevance" has been used in education. Based on their review, they formed a multidimensional relevance model that summarises central ideas from earlier literature. In Stuckey et al.'s definition, the meaning of relevance is modelled through different dimensions (personal, societal and vocational) and the relevance may be experienced as internal or external in the present moment or in the future. (see Stuckey et al., 2013)

The lack of relevance has at least two dramatic effects – a lack of applicants and a great dropout number during university studies (Hailikari & Nevgi, 2010; Heublein & Schmelzer, 2018; Hill et al., 1990; Valto & Nuora, 2019). From the perspective of chemistry studies, this means that students don't experience chemistry as an interesting or an important subject and therefore don't choose it as their future study field. Also, from those who enrol for chemistry bachelor studies, about 30–40% of will drop out (Heublein & Schmelzer, 2018; Hill et al., 1990; Valto & Nuora, 2019). Many switch into more vocationally clearer fields like medical studies or drop out university studies altogether (Hailikari & Nevgi, 2010). The lack of relevance has led to a situation where too few young people enrol for chemistry studies and even fewer graduate, resulting a major lack of expertise. The situation is challenging because the need is massive. Chemistry is one of the world's biggest fields measured by any economical meter and provides jobs for over 15 million people (Oxford Economics, 2019).

In order to solve the relevance challenge and secure the talent pipeline from school to industry, the field is seeking answers from chemistry education research (Eilks & Hofstein, 2015). CER field has the key role in solving the relevance challenge of chemistry studies. Firstly, CER scholars develop new research-based solutions (e.g. learning materials, evaluation methods, curricula etc.) for supporting relevant chemistry education. This research area has been quite active in the recent years (see Eilks & Hofstein, 2015). Secondly, CER field educates a majority of future chemistry teachers who are introducing the field to countless children every day. According to research, teachers have a significant role in career decision making (Hill et al., 1990; Hugerat et al., 2015) and therefore, chemistry teachers are the most important group of professionals inspiring young people into the chemistry field. Even though chemistry teachers' role is crucial, there is a lack of relevance studies conducted in pre-service chemistry teacher education (see the next section for more details).

Through this research, we contribute to solving the relevance challenge by studying future chemistry teachers' perceptions of vocationally relevant learning methods (e.g. laboratory exercises, research tasks, writing assignments, learning discussions etc.). The study was directed through the following research questions: RQ1: What kinds of learning methods do future chemistry teachers consider most relevant or irrelevant for their learning and future career? RQ2: What kinds of arguments do they present for relevant and irrelevant methods? We propose that answering these questions is important for pre-service chemistry teacher education because:

1. Learning methods have a crucial role in engaging, inspiring and motivating students into chemistry learning. For example, carrying out laboratory experiments is experienced significantly more interesting than watching or planning experiments. (Bolte et al., 2013) If the most relevant and irrelevant methods can be identified, it enables developing pre-service chemistry teacher education into a more professionally relevant direction through a research-based approach.
2. Future chemistry teachers must be taught through versatile methods, because they learn how to teach and learn chemistry through those examples. Students build their professional identity around methods that they experience as supporting their own learning and use them in their future profession as chemistry teachers. (Aksela, 2010)

Our hypothesis is that methods that students find vocationally relevant, support building their chemistry knowledge, pedagogical content knowledge (PCK), professional confidence and self-efficacy. Self-confident chemistry teachers who trust their professional knowledge and skill set are one of the key solutions in solving the relevance challenge of chemistry studies.

VOCATIONAL RELEVANCE OF CHEMISTRY TEACHER EDUCATION

In Stuckey et al.'s (2013) relevance model, the vocational dimension refers to knowledge, skills and formal certificates that prepare or enable succeeding in the future profession (see Table 1). Analysed from the perspective of pre-service chemistry teacher education, the vocational dimension can be focused on many different skills or knowledge components. This is due to the diverse structure of the degree. The structure varies from country to country, but e.g. in Finland, training lasts five years including chemistry studies (1st teaching subject – two years), 2nd teaching subject (e.g. mathematics, physics, biology, computer sciences – one year), pedagogy (including teaching practice training – one year), chemistry education and its research (e.g. bachelor's and master's theses – one year). (Aksela, 2010) In this section, we don't address vocational relevance aspects related to chemistry subject studies, 2nd teaching subject or pedagogical studies, because our data is collected during chemistry education courses and targeted on learning methods included on those courses.

Table 1. Examples of vocational dimension in different levels and states (Stuckey et al., 2013).

Vocational Dimension	Intrinsic	Extrinsic
Present	Orientation about potential careers for chemistry teachers.	Passing exams for getting the degree.
Future	Knowledge, skills and networks that secure getting a satisfactory job.	Contributing to society's economic wellbeing.

We have viewed literature through the above limitations. Our review indicates that vocational relevance of teacher education in general has been studied extensively (see e.g. Sheridan, 2013), but there is a lack of studies conducted in chemistry teacher education. Fundamentally, the vocational perspective of teacher education is clear. Teacher training offers a clear pathway to a specific teaching profession. Therefore, also the vocational relevance of chemistry teacher education itself is clearer compared to e.g. the profession of a chemist. For example, Ogunde (2017) found that students mainly apply into chemistry BSc programs because they are interested in chemistry. Ogunde argues that undergraduate students see chemistry studies as a possibility for many kinds of careers, but only few have an accurate career objective.

CER field has been active in developing the relevance of chemistry education in all education levels except in chemistry teacher training (Eilks & Hofstein, 2015). Scholars have been developing e.g. authentic research-based learning environments for supporting the science career choice (e.g. Nuora & Välisaari, 2018; Veale et al., 2018) or approaching the relevance issue through a specific subject like e.g. sustainable development (Juntunen & Aksela, 2014) or tattoo colours (Stuckey & Eilks, 2014).

There are only few articles published that address the vocational relevance of chemistry teacher education. Early mentions have been made by Childs (2002) who reported a case study of different development actions made in the Irish chemistry education during 1999–2002. Childs described structures and processes that were developed for promoting career awareness in chemistry and physics but also in their teaching profession. Hugerat et al. (2015) argue that the vocational dimension is often neglected in pre-service chemistry teacher training. They propose that it can be strengthened by teaching future chemistry teachers in a similar way that they are taught to teach their future pupils – i.e. through inquiry-based collaborative learning in a highly relevant context.

The vocational possibilities of non-formal learning for chemistry teacher education is the most studied topic under this theme (Affeldt et al., 2015, 2017; Aksela, 2017; Garner et al., 2014, 2015; Garner & Eilks, 2015). These studies are carried out in non-formal chemistry laboratories located in universities or chemical industry (Tolppanen et al., 2015). According to these studies, non-formal learning offers two great possibilities. The first one is promoting in-service teachers' continuous professional development through learning in non-formal chemistry laboratories during study visits (e.g. Affeldt et al., 2017). The second one is using a non-formal chemistry laboratory as a learning environment in undergraduate chemistry education courses which seem to offer many possibilities for learning and developing teacher identity. Aksela (2017) studied pre-service chemistry teachers' perceptions of relevance when they engage in guiding study visits in a non-formal chemistry laboratory. According to her case study, analysed from the vocational perspective, it strengthened their knowledge of chemistry and PCK. In addition, it confirmed the right career selection and increased self-confidence.

METHODS

This research was carried out as a case study utilising a mixed methods approach (Cohen et al., 2007). Data was gathered via an online questionnaire between January 2017 and December 2019 in the end of every chemistry education course held in the Unit of Chemistry Teacher Education at the Department of Chemistry in the University of Helsinki, Finland. The unit organises eight courses every year. All learning methods (see Table 2) included in the courses are selected through latest CER recommendations and these are aligned with the objectives set by the Finnish curriculum. (see Aksela, 2010)

All together 72 future chemistry teachers participated in the research. 34 respondents were studying chemistry as their 1st teaching subject, 36 as their 2nd teaching subject and two respondents left teaching subjects unanswered.

The questionnaire included 14 items divided into five sections (1. Background information, 2. Writing, oral and lab exercises, 3. Teaching and presentations, 4. Chemistry education research and 5. Other feedback). For ensuring a mixed methods approach, the questionnaire included both closed and open items. Closed items were five-point Likert-scales (1 completely meaningless – 2 somewhat meaningless – 3 neutral option – 4 somewhat meaningful – 5 very meaningful) and they were used for gathering students' perceptions of the relevance of different learning methods (see full list from Table 2). Every closed item was followed by two open items where respondents were asked to write justifications for the most relevant and irrelevant methods.

The most relevant and irrelevant methods (RQ1) were analysed via descriptive statistics including frequency distributions, means and standard deviations. Statistical phase was used for identifying the most relevant and irrelevant methods. Data from open items triangulated statistical results. They were used for understanding the reasons why future chemistry teachers experience some methods more relevant or irrelevant than others (RQ2).

RESULTS

Future chemistry teachers experienced that laboratory related methods *(M_{design} = 4.6, SD = 0.65; $M_{inquiry\text{-}based}$ = 4.3, SD = 0.68; M_{short} = 4.2, SD = 0.84)*, teaching sessions for peers *(M = 4.5, SD = 0.62)*, working in a non-formal learning environment with real pupils *($M_{guiding}$ = 4.4, SD = 0.89; $M_{observing}$ = 4.3, SD = 0.78)*, discussions *(M = 4.4, SD = 0.71)* and group work exercises *(M = 4.3, SD = 0.83)* were highly relevant from the vocational perspective. Also, traditional chemistry exercises (e.g. calculations and reaction mechanisms) *(M = 4.3, SD = 1.00)* and lectures *(M = 4.2, SD = 0.76)* were reported important. Writing assignments like learning diaries *(M = 3.5, SD = 1.05)*, summaries and short texts *(M = 3.6, SD = 0.96)* and drama activities *(M = 3.5, SD = 0.90)* were experienced less relevant than hands on activities or teaching exercises. Writing a blog text about personal learning was experienced irrelevant *(M = 2.5, SD = 0.81)* (see Table 2).

Table 2. Learning methods organised from relevant to irrelevant.

Learning activity	**Activity Category**	**1**	**2**	**3**	**4**	**5**	**Mean**	**Std. Deviation**	**N**	**Response rate**
Designing laboratory activities	Laboratory	0	0	6	15	47	4.6	0.65	68	94%
Peer teaching session	Teaching	0	1	1	24	36	4.5	0.62	62	86%
Discussions	Collaboration	0	2	3	28	37	4.4	0.71	70	97%
Guiding a study visit in a non-formal chemistry laboratory	Teaching	1	1	6	15	33	4.4	0.89	56	78%
Group work	Collaboration	1	3	1	32	33	4.3	0.83	70	97%
Observing a study visit in a non-formal chemistry lab	Teaching	0	2	1	18	16	4.3	0.78	37	51%
Inquiry-based open laboratory activities	Laboratory	0	1	5	33	25	4.3	0.68	64	89%
Chemistry exercises	Exercise and lecture	1	2	0	13	15	4.3	1.00	31	43%
Lectures	Exercise and lecture	0	2	8	33	26	4.2	0.76	69	96%
Shorter closed laboratory activities	Laboratory	0	3	5	23	21	4.2	0.84	52	72%
Peer evaluation	Evaluation	0	1	6	39	19	4.2	0.65	65	90%
Project working	Collaboration	1	2	7	36	20	4.1	0.82	66	92%
Textbook content analysis	Chemistry education research	0	1	4	15	8	4.1	0.77	28	39%
Design-based research	Chemistry education research	0	4	5	15	13	4.0	0.97	37	51%
Short oral presentation	Teaching	1	1	12	28	14	3.9	0.84	56	78%

School visit	Teaching	0	5	9	19	16	3.9	0.97	49	68%
Scientific essay	Chemistry education research	0	6	8	24	16	3.9	0.95	54	75%
Research group visit	Exercise and lecture	0	4	7	17	11	3.9	0.94	39	54%
Research report	Chemistry education research	1	1	8	16	9	3.9	0.93	35	49%
CER data gathering via questionnaire	Chemistry education research	2	1	5	13	9	3.9	1.11	30	42%
Case study	Chemistry education research	1	4	7	15	10	3.8	1.06	37	51%
Summary or short text	Writing	1	5	9	21	6	3.6	0.96	42	58%
Learning diary	Writing	2	9	9	26	7	3.5	1.05	53	74%
Roleplay and drama exercises	Exercise and lecture	0	7	11	19	4	3.5	0.90	41	57%
Blog texts	Writing	1	12	5	3	0	2.5	0.81	21	29%

Justifications for vocationally relevant learning methods

Laboratory work was seen as vital in chemistry teacher education. An exercise where students designed new laboratory activities was experienced especially relevant. Respondents felt that this kind of expertise has a major role in chemistry teacher's daily work. It also enables thinking about pupils' learning needs and supports their own learning.

- *"Designing new laboratory activities has a major role in chemistry teacher's work. Even the new curriculum guides into this direction."* (R6)
- *"Designing laboratory activities enabled studying the content more carefully."* (R23)
- *"Designing laboratory activities enabled thinking about what pupils should think.*" (R24)

On the other hand, e.g. open inquiry-based laboratory activities were experienced difficult if the results are not clear. In addition, the relevance of laboratory work can be supported through interesting contexts.

- *"Inquiry-based laboratory activities don't always provide meaningful results."* (R1)
- *"Laboratory work was a bit like a separate section. It could have been integrated inside some other theme."* (R48)

All learning methods that increase teaching experience were experienced highly relevant. For example, teaching example lessons for peers helped learning content knowledge and getting familiar with teaching material development. Working in a non-formal chemistry laboratory with real pupils gave teaching experience and strengthened self-confidence.

- *"When we prepared the peer teaching session, we had to think about what is important for future chemistry teachers."* (R11)
- *"While we prepared materials for the peer teaching session, we had to learn the content profoundly and analyse our presentation critically."* (R13)
- *"Guiding a study visit for 7–9 grade pupils gave me experience on teaching chemistry through laboratory work. I found it useful."* (R54)

- *"Working in a non-formal learning environment helped me to understand what it is like to work with pupils. Experience of real teacher work."* (R51)

Future chemistry teachers experienced learning discussions (e.g. online/face-to-face discussions in pairs, small groups or within the whole class) as one of the most relevant learning methods. They felt that sharing own ideas, and hearing each other's thoughts forced to think and argument. Collaboration with peers enabled creating new ways to see things. Online discussions were reported challenging if instruction was experienced unclear.

- *"Discussions, if they stayed on topic, forced to think and argument."* (R3)
- *"Discussions with peers expanded my thoughts about teacher's vocation."* (R10)
- *"In discussions, I got feedback from my own thoughts and heard different opinions. I feel that discussions expanded my thinking."* (R13)
- *"Online discussions were poorly instructed, and I didn't get much out of them."* (R39)

Justifications for vocationally irrelevant learning methods

Writing assignments were experienced vocationally most irrelevant. Some respondents felt that writing did not support learning, or they felt that writing is not done to support their own learning.

- *"I can't evaluate my learning through writing assignments."* (R50)
- *"I feel that learning diaries are totally useless. They only add stress."* (34)
- *"Sometimes reflections are written for the teacher not for yourself. That's why they are not meaningful for supporting learning. Even though writing is a good way to learn."* (R11)

Some students responded that an assignment is irrelevant because they already know how to write that particular text type (e.g. summaries). Some felt learning diaries and blog texts unclear or not suitable for supporting learning or teaching.

- *"I am already familiar with writing summaries."* (R2)
- *"Learning diary is an unclear idea."* (R32)
- *"I don't see any use for blogs in teaching or learning."* (R12)
- *"Blog writing is a personal way to express oneself so it should be optional."* (R4)

Drama exercises divided opinions. Some students found them relevant and others disliked them. Responses show that sometimes the perception of irrelevancy may result from the unclear assignment description.

- *"Roleplay and drama exercises are a waste of efficient study time. I understand that others like them and it seems that they have some pedagogical value. However, many times the content suffers because of the entertainment perspective. These favour people that like to entertain by their nature. Teachers need to learn how to present a lesson in a classroom. It is not acting.* (R9)
- *"Drama exercise taught me to explore my boundaries, so I don't think that it was meaningless."* (R21)

DISCUSSION AND CONCLUSIONS

The most relevant learning methods experienced by future chemistry teachers were different kinds of laboratory activities, teaching exercises and discussions. Writing exercises were seen less relevant than other types of learning methods. When analyzing the results, one must keep in mind that these are preliminary findings. This case study is a starting point for learning method discussion in pre-service chemistry teacher education.

From the laboratory activities, especially designing new laboratory work was seen relevant in multiple ways, e.g. laboratory working has an essential role in chemistry teacher's work or an efficient method for supporting own and pupils' learning. Future chemistry teachers experienced designing new activities more relevant than just performing them, which differs from upper secondary school students' perceptions. Upper secondary school students found performing laboratory activities more relevant than planning them (see Bolte et al., 2013).

All kind of collaboration with peers (e.g. teaching example lessons for peers and learning discussions) was also experienced highly relevant. Our findings concerning the possibilities of non-formal learning are consistent with earlier research. Aksela (2017) reported that working with study visits strengthened students' chemistry knowledge, CPK, self-confidence and career choice. Our results showed that both engaging in non-formal learning environment and teaching example lessons for peers have the same kind of effects.

It was interesting that writing exercises were experienced the least relevant. After all, writing is one of the most important ways to express thoughts, especially for academically trained experts. According to our data, it seemed that the problem was in many cases an unclear assignment description. Students felt that they had to write for the teacher, and that it didn't support their own learning. For future research, we suggest that it would be important to develop writing task models that would be experienced more relevant.

Analysing these results through Stuckey et al.'s (2013) model, the vocational relevance related to learning methods was mainly internal (skills and knowledge for career) and focused partly in the present learning needs and partly in the future career orientation. Extrinsic perspectives were not present in this data.

For ensuring the high vocational relevance in chemistry teacher education, we encourage chemistry teacher training programs to increase engaging with non-formal learning environments and all kinds of teaching exercises. Designing learning materials, preparing and holding lessons, evaluating learning effects and re-designing lessons in a collaborative learning setting is an efficient model for supporting future chemistry teachers' professional development. We agree with Hugerat et al. (2015) and Aksela (2010), who argue that students need to be taught using versatile methods. An active learner will become an active teacher. Good practices learned during university years will transfer into their teaching. Enthusiastic and proficient chemistry teachers will be the key solution for increasing the relevance of chemistry studies, and that is why developing chemistry teacher education into a more relevant direction is important.

ACKNOWLEDGEMENT

We would like to thank our SECO research group members for participating in the development of the online questionnaire and in data collection. Together we are more!

REFERENCES

Affeldt, F., Tolppanen, S., Aksela, M., & Eilks, I. (2017). The Potential of the Non-Formal Educational Sector for Supporting Chemistry Learning and Sustainability Education for All Students—A Joint Perspective from Two Cases in Finland and Germany. *Chemistry Education Research and Practice*, *18*(1), 13–25. https://doi.org/10.1039/C6RP00212A

Affeldt, F., Weitz, K., Siol, A., Markic, S., & Eilks, I. (2015). A Non-Formal Student Laboratory as a Place for Innovation in Education for Sustainability for All Students. *Education Sciences*, *5*(3). https://doi.org/10.3390/educsci5030238

Aksela, M. (2010). Evidence-based teacher education: Becoming a lifelong research-oriented chemistry teacher? *Chemistry Education Research and Practice*, *11*(2), 84–91. https://doi.org/10.1039/C005350N

Aksela, M. (2017). ChemistryLab Gadolin as a Relevant Learning Environment for Lifelong Learning. *ESERA 2017 Conference Proceedings*. ESERA 2017, Dublin.

Bolte, C., Streller, S., & Hofstein, A. (2013). How to Motivate Students and Raise Their Interest in Chemistry Education. In I. Eilks & A. Hofstein (Eds.), *Teaching Chemistry – A Studybook: A Practical Guide and Textbook for Student Teachers, Teacher Trainees and Teachers* (pp. 67–95). SensePublishers. https://doi.org/10.1007/978-94-6209-140-5_3

Childs, P. E. (2002). Securing the future of chemistry: A case study of developments in chemical education in Ireland. *Chemistry Education Research and Practice*, *3*(3), 361–369. https://doi.org/10.1039/B2RP90027K

Cohen, L., Manion, L., & Morrison, K. (2007). *Research methods in education* (6th ed). Routledge.

Eilks, I., & Hofstein, A. (Eds.). (2015). *Relevant Chemistry Education: From Theory to Practice*. Sense Publishers. https://ebookcentral.proquest.com

Garner, N., & Eilks, I. (2015). The Expectations of Teachers and Students Who Visit a Non-Formal Student Chemistry Laboratory. *EURASIA Journal of Mathematics, Science & Technology Education*, *11*(5), 1197–1210. https://doi.org/10.12973/eurasia.2015.1415a

Garner, N., Hayes, S. M., & Eilks, I. (2014). Linking Formal and Non-Formal Learning in Science Education – A Reflection from Two Cases in Ireland and Germany. *Sisyphus - Journal of Education*, *2*, 10–31. https://doi.org/10.25749/sis.4064

Garner, N., Siol, A., & Eilks, I. (2015). The Potential of Non-Formal Laboratory Environments for Innovating the Chemistry Curriculum and Promoting Secondary School Level Students Education for Sustainability. *Sustainability*, *7*(2), 1798–1818. https://doi.org/10.3390/su7021798

Hailikari, T. K., & Nevgi, A. (2010). How to Diagnose At-Risk Students in Chemistry: The Case of Prior Knowledge Assessment. *International Journal of Science Education*, *32*(15), 2079–2095. https://doi.org/10.1080/09500690903369654

Heublein, U., & Schmelzer, R. (2018). *Die Entwicklung der Studienabbruchquoten an den deutschen Hochschulen—Berechnungen auf Basis des Absolventenjahrgangs 2016 (Eng. The development of dropout rates at German universities—Calculations based on the graduate year 2016)* (DZHW-Projektbericht). Deutsches Zentrum für Hochschul- und Wissenschaftsforschung (DZHW). https://www.dzhw.eu/en/publikationen

Hill, O. W., Pettus, W. C., & Hedin, B. A. (1990). Three studies of factors affecting the attitudes of blacks and females toward the pursuit of science and science-related careers. *Journal of Research in Science Teaching*, *27*(4), 289–314. https://doi.org/10.1002/tea.3660270403

Hugerat, M., Mamlok-Naaman, R., Eilks, I., & Hofstein, A. (2015). Professional Development of Chemistry Teachers for Relevant Chemistry Education. In I. Eilks & A. Hofstein (Eds.), *Relevant Chemistry Education: From Theory to Practice* (pp. 369–386). SensePublishers. https://doi.org/10.1007/978-94-6300-175-5_20

Juntunen, M. K., & Aksela, M. K. (2014). Education for sustainable development in chemistry – challenges, possibilities and pedagogical models in Finland and elsewhere. *Chemistry Education Research and Practice*, *15*(4), 488–500. https://doi.org/10.1039/C4RP00128A

Nuora, P., & Välisaari, J. (2018). Building natural science learning through youth science camps. *LUMAT: International Journal on Math, Science and Technology Education*, *6*(2). https://doi.org/10.31129/LUMAT.6.2.326

Ogunde, J. C., Overton, T. L., Thompson, C. D., Mewis, R., & Boniface, S. (2017). Beyond graduation: Motivations and career aspirations of undergraduate chemistry students. *Chemistry Education Research and Practice*, *18*(3), 457–471. https://doi.org/10.1039/C6RP00248J

Osborne, J., & Dillon, J. (2008). *Science Education in Europe: Critical Reflections, Report to the Nuffield Foundation* (pp. 1–32). King's College London. http://www.nuffieldfoundation.org/sites/default/files/Sci_Ed_in_Europe_Report_Final.pdf

Osborne, J., Simon, S., & Collins, S. (2003). Attitudes towards science: A review of the literature and its implications. *International Journal of Science Education*, *25*(9), 1049–1079. https://doi.org/10.1080/0950069032000032199

Oxford Economics. (2019). *The Global Chemical Industry: Catalyzing Growth and Addressing Our World's Sustainability Challenges* (pp. 1–29). International Council of Chemical Associations (ICCA). https://www.icca-chem.org/wp-content/uploads/2019/03/ICCA_EconomicAnalysis_Report_030819.pdf

Sheridan, L. D. (2013). Changes in Pre-Service Teachers Perceptions' of Teacher Qualities: Development from Egocentric to Student Centric. *Australian Journal of Teacher Education*, *38*(9), 55–75. https://doi.org/10.14221/ajte.2013v38n9.2

Sjøberg, S., & Schreiner, C. (2010). *The ROSE project: An overview and key findings, Report to the European Commission* (pp. 1–31). University of Oslo. http://www.cemf.ca/%5C/PDFs/SjobergSchreinerOverview2010.pdf

Stuckey, M., & Eilks, I. (2014). Increasing student motivation and the perception of chemistry's relevance in the classroom by learning about tattooing from a chemical and societal view. *Chemistry Education Research and Practice*, *15*(2), 156–167. https://doi.org/10.1039/C3RP00146F

Stuckey, M., Hofstein, A., Mamlok-Naaman, R., & Eilks, I. (2013). The meaning of 'relevance' in science education and its implications for the science curriculum. *Studies in Science Education*, *49*(1), 1–34. https://doi.org/10.1080/03057267.2013.802463

Tolppanen, S., Vartiainen, J., Ikävalko, V.-M., & Aksela, M. (2015). Relevance of Non-Formal Education in Science Education. In I. Eilks & A. Hofstein (Eds.), *Relevant Chemistry Education* (pp. 335–354). SensePublishers. https://doi.org/10.1007/978-94-6300-175-5_18

Valto, P., & Nuora, P. (2019). The role of guidance in student engagement with chemistry studies. *LUMAT: International Journal on Math, Science and Technology Education*, *7*(1), 165–182. https://doi.org/10.31129/LUMAT.7.1.402

Veale, C. G. L., Krause, R. W. M., & Sewry, J. D. (2018). Blending problem-based learning and peer-led team learning, in an open ended 'home-grown' pharmaceutical chemistry case study. *Chemistry Education Research and Practice*, *19*(1), 68–79. https://doi.org/10.1039/C7RP00180K

THE TWO-SIDED COIN OF EFFECTIVE EVOLUTION EDUCATION: TEACHERS' COMPETENCIES AND STUDENTS' RECEPTIVITY

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Despite the centrality of evolution within the biosciences, it remains a 'controversial' topic among the general public, meaning that it is not uncommon for students to enter the classroom with misconceptions about the validity of evolutionary theory. The complexity of evolution, coupled together with the perceived debate around it, makes teaching evolution that much more challenging for teachers. To support students' ability to understand the validity of evolution and the general nature of science a lesson plan was created that allows students to take on the role of the scientific investigator as they create and 'test' their own hypotheses regarding the existence and possible location of intermediary fossils. To test the applicability of this lesson plan, we conducted a trial run with a group of pre-service teachers at a German university. In addition to testing the usability and applicability of the lesson plan, we also asked the participants a series of questions before and after the lesson. Results from the questionnaire showed that the participants had an increased understanding of the validity of evolution following the lesson and also saw themselves as more capable of dealing with future anti-evolution challenges in the classroom. Post-lesson interviews also showed that the participants found the lesson material to be challenging but engaging and thus very applicable to the classroom.

Keywords: Nature of Science, Initial Teacher Education (Pre service), Misconceptions

INTRODUCTION

Teaching in general is emotionally laborious and this is especially true when teaching 'controversial' subjects such evolution or climate change. The emotional complexities and pressures that accompany the teaching of 'controversial' topics are often the reason why some teachers attempt to circumvent lessons on such polarizing topics, citing self-doubt about content knowledge and concerns about audiences' responses as motivations for this aversion (Swim & Fraser, 2013). This situation is exacerbated by the creation of materials such as "Ten Questions to Ask Your Biology Teacher about Evolution" by Jonathan Wells (2002) which aim to disrupt lessons on evolution and place teachers in the uncomfortable position of feeling personally responsible for upholding the validity of the theory of evolution (Watts, Levit, & Hossfeld, 2016).

Due the importance of the understanding of evolution for the general development of scientific literacy, this issue needs to be addressed both from the side of the student through the development of new engaging materials that act to counter materials such as the "Ten

Questions". At the same time, new training opportunities need to be developed that better prepare teachers to teach this complex topic in the face of continued 'controversy'.

To address this issue, a sample lesson plan was developed "Missing Links – Missing Evidence?" that focuses on the validity of the theory of evolution while also showing students how this theory can be tested. The lesson plan was originally published in the book *Neanderthals in the Classroom* (Watts, 2019) as a theoretical means of addressing misconceptions about evolution in the classroom. This lesson plan was then incorporated into a pre-service teacher training session that was taught together with Clemens Hoffmann in order to evaluate the lesson materials and gauge the participants' knowledge about evolution and their preparedness for the task of teaching evolution in the face of controversy.

The role of nature of science in evolution education

In addition to focusing on the facts of evolution, the lesson plan also seeks to inform students about the nature of science (NOS). In the sense of epistemological beliefs, ideas about NOS can influence the examination of other scientific content. Moreover, such beliefs about NOS can also serve as a filter (Fives & Buehl, 2012) and affect a person's experiences and perception. In other words, they influence how the environment, how objects and phenomena are perceived, how and which incoming stimuli are processed and how new experiences are linked with existing ones. In this way, they also have an impact on learning. This effect can be leveraged within a science class by combining subject content with the lessons of NOS (Kircher & Dittmer, 2004). Theoretical and historical elements of science thus represent an inadequately appreciated component of motivational and communicative learning in schools (Baumert, Bos, & Lehmann, 2000).

It is important that NOS is addressed directly in the classroom as ideas about NOS are often passed on to students subconsciously by teachers through their use of language and terminology (Miele, 2014). Teachers thus act as a multiplier system and it is thus imperative that teachers therefore develop appropriate ideas about how natural sciences work (Bruns, 2009). An additional advantage of incorporating components of NOS into the lesson is that it presents teachers with the opportunity to increase their students' general level of science literacy and socio-scientific decision making (Clough, 2017) as students have the opportunity to better understand the value of science as a central tool in explaining and understanding the natural world (McComas, 2017). In this way, they can better appreciate how scientists use observation, empirical data and other evidence to develop working theories that may change over time as new data is gathered. This newly gained knowledge, not only about evolution but also about scientific endeavour, may also enable students to better judge which sources are the most reliable with regard to statements about the validity of evolution and enable them to eventually distinguish between reliable and unreliable sources, which further increases their scientific literacy potential.

THE LESSON PLAN

The idea of missing links plays a central role in creationist argumentation. Creationists often claim that there is a lack of intermediate forms within the fossil record and that the theory of evolution must therefore be incorrect (Graf, 2011). Intelligent design proponents make similar arguments using different terminology such as ‘information problems’ (Watts, Hossfeld, Tolstikova, & Levit, 2016).

This lesson provides students with a great overview of macroevolution, which has been argued to be one of the most effective ways of teaching any student or adult about the validity of the theory of evolution (Padian, 2010), while also supporting students’ understanding of NOS as they take on the role of a scientist, creating and testing hypotheses.

Goals and expectations

The primary goal of this lesson is to support the development of scientific literacy and increase students’ interest in science. For a student to be considered “scientifically literate”, they need to be able to make scientific, evidence-based judgments for themselves and not simply memorize and repeat facts (DeBoer, 2000; Oulton, Dillon, & Grace, 2004). This lesson is thus designed to allow students to learn about evolution by taking on the role of the primary investigator as they reconstruct the historic discovery of *Tiktaalik* by learning to develop hypotheses regarding intermediary forms and then coming up with ways to test their hypotheses.

More specifically, this lesson familiarizes students with cladograms and geologic times scales and teaches them how to extract information from these visual aids in order to formulate a hypothesis. The lesson plan also integrates the use of new medias in the form of Macrostrat ® (Figure 1), which is a collaborative platform for geological data exploration.

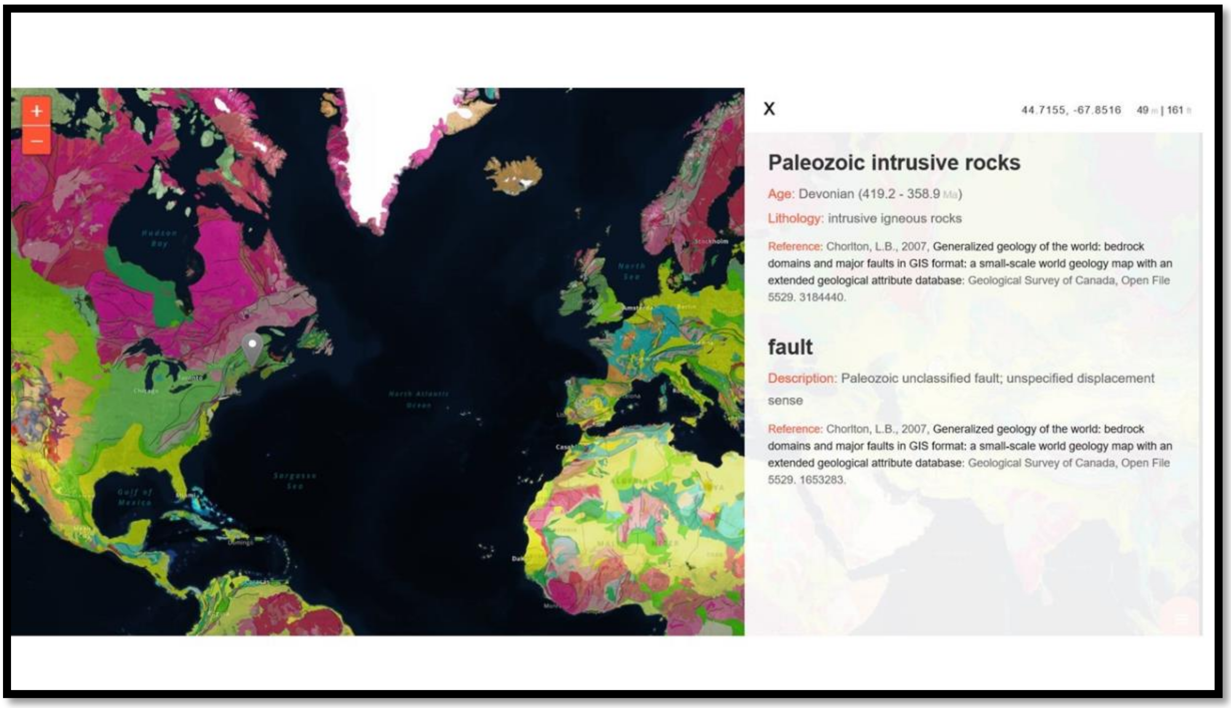

Figure 1. Example of Macrostrat, a collaborative platform for geological data exploration.

Various components of NOS are integrated into the different components of the lesson, which were designed to allow students to develop a better insight into the how scientific research is conducted as it has been shown that understanding this aspect of NOS is particularly useful for students (Markert, 2012). During the lesson, the students take on the role of researchers who are planning a hypothetical dig. This requires them to first develop a testable hypothesis and come up with a hypothetical location where they can test their hypothesis. As part of the preparation for this hypothetical dig, they must plan an excavation and defend their project location against the alternatives of the other groups. To do this, they must present their considerations comprehensibly and justify their processes according to budget restrictions and likelihood of success. In this way students not only practice their scientific argumentation, but also reflect that scientific endeavor is often embedded in a social context. In the end, only one group receives funding for their planned project.

Procedure

Working in groups, the students took on the role of researchers who are attempting to find the fossil remains of the 'missing link' between fish and amphibians. Students were provided a cladogram and a geological timescale so that they can make a prediction on how long ago this intermediary animal would have lived. Using the information sources provided to them the students were able to determine that this intermediary form should have existed during the Devonian period. Using Macrostrat®, the students then work in groups to choose a hypothetical dig site to test their hypotheses.

Once each group has chosen a hypothetical digging site, one member of the group should present their ideas to the 'committee'. In order to procure funding for their project, they needed to convince the committee that their chosen dig site would be the most suitable place to test their hypothesis. Each of the groups was able to create solid arguments based on both the age of the rocks as well as other arguments such as accessibility and costs.

Lesson conclusion

Once students had finished, we went over the story of *Tiktaalik* to discuss how scientists had actually conducted these same steps and were successful in finding the intermediary fossils (Daeschler, Shubin, & Jenkins, 2006). We concluded by watching a short 5-min video as Neil Shubin discussed how the group of scientists searched along the ancient Devonian shoreline in an attempt to find this then-hypothetical intermediary and how they ultimately discovered *Tiktaalik* (PBS, 2014).

PRE-SERVICE TEACHER EVALUATION OF THE LESSON PLAN

In order to test the effectiveness of this lesson plan, a group of twenty-five pre-service teachers were given the lesson plan to run through it in the role of a student and then the lesson plan was discussed as a potential lesson that they could later use in the classroom when confronted by anti-evolution arguments or as a means of teaching evolution and the nature of science. The goal of this intervention was to increase their understanding of evolution and to increase their confidence in their ability to teach their future students about evolution.

In that sense, the pre-service teachers took on the role of both a hypothetical student and a future teacher. In addition to trying out and evaluating the materials, they also participated in a questionnaire that examined their own views of evolution, their expectations regarding creationist beliefs in the classroom and their level of confidence in their ability to deal with classroom disputes over the validity of evolution. The participants answered an identical set of four questions before and after the lesson (Table 1). The pre-questionnaire was conducted using Mentimeter®, while the post-questionnaire was paper based.

Table 1. Pre- Post- question set for pre-service teachers.

Please rate the following statements about evolutionary theory: (strongly agree, agree, neither agree or disagree, disagree, strongly disagree)
1. Evolution cannot be considered a scientific theory because it cannot be tested, and thus cannot be confirmed or refuted. _____________
2. The theory of evolution cannot satisfactorily explain the origin of the species, since intermediary fossils have not yet been found. _____________
Please rate the following statements about your own approach to teaching evolutionary theory in the classroom: (The same scale)
3. As a teacher, I expect to have students in my classes who question the theory of evolution from a creationist perspective. _____________
4. Dealing with situations in which students critically question evolutionary theory will be easy for me. _____________

Evaluation of the lesson

During the lesson the pre-service teachers were highly engaged with the material. The general consensus based on a collection of written commentary was that the material was difficult/challenging but engaging and that they believed that they could and would implement it in the classroom. Most of the participants said that they believed that students would benefit from a pre-exercise to make sure that they were familiar with all of the concepts before beginning with the actual lesson.

Figure 2. Biology education students participating in analysis of lesson plan in Jena, Germany.

The results of the questionnaire showed a positive trend in their understanding of the theory of evolution, as there was an increase in the number of students who answered 'disagree' or 'strongly disagree' to items #1 and #2 (Table 1) on the post-questionnaire than on the pre-questionnaire. It also showed an increase in their levels of self-confidence regarding their ability to deal with future anti-evolution challenges which is marked by more pre-service teachers answering 'strongly agree' or 'agree' in item #4 (Table 1) on the post-questionnaire than on the pre-questionnaire. However, the pre-service teachers' expectations of being confronted with creationist argumentations remained steady (agree or strongly agree on item #3, Table 1) in both the pre- and post-questionnaire.

CONCLUSION

Improving the efficacy of evolution education requires a two-pronged approach: (1) creating engaging materials for students and (2) better preparing pre-service teachers to deal with the challenges that they will face from creationist students. The results of the lesson plan evaluation showed that the classroom materials were effective in that they were engaging and assisted to the students in their ability to better understand the validity of evolution through investigative, self-guided learning. The availability of these materials and the opportunity to try out the materials in a group setting increased not only the pre-service teachers' understanding of the validity of evolution but also increased their overall confidence in their teaching abilities with regard to evolution.

ACKNOWLEDGEMENT

We would like to thank all of the pre-service teachers who participated in this study.

REFERENCES

Baumert, J., Bos, W., & Lehmann, R. (Eds.). (2000). *Mathematische und physikalische Kompetenzen am Ende der gymnasialen Oberstufe (TIMSS/III, dritte internationale Mathematik- und Naturwissenschaftsstudie; mathematische und naturwissenschaftliche Bildung am Ende der Schullaufbahn)* (Vol. 2). Opladen: Leske + Budrich.

Bruns, J. (2009). *Auf dem Weg zur Förderung naturwissenschaftsspezifischer Vorstellungen von zukünftigen Chemie-Lehrenden. Chancen und Grenzen eines kombinierten theoretisch-expliziten und praktisch-reflektierten Ansatzes* Studien zum Physik- und Chemielernen, Bd. 92. Dissertation. Berlin: Logos-Verl.

Clough, M. P. (2017). History and Nature of Science in Science Education. In K. S. Taber & B. Akpan (Eds.), *Science education: An international course companion* (pp. 39-51). Rotterdam, The Netherlands: Sense Publishers.

Daeschler, E. B., Shubin, N. H., & Jenkins, F. A. (2006). A Devonian tetrapod-like fish and the evolution of the tetrapod body plan. *Nature, 440*(7085), 757-763. doi:10.1038/nature04639

DeBoer, G. E. (2000). Scientific Literacy: Another Look at Its Historical and Contemporary Meanings and Its Relationship to Science Education Reform. *Journal of Research in Science Teaching, 37*(6), 582-601.

Fives, H., & Buehl, M. M. (2012). Spring cleaning for the "messy" construct of teachers' beliefs: What are they? Which have been examined? What can they tell us? In K. R. Harris (Ed.), *APA educational psychology handbook, Volume 2: Individual differences* *and cultural and contextual factors (APA handbooks in psychology, 1st ed.* (pp. 471–499). Washington, D.C.: American Psychological Association (APA).

Graf, D. (Ed.) (2011). *Evolutionstheorie - Akzeptanz und Vermittlung im europäischen Vergleich*. Berlin Heidelberg: Springer.

Kircher, E., & Dittmer, A. (2004). Lehren und Lernen über die Natur der Naturwissenschaften - ein Überblick. In C. Hößle, D. Höttecke, & E. Kircher (Eds.), *Lehren und Lernen über die Natur der Naturwissenschaften* (pp. 2-22). Baltmannsweiler: Schneider-Verl. Hohengehren.

Markert, M. (2012). *Wissenschaftsgeschichte im Unterricht. Eine Analyse von Schulbüchern im Fach Biologie.* Friedrich-Schiller-Universität Jena, Jena.

McComas, W. F. (2017). Understanding how science works: the nature of science as the foundation for science teaching and learning. *The School science review, 98*(365), 71-76.

Miele, E. (2014). Using the draw-a-scientist test for inquiry and evaluation. *Journal of College Science Teaching, 43*(4), 36–40.

Oulton, C., Dillon, J., & Grace, M. (2004). Reconceptualising the Teaching of Controversial Issues. *International Journal of Science Education, 26*(4), 411-423.

Padian, K. (2010). How to Win the Evolution War: Teach Macroevolution! *Evolution: Education and Outreach, 3*(2), 206-214. doi:10.1007/s12052-010-0213-5

PBS. (2014). Your Inner Fish | Amazing Places, Amazing Fossils: Tiktaalik. https://www.youtube.com/watch?time_continue=1&v=T2vKlEUX7DI&feature=emb_title (Accessed 27.10.2019).

Swim, J. K., & Fraser, J. (2013). Fostering Hope in Climate Change Educators. *Journal of Museum Education, 38*(3), 286-297. doi:10.1179/1059865013z.00000000031

Watts, E. (2019). *Neanderthals in the Classroom*. Boca Raton, FL.: Taylor & Francis.

Watts, E., Hossfeld, U., Tolstikova, I. I., & Levit, G. S. (2016). Beyond borders: On the influence of creationist movement on the educational landscape in the USA and Russia. *Theory in Biosciences, 136*(1-2), 31-48.

Watts, E., Levit, G. S., & Hossfeld, U. (2016). Science Standards: The foundation of evolution education in the United States. *Perspectives in Science, 10*, 59-65.

Wells, J. (2002). *Icons of Evolution: Science or Myth? Why Much of What We Teach About Evolution Is Wrong*. Washington, DC: Regnery Publishing.

THE IMPLEMENTATION OF TPACK AND SAMR MODELS IN SCIENCE TEACHER TRAINING PROGRAMS AT THE UNIVERSITY OF LJUBLJANA

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Teachers need skills and knowledge to be effective in implementation of ICT enhanced teaching and learning in the informational age. The TPACK and SAMR models can be used to guide the planning, assessing, evaluating and use of technology in education. Thereby, the concept "TPACK + SAMR constructs" is used in order to address various combinations of TPACK and SAMR stages held by teachers. In order to support university teachers in using ICT in their teaching of prospective teachers the project "ICT in Teacher Training Study Programs at the University of Ljubljana" was launched from April 2017 to September 2018. The project involved 67 pilot-renewals, thereby 22 pilot-renewals in science teacher training programs, which are the focus of this article. The university teachers' reports about their pilot-renewals were analyzed with the focus on various kinds of ICT supported activities for prospective science teachers, that were imbedded in the implemented pilot-renewals. Pilot-renewals' reports were also examined about the levels of "TPACK + SAMR constructs" in ICT supported activities imbedded in the implemented pilot-renewals. The results indicate that most frequently used ICT supported activities were related to: (1) Presentations; (2) Laboratory experimental work; (3) Formative assessment and (4) Learning management system and materials. Additionally, it was found that university teachers most frequently planned their ICT supported activities on TCK-Augmentation level, which was included in more than half of analyzed pilot-renewals. The study provides inside into the state of art regarding the use of ICT in the teacher training study programs at the University of Ljubljana, Slovenia in science teaching area and points to the needs for further improvement and development possibilities in the future.

Keywords: ICT Enhanced Teaching and Learning, Initial Teacher Education, Science Education

THEORETICAL FRAMEWORK

Teachers need skills and knowledge to be effective in technology environments in order to design technology-rich learning experiences for students (Walser, 2008). The TPACK and SAMR models can be used to guide the planning, assessing, evaluating and use of technology in education (Jude, Kajura, & Birevu, 2014; Pamuk, 2012).

The TPACK encompasses the connections between teachers' Technological Knowledge (TK), Pedagogical Knowledge (PK) and Content Knowledge (CK) (Koehler & Mishra, 2009) and involves various interrelationships between its components (Chai, Koh, Tsai, et al., 2011) as presented in Figure 1.

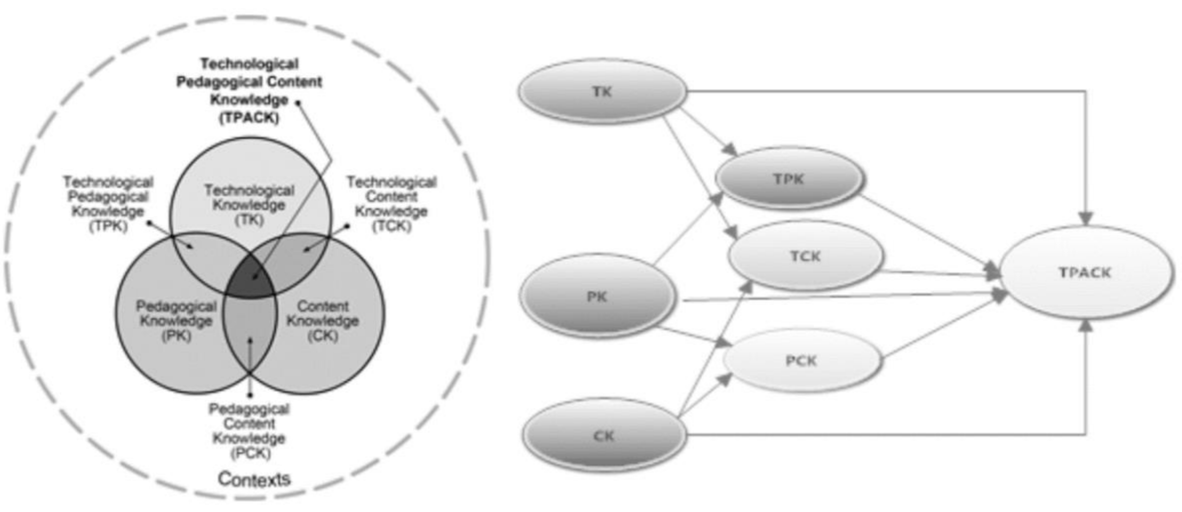

Figure 1. ***TPACK components and the structural model of interrelationships among TPACK components (Chai, Koh, Tsai, et al., 2011; Koehler & Mishra, 2009).***

On the other hand, the SAMR model is a tool for assessing and evaluating technology practices and their impacts in a classroom setting. It is divided into four different levels of classroom technology integration as seen from Figure 2: (1) Substitution (technology acts as a direct tool substitute, with no functional change); (2) Augmentation (Technology acts as a direct tool substitute, with functional improvement); (3) Modification (Technology allows for significant task redesign) and (4) Redefinition (Technology allows for the creation of new ideas) (Puentedura, 2013).

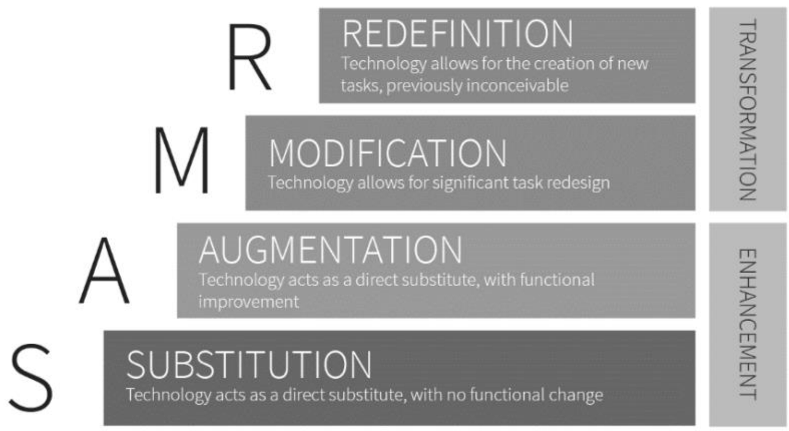

Figure 2. SAMR models levels as a tool for assessing and evaluating technology practices (Puentedura, 2013).

In order to facilitate the development of "TPACK and SAMR"- aware university teachers and assistants in science teaching, teacher training institutions must integrate relevant tools within the teacher training curriculum that considers a continuing change as a process (Thomas, Herring, Redmond, & Smaldino, 2013). Kihoza et al. (2016) introduced the concept "TPACK + SAMR constructs" in order to address various combinations of TPACK and SAMR constructs dealing with ICT implementations in the teaching process as planned by the teachers (Figure 3).

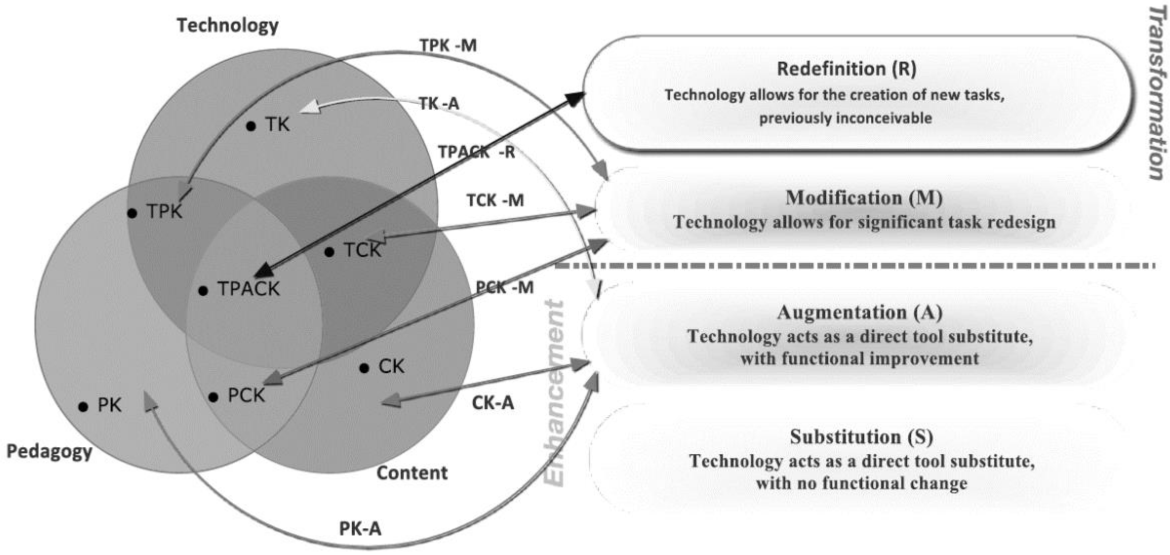

Figure 3. ***TPACK and SAMR models in correlation (*****Kihoza et al., 2016).**

The professional development of prospective teachers' related to the use of ICT during their study at the university is necessary for the successful implementation of the ICT-supported innovative approaches and effective teaching and learning in their prospective school practice.

To support the prospective teachers' development at University of Ljubljana, Slovenia, the project entitled "ICT in Teacher Training Study Programs at the University of Ljubljana" was launched from April 2017 to September 2018. The overall project included the renewal of 48 pedagogical study programs at the first and/or second Bologna levels at nine faculties of the University of Ljubljana. The involved pilot-renewals of the subjects/modules/programs based on the didactic implementations of ICT in the innovative teaching materials for students, the improvement of ICT-supported approaches to teaching and learning, and the development of pedagogical models.

AIM AND RESEARCH QUESTIONS

The main aim of this study was to investigate, which kinds of activities for prospective teachers the university teachers and assistants implemented in the pilot-renewals in science teaching area and on which level of "TPACK + SAMR constructs" were they.

With regard to this research aim, the following research questions (RQ) were defined:
(1st RQ) Which kinds of ICT supported activities for prospective science teachers were imbedded in the implemented pilot-renewals?

(2nd RQ) On which level of "TPACK + SAMR constructs" are the ICT supported activities for prospective science teachers imbedded in the implemented pilot-renewals?

RESEARCH METHOD AND DESIGN

Sample. The sample consisted of 25 university teachers and assistants in science teaching (12 female, 13 male) who participated in the developing pilot-renewals in the framework of the project entitled "ICT in Teacher Training Study Programs at the University of Ljubljana".

Pilot-renewals. 22 pilot-renewals in teacher training programs were implemented in the following subject-areas of the elementary and secondary prospective teachers´ education: Biology, Chemistry, Physics, and Science. All pilot-renewals took place in the study year 2017/18 at University of Ljubljana. The pilot-renewals included from 5 to 75 hours of upgraded activities, in each 10 to 87 prospective teachers (all together 673 prospective teachers) participated. Each of the pilot-renewals consisted of 1 to 7 new ICT-supported activities.

Data Collection. After the conclusion of the pilot-renewals, the university teachers and assistants filed out pilot-renewals reports. For the purpose of this paper, the following parts of the pilot-renewals reports are essential: descriptive data (course, study programme of prospective teachers, number of participating prospective teacher, range of upgraded activities) and content part of the report (purpose of the activities in pilot-renewal, description of the activities in pilot-renewal).

Data Analysis. In order to derive categorization of the implemented activities in the framework of pilot-renewals and “TPACK + SAMR constructs” of the implemented activities, pilot-renewals were analyzed based on Kihoza et al. (2016) categorization framework. The categorization was independently implemented by the two authors of the article with regard to the prevailing activity in particular parts of pilot-renewals. Each researcher independently grouped the characteristics into individual criteria. Finally, to reduce bias issues, through discussion, reconstruction and agreement, both researchers came to the final version of the rubric, which enabled a 95% inter-rater reliability about the categorisation of the analysed items.

FINDINGS

The analysis related to the ***1st research question*** (*Which kinds of ICT supported activities for prospective science teachers were imbedded in the implemented pilot-renewals?)* revealed that various kinds of ICT supported activities were included in implemented pilot-renewals by the university teachers and assistants in science teaching area, such as: Presentations; Laboratory experimental work; Formative assessment; Learning management systems and materials; Models, simulations and animations; Educational games; Data analysis; Project-based learning and Practical pedagogical training.

As can be seen from Table 1 most frequently used ICT supported activities for prospective teachers were related to: (1) Presentations (fa(%)=30.14, fa=22); (2) Laboratory experimental work (fa(%)=23.29, fa=17); (3) Formative assessment (fa(%)=17.81, fa=13) and (4) Learning management system and materials (fa(%)=13.70, fa=10).

Table 1. Description of prospective teacher's categories of activities related to the use of ICT.

Description of prospective teacher's activities related to the use of ICT	Activities	
	f_a	f_a [%]
PRESENTATIONS	22	30,14
LABORATORY EXPERIMENTAL WORK	17	23,29
FORMATIVE ASSESMENT	13	17,81
LEARNING MANAGEMENT SYSTEMS AND MATERIALS	10	13,70
MODELS, SIMULATIONS AND ANIMATIONS	6	8,22
EDUCATIONAL GAMES	2	2,74
DATA ANALYSIS	1	1,37
PROJECT-BASED LEARNING	1	1,37
PRACTICAL PEDAGOGICAL TRAINING	1	1,37

In activities related to ***Presentations***, the prospective teachers' observation of the use of presentational software (fa(%)=5.48, fa=4) and evaluation of various tools for preparation of concept maps (fa(%)=5.48, fa=4) prevailed as can be seen from Table 2.

Table 2. Description of students' activities in the category Presentations.

Description of students' activities	Activities		SAMR	TPACK + SAMR
	f_a	f_a [%]		
PRESENTATIONS	22	30,14		
Observation of the use of presentational software	4	5,48	A	TCK-A
Evaluation of tools for preparation of concept maps in specific topic	4	5,48	M	TCK-M
Use of presentational software	3	4,11	A	TCK-A
Development of meaningful implementation of specific software for representing partic. phenomena (e.g. animations)	2	2,74	R	TPACK-R
Development of meaningful impl. of QR-codes in specific topic	2	2,74	R	TPACK-R
Development of meaningful impl. of digital dichotomous identification keys	2	2,74	R	TPACK-R
Use of ICT in support of reporting about experimental work in specific topic	1	1,37	A	TCK-A
Evaluation of ICT in support of reporting about experimental work in specific topic	1	1,37	M	TCK-M
Observation of the use of videos for representing partic. phenomena	1	1,37	A	TCK-A
Evaluation of videos for representing partic. phenomena	1	1,37	M	TCK-M
Development of meaningful implementation of comic strips	1	1,37	R	TPACK-R

Most frequently implemented activities related to ***Laboratory experimental work*** was use of mobile application for capturing, presenting and analyzing experimental data (fa(%)=5.48, fa=4), further details are presented in Table 3.

Table 3. Description of students' activities in the category Laboratory experimental work.

Description of students' activities	Activities		SAMR	TPACK + SAMR
	f_a	f_a [%]		
LABORATORY EXPERIMENTAL WORK	17	23,29		
Use of mobile application for capturing, presenting and analysing experimental data	4	5,48	A	TCK-A
Use of sensors with software for capturing, presenting and analysing experimental data	3	4,11	A	TCK-A
Use of microscopy	2	2,74	A	TCK-A
Use of microscopy and presentation of results	2	2,74	A	TCK-A
Development of meaningful implementation of sensors with software for capturing, presenting and analysing experimental data	1	1,37	R	TPACK-R
Observation of the use of sensors with software for capturing, presenting and analysing experimental data	1	1,37	A	TCK-A
Evaluation of mobile applications for capturing, presenting and analysing experimental data	1	1,37	M	TCK-M
Evaluation of various sensors and mobile applications for capturing, presenting and analysing experimental data	1	1,37	M	TCK-M
Observation of the use of microscopy	1	1,37	A	TCK_A
Evaluation of sensors with software for capturing, presenting and analysing experimental data	1	1,37	M	TCK-M

As can be seen from Table 4, the the highest proportion of implemented activities related to ***Formative assessment*** achieved prospective teachers' observation of the use of response systems (fa(%)=13.70, fa=10). Within activities using Learning management system and materials, use of learning management system prevailed (fa(%)=8.22, fa=6).

Table 4. Description of students' activities in the category Formative assessment.

Description of students' activities	Activities		SAMR	TPACK + SAMR
	f_a	f_a [%]		
FORMATIVE ASSESMENT	13	17,81		
Observation of the use of response systems	10	13,7	A	TCK-A
Evaluation of response systems	1	1,37	M	TCK-M
Development of meaningful implementation of response systems	2	2,74	R	TPACK-R
LEARNING MANAGEMENT SYSTEM AND MATERIALS	10	13,7		
Use of learning management system	6	8,22	A	TCK-A
Observation of the use of collection of learning materials for representing particular phenomena	2	2,74	A	TCK-A
Observation of the use of ICT in support of active learning	1	1,37	A	TCK-A
Use of ICT in support of active learning	1	1,37	A	TCK-A
MODELS, SIMULATIONS AND ANIMATIONS	6	8,22		
Observation of the use of specific software for representing particular phenomena	5	6,85	A	TCK-A
Use of specific software for representing particular phenomena	1	1,37	A	TCK-A

From Table 4, it can also be seen that specific activities related to ***Models, simulations and animations***, were used, e.g. more specifically, prospective teachers' observation of the use of presentational software for represented particular phenomena (fa(%)=6.85, fa=5). Beside the mention activities, there are also several other activities that occurred in low frequencies.

The analysis related to the ***2nd research question*** (*On which level of "TPACK + SAMR constructs" are the ICT supported activities for prospective science teachers imbedded in the implemented pilot-renewals?*) revealed that different "TPACK + SAMR constructs" were included in implemented pilot-renewals by the university teachers and assistants in science teaching area, which is presented in Table 5.

Table 5. The proportion of different "TPACK + SAMR constructs" in science teaching pilot-renewals.

TPACK + SAMR constructs		Activities		Pilot-renewals	
TPACK	SAMR level	f_a	f_a [%]	f_{pr}	f_{pr} [%]
Technological knowledge (TK)	Substitution (S)	0	0	0	0
	Augmentation (A)	0	0	0	0
	Modification (M)	0	0	0	0
	Redefinition (R)	0	0	0	0
Technological content knowledge (TCK)	Substitution (S)	10	13,70	7	31,82
	Augmentation (A)	30	41,10	13	59,09
	Modification (M)	8	10,96	6	27,27
	Redefinition (R)	1	1,37	1	4,55
Technological pedagogical knowledge (TPK)	Substitution (S)	0	0	0	0
	Augmentation (A)	0	0	0	0
	Modification (M)	0	0	0	0
	Redefinition (R)	0	0	0	0
Technological Pedagogical content knowledge (TPACK)	Substitution (S)	0	0	0	0
	Augmentation (A)	0	0	0	0
	Modification (M)	12	16,44	9	40,91
	Redefinition (R)	12	16,44	8	36,36

Most frequently used ICT supported activities for prospective teachers were on TCK-A level (fa(%)=41.10, fa=30), which were included in more than half of pilot-renewals (fpr(%)=59.09, fpr=13). More advanced ICT supported activities for prospective teachers on TPACK – M level (fa(%)=16.44, fa=12) and TPACK – R level (fa(%)=16.44, fa=12) followed, and were implemented in more than one third of the pilot renewals (fpr(%)=40.91, fpr=9; fpr(%)=36.36, fpr=8), which is a good starting point to be encouraged.

About one third of the pilot renewals (fpr(%)=31.82, fpr=7; fpr(%)=27.27, fpr=6) implemented ICT supported activities for prospective teachers on TCK-S level (fa(%)=13.70, fa=10) and TCK-M level (fa(%)=10.96, fa=8), whereas it is interesting that was no activity in any pilot-renewal categorized as an activity on the TK–S/A/M/R levels, TPK–S/A/M/R levels and TPACK–S/A levels.

DISCUSSION OF FINDINGS AND IMPLICATIONS

ICT enhanced teaching and learning is crucial part of preservice science teachers' training in the informational age. The most frequently used models for guiding the planning, assessing, evaluating and use of technology in education are TPACK and SAMR models.

22 pilot-renewals in science teacher training programs at University of Ljubljana, Slovenia, where studied from two perspectives: (1) kinds of ICT supported activities, (2) levels of “TPACK + SAMR constructs” in ICT supported activities.

It was found that the most frequently used ICT supported activities were presentations, laboratory experimental work, formative assessment, learning management system and materials.

In Kihoza’s model targeting TPACK and SAMR correlation, only one construct has been proposed for each of the TPACK component (e.g. TK-A, CK-A, PK-A TPK-M, TCK-M, PCK-M, TPACK-R). Our research has indicated that several construct for some of the TPACK components are needed, namely more than half of analyzed pilot-renewals of the university teachers implemented ICT supported activities on TCK-Augmentation level, also about one third of the pilot renewals addressed TCK-S level and TCK-M levels. Similarly, TPACK-M and TPACK-R levels were present in more than one third of the pilot renewals.

We are glad to find out that TPACK-Modification and TPACK-redefinition levels were present in notable proportion of the pilot-renewals in the framework of the project entitled "ICT in Teacher Training Study Programs at the University of Ljubljana" were identified. The last can be used as examples of good practice for the further development in the teacher training study programs in science teaching and with other international projects point to development possibilities in the future.

REFERENCES

Chai, C. S., Koh, J. H. L., & Tsai, C. C. (2011). Exploring the factor structure of the constructs of technological, pedagogical, content knowledge (TPACK). *The Asia-Pacific Education Researcher*, *20*(3), 595-603.

Jude, L. T., Kajura, M. A., & Birevu, M. P. (2014). Adoption of the SAMR model to asses ICT pedagogical adoption: A case of Makerere University. *International Journal of e-Education, e-Business, e-Management and e-Learning*, *4*(2), 106.

Kihoza, P., Zlotnikova, I., Bada, J., & Kalegele, K. (2016). Classroom ICT integration in Tanzania: Opportunities and challenges from the perspectives of TPACK and SAMR models. *International Journal of Education and Development Using Information and Communication Technology*, *12*(1), 107-128.

Koehler, M., & Mishra, P. (2009). What is technological pedagogical content knowledge (TPACK)? *Contemporary issues in technology and teacher education*, *9*(1), 60-70.

Pamuk, S. (2012). Understanding preservice teachers' technology use through TPACK framework. *Journal of Computer Assisted Learning*, *28*(5), 425-439.

Puentedura, R. R. (2006). SAMR: Getting to Transformation [Web log post]. Retrieved from http://www.hippasus.com/rrpweblog/archives/2013/04/16/SAMRGettingToTransformation.pdf

Thomas, T., Herring, M., Redmond, P., & Smaldino, S. (2013). Leading change and innovation in teacher preparation: A blueprint for developing TPACK ready teacher candidates. *TechTrends*, *57*(5), 55-63.

Walser, N. (2008). Teaching 21st century skills. *Harvard Education Letter*, *24*(5), 1-3.

ACKNOWLEDGEMENT

The authors would like to acknowledge to the project “ICT in Teacher Training Study Programs at the University of Ljubljana”, which was co-financed by the Republic of Slovenia and EU from the European Social Funds."

TEACHER EDUCATION IN QUANTUM PHYSICS – A PROPOSAL FOR IMPROVING PEDAGOGICAL CONTENT KNOWLEDGE

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Quantum physics is an important topic for physics courses at high school. In recent times big advances in the field of quantum information require corresponding modern approaches. Therefore preparation of teachers has to be adapted in developing systematically content (CK) and pedagogical content knowledge (PCK). Therefore, a seminar supplementing the quantum physics education of teacher students from an educational perspective has been developed along the model of educational reconstruction on university level. It was evaluated by a questionnaire with closed and open items and concept maps in a pre-post design with control group. The participating students showed a strong increase in CK and PCK where especially weak students profited strongly. The concept maps showed a clear shift in the desired direction and understanding of concepts. However, only a few students used the modern approach in their lesson plans.

Keywords: Quantum physics, teacher education, educational reconstruction

INTRODUCTION

In the 21st century physics education at high school is not complete without an insight into quantum physics. This includes nowadays also an introduction into the basics of quantum information as this area will influence future technologies and as corresponding reports find their way into the media. As future citizens all students should be able to value adequately media reports on advances in quantum technologies. In order to be able to do so a basic understanding of the principles of quantum physics and insight into quantum information is necessary. In addition differences between quantum physics and classical physics contribute to building a modern physics world view as part of general education.

Therefore, teaching topics of quantum physics in a way that promotes understanding of its basic concepts requires careful alignment of theoretical aspects and experiments as well as appropriate teaching methods. In the last years the two state-systems approach gained importance for teaching. There are hints that e. g. the concepts of a quantum state or uncertainty are better understood with this approach than with teaching along more traditional lines (Sadaghiani 2016, Zuccarini 2014). In order to reach a twofold goal – understanding the core concepts and insight into quantum information – teachers are needed who are able and willing to enter new ways of teaching on different levels. This requires a suitable preparation of future and in-service teachers which is not given in general. The prerequisites are that the teachers master the basics of quantum physics – including mathematical formalism – and that they feel prepared to transfer their knowledge into the classroom. Therefore they schould be able to explain quantum physics in an understandable way to school students including visual as well as formal means. This is the more important as the situation of teaching quantum physics is special in that there is a big gap between the complexity of the teaching level at university and the possibilities of teaching at school. Therefore the university teaching has to be adapted to the needs of future teachers, meaning that pedagogical content knowledge (PCK) in connection with content knowledge (CK) has to be developed systematically. Without explicit reflection on practice most teachers structure their lessons based on their own experience from school and their study at university. Hence, special attention has to be given to the goal that future teachers know different approaches and teaching-learning sequences such that they are able to develop appropriate teaching pathways according to modern view points. As they often rely on the obligatory school curriculum they should know how the different building blocks – the basic concepts, the traditional contents and modern contents – interplay and how they can combine different aspects.

EDUCATIONAL RECONSTRUCTION IN UNIVERSITY CONTEXT

In the following we will first shortly describe our use of the model of educational reconstruction in the context of university for this purpose.

Development of pedagogical content knowledge (PCK)

According to Shulman "PCK represents the blending of content and pedagogy into an understanding of how particular topics, problems, or issues are organized, represented, and adapted to the diverse interests and abilities of learners, and presented for instruction" (Shulman, 1987, S.8). Recently, Riese (2012) has shown that using a standard teaching procedure is correlated with a low level of expertise of teachers. Borowski et al (2011) hints that teachers develop school-relevant expertise mainly by actual responsible teaching in developing scripts for the topic at hand. Nevertheless, the earliest possible promotion of content knowledge (CK) and PCK is necessary, i. e. already during university studies. Reinhold (2004, p.134) cites as goals for the competence development "A curriculum for pedagogical content knowledge in the first phase of teacher training would then include basic, well-structured and connected knowledge at the levels of content knowledge/ reflection/ communication/ judgement and examplary knowledge at the levels of analysis and assessment/ planning/ testing/ evaluation". According to van Dijk and Kattmann (2007), PCK is individual and cannot be passed on directly from an expert to a novice, because teaching experience is essential for its development (Borowski et al 2011). However, own experiences as a teacher student at university are not enough, only the own teaching experience makes the difference. From this van Dijk and Kattmann (2007) conclude that PCK is acquired in an obligatory teacher training designed to enable novices and experienced teachers to learn from their experiences. One possibility of gaining such experiences is for example the theory-based independent development of a teaching-learning-sequence and its discussion. The teacher preparation at university should provide such learning environments.

Educational reconstruction for teacher education in quantum physics

To develop a learning environment at univeristy suitable for future teachers an extension of the model of educational reconstruction was developed, the so-called PCK-S (PCK in studies). It includes expertise in the design of learning environments, the associated analysis of student perceptions and the professional knowledge that teachers acquire during their individual teaching experience in the classroom. It is described as: „The educational ideas, [..] the field within educational research that focuses its research on the PCK that teachers possess, are different from teachers' PCK since they are extracted from their context: the knowledge, beliefs and experiences of the individual teacher."(van Dijk&Kattmann 2007, p.893). PCK-S represents a reconstruction and thus generalization of individual teaching practice and serves to develop new learning environments, which can be adapted for other teachers. van Dijk&Kattmann (2007, p.895) express: "PCK-S influence the design process if the teacher has acquired, during his or her teaching career, ways to present the subject knowledge in a for students understandable way. The results of this research process can then be used to improve teacher education.". This model has been adapted to quantum physics (see figure 1).

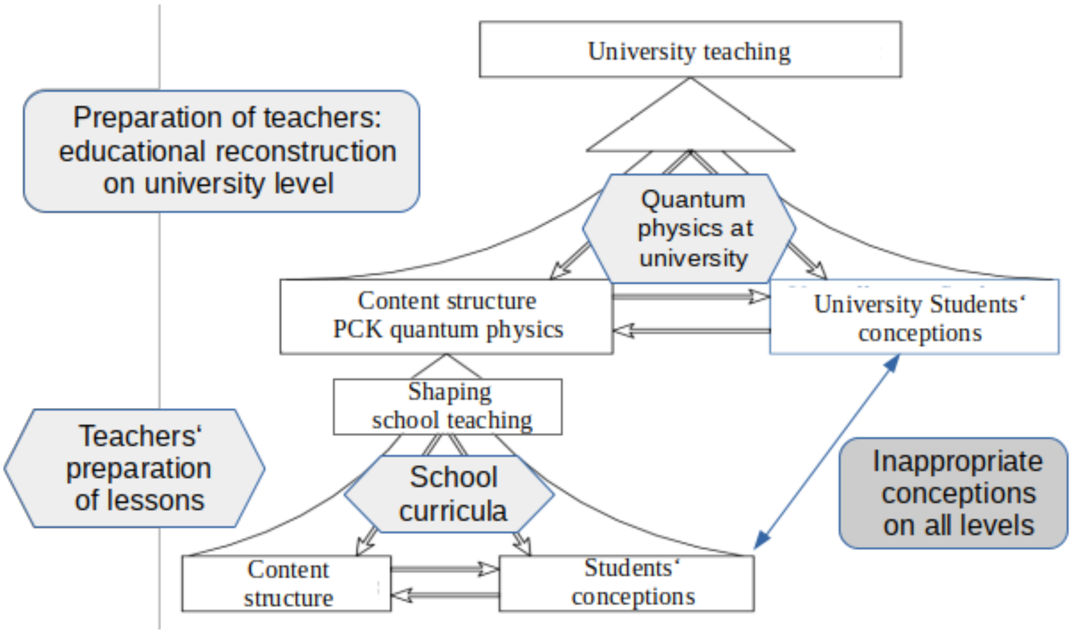

Figure 1. The model of educational reconstruction adapted for teacher education at university according to van Dijk and Kattmann, specified for teacher education in quantum physics

Quantum physics is a particularly demanding subject in teacher education with many problems on the way. First of all the abstract formalism of quantum physics together with the conceptual differences to classical physics requires a special preparation of the future teachers in order that they see possible elementarizations. Furthermore there is a nearly complete absence of real experiments suitable for school which may be a hindrance for many teachers who prefer teaching by visualizing with experiments. In addition there are strong teaching traditions (mainly the position first approach) with formal difficulties influencing teachers in their perception of the complexity of quantum physics. The new developments in quantum information and the two state systems approach are still often unknown to teacher students and have to be made explicit to them together with concrete teaching proposals. These should focus on central concepts: superposition, uncertainty, entanglement and the measuring process. An university course for teachers should therefore combine content knowledge, discussion of concepts to enhance PCK and the own development of teaching-learning sequences.

Analysis of content structure

The analysis of content as part of educational reconstruction serves to identify essential concepts with general educational value and high connectivity. Quantum physics is the only subject area at school still in flux. Today, there are many experimental implementations of earlier thought experiments and new areas of application are being opened up. In addition, the philosophical debate on the interpretation of quantum physics is still ongoing. Both aspects are reflected in the different approaches and proposals for teaching currently discussed. There are the milq-concept by Müller & Wiesner (2008), the Dirac-concept by Michelini et al. (2000) and the proposals by Pospiech (2000) with a focus on quantum information aspects. All these proposals focus in different ways on interference, state, uncertainty/ complementarity and information, on entanglemant and analysis of measuring process as core concepts. These abstract concepts and the complex formalism of quantum physics requiring a high mathematical effort make it difficult to elementarize. Nevertheless, a reduction of the learning material is possible by restricting it to essential phenomena, model experiments and guiding principles. The emphasis of the main principles of quantum physics such as superposition, interference and probability describes a pathway to an elementarisation. The characteristics of quantum information make it comparably easy to develop corresponding teaching sequences. This is reflected in the fact that recently quantum information approaches slowly find their way into the physics textbooks on different levels.

Analysis of students' conceptions

In order to enable the didactic structuring appropriate for school teaching the students' ideas have to be taken into account. There has been a large number of studies of student conceptions of quantum physics since the beginning of the 1970s, mainly on high school level, although significantly less than for classical physics. These concentrate mainly on atomic ideas, but also investigate the photo- and Compton effect, the Franck-Hertz experiment and double-slit experiments. There are also investigations on more abstract concepts like inexistence of permanent localization, uncertainty, for the interpretation of probability and the concept of state. A very comprehensive overview is given by Schorn (2014, p.26ff). We here refer mainly to the conceptions found e. g. according to Kalkanis et al. (2003) as well as Müller and Wiesner (1998). In summary, it can be seen that students' ideas about quantum physics are often based on the assimilation of new concepts into the construct of classical physics, e. g. the ontological nature of quantum physical uncertainty is not recognized. Often students' alternative conceptions correspond to the still prevailing traditional approaches to teaching quantum physics. It turns out that similar problems affect university students (Müller and Wiesner, 1998).

In order to overcome these traditional views and teaching methods a seminar for university for future teachers should be developed and evaluated that provides them with the necessary PCK and makes additions to their CK together with broad possibilities of reflection and discussion of view points.

RESEARCH METHOD AND DESIGN

It was the goal of the study presented here to elicit the needs of teacher students regarding their education and preparation for teaching on the field of quantum physics. Building on the revealed drawbacks and students' needs a seminar was developed and evaluated that focused on strengthening the PCK in quantum physics building on existing content knowledge and focusing on the two-states approach and giving insight into quantum information.

Research Questions

The following research questions were formulated:

Q1 What requirements do students have regarding quantum physics education of future teachers?

Q2 What is the students' content and pedagogical content knowledge at the end of the theoretical training in quantum theory?

Q3 Is a supplementary seminar constructed along the lines of the educational reconstruction effective in terms of content and educational competences? Is an expansion of the students' conceptual understanding observed?

Starting point of development of seminar

To answer research question Q1 teacher students were asked which quantum physics topics they think appropriate for teaching at school. The study was performed by an on-line questionnaire, after piloting sent to universities throughout Germany who offer study courses for future physics teachers. This questionnaire aimed at revealing the expectations of students as well as their experiences in learning quantum physics (Schöne, 2017). Therefore students from their third year at university on answered. Overall 110 students took part in this survey. The focus was if they felt prepared for teaching quantum physics at school and which topics they saw as adequate for school teaching. This was not a representative study but its results served as hints to the students' thinking and development of CK and PCK and their needs with respect to the development of a suitable seminar. The results showed that students mostly orient themselves towards the content they themselves learned at school. They proved to be more skeptical towards new contents or very mathematical aspects. Among the new contents quantum cryptography and quantum computer seemed to be especially attractive to the students (Schöne 2017). Therefore these topics in combination with the two state approach should play a role in the seminar to be developed.

Content and Structure of Seminar

It was supposed that all the participating students had attended the regular lecture on quantum theory before, thus having good content knowledge. Therefore the seminar relied on three intertwined threads: First of all it could not be supposed that students knew the two-state-systems approach. Therefore this was introduced in a way that could more or less be used as a pathway in school teaching. A second important thread were different variants of the double slit experiment with different objects (photons, electrons, molecules), which way information, quantum eraser, interaction free measurement and delayed choice. In this context the Mach-Zehnder-Interferometer was used as central experimental device and it was emphasized that the two arms of the interferometer are comparable to the double slit. A small Mach-Zehnder-Interferometer was available for model experiments. The third thread contained a formal description of the quantum physical processes. The Dirac notation was introduced and related to the physical interpretation of the mathematical structures of quantum physics. In order to give the students the means for treating these concepts in lessons also different representations and metaphors for superposition, uncertainty and entanglement were presented in order to promote understanding (Pospiech 2019). The concepts were anchored in concrete visual experiences by model experiments using calcite crystals. A strong emphasis was laid on discussion of the meaning of the basic concepts superposition, uncertainty, entanglement and the measuring process.

In order to deepen the insights aspects of quantum information were treated as this topic is being researched intensely and quantum technologies are being developed at an increasing pace and rapidly gaining significance. In addition quantum information can show the quantum principles at work as e. g. uncertainty is relevant for quantum cryptography, entanglement for quantum teleportation and the characteristics of the measuring process are used for proving the non-cloning theorem (also requiring the formal description).

All these threads were taken together by continous activities of students who had ample opportunity for discussion. As part of explicitly teaching PCK the students studied and compared different approaches to teaching quantum physics at school, the use of different types of visualization and they reflected on metaphors. In order to increase the practical aspects an important part of the seminar was that the teacher students developed in group work an own sequence of a teaching unit and the corresponding lesson plans.

Research method

Research questions Q2 and Q3 were answered in a pre-post design together with a comparison between intervention and control group. Whereas the intervention group attended the described seminar voluntarily, the control group attended an obligatory lecture combined with a seminar about history of physics with focus on teaching the nature of physics. Both courses comprised about the same amount of time.

The instruments were a combined questionnaire of content knowledge and pedagogical conent knowledge based on existing instruments (Müller 2003, Riese 2009). The content knowledge was evaluated with one open item and eleven closed items and the PCK was tested with 7 open items (including vignettes). The evaluation of the open items was controlled by interraters with a very good agreement (82%).

In addition the students of the intervention group made concept maps from given concepts and prepositions. The concept maps were evaluated with respect to their centrality and the frequency of the words were compared.

RESULTS

The intervention group (N=25) and control group (N=11) were students in the 4th to 5th year of study. As expected all students had attended lectures on quantum theory before.

Characterization of participants

The results of the pretest showed that there were no significant differences between the intervention and control groups (research question Q2). From all participants four groups of students could be identified (cluster analysis with the Ward method): There was an overall high performing group (16 %) and equally a low performing group (16%). These had either very good or very weak results in both parts of the questionnaire. Also a big group with focus on pedagogical content (52%) was identified and a small group with a strength on theoretical aspects and weaknesses in dealing with students' ideas (16%) (Schöne 2017). This is in line with other studies showing that teacher students have quite a clear vision of their future profession and prefer study contents related to what they will need in teaching at school (Gramzow et al 2011).

Evaluation of the seminar

The main goal was to evaluate in which way the students' CK and PCK developed during the seminar (research question Q3). Starting from the initial situation the teacher students profited highly concerning their content knowledge in quantum physics (CK) and their PCK. The overall picture showed that the development of content knowledge was increasing in the intervention group and decreasing in the control group. The PCK developed positively in the intervention group as expected but the control group showed constant results (see figure 2).

A closer look showed that the change of knowledge depends on initial knowledge in the sense that weaker students profited more in both areas of professional knowledge (see figure 3). A regression analysis showed that the changes of CK or PCK can be explained best alone from the initial CK or PCK respectively. A test for interaction with the preknowledge in the other domain did not show a better explanation of the results.

Concept maps and students' teaching proposals

In order to analyse in more depth the knowledge acquisition and conceptual change processes the students should also make concept maps before and after the seminar. Concept maps serve as a predominantly qualitative survey instrument, but also can be evaluated quantitatively according to various structural parameters (Krüger et al 2014, p.331). The most important concepts and prepositions were collected in a pilot study, generalised and then given as material (state, wave function, preparation, position, momentum, photo effect, Compton effect, Mach-Zehnder-Interferometer, photon, electron, quantum object, superposition, uncertainty, uncertainty relation, entanglement, non localization) in the main study. This reduces the difficulty for participants and results in a better comparability of the maps (Ruiz-Primo&Shavelson 1996). The structure of the map itself was not specified, so that the task was of a half-open type. The concept maps were drawn on paper by the students.

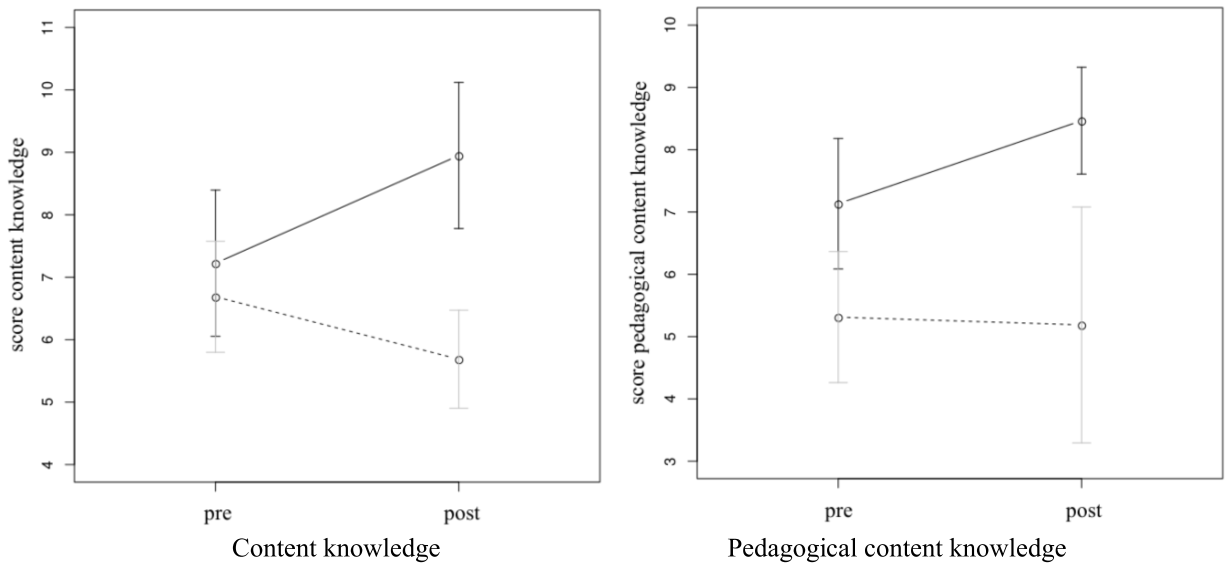

Figure 2. In the left part the development of the content knowledge from pretest to posttest of intervention and control groups is shown in an interaction plot; in the right plot similarly the development of the pedagogical content knowledge of both groups is shown. It is seen that the intervention group profits even in the content knowledge even if the main focus was on didactic aspects. In both graphs the solid line is the intervention group, the dotted line the control group (Schöne 2017).

An average map with weighted concepts and propositions was created from the individual maps. In the presentation we concentrate on the most central and frequent concepts. With several maps it can be observed that after the seminar quantum states are associated on shorter pathways with uncertainty and the newly appearing term "preparation". After the seminar the following observations are made: In some maps the terms uncertainty and uncertainty relation are distinguished. On average, in the intervention group new concepts, such as the experiment with the Mach-Zehnder interferometer were added. In some maps, the superposition and the wave function are included. Photons and electrons are used as examples of more generally perceived quantum objects. The concept of quantum object becomes much more central and thus more interconnected. Position and momentum as properties of quantum objects only appear in some maps. Similarly, the idea of particles in the Compton and photo electric effect disappears in some maps. But the concepts of uncertainty and entanglement increased in importance. Globally, the agreement of the propositions and concepts in the pre- and post concept maps of the control group is significantly greater than in the intervention group (centrality and frequency). As a form of forgetting, the density in the concept maps decreases clearly more in the control group than in the intervention group, although this effect is not significant due to the small sample size (not all students created two concept maps). These results show that the seminar is able to change the students' cognitive structure.

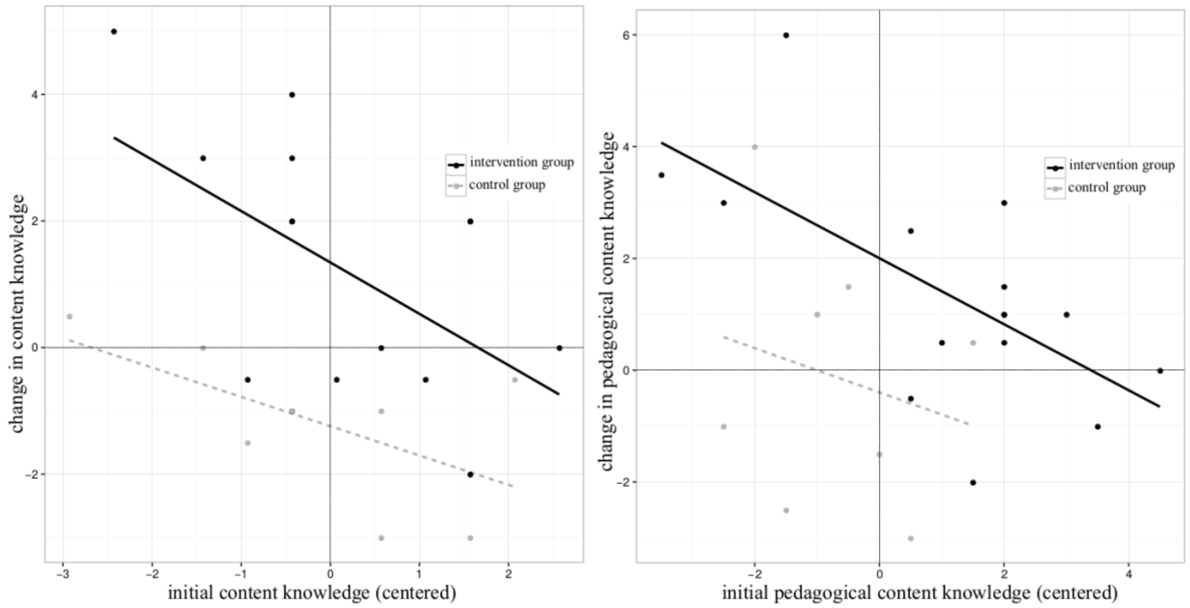

Figure 3. In the left graph the change of content knowledge in dependence on the pre knowledge for both groups is shown. It can be inferred that with lesser preknowledge the increase of CK is higher whereas with high preknowledge there is nearly no increase. A similar picture is seen in the PCK (right graph). This development is stronger visible with the intervention group. It is seen that in the intervention group especially the weaker students profited most from the seminar in both kinds of knowledge (Schöne 2017).

As a supplement, the frequency of concepts that stand out in the concept maps was analysed in the participants' lesson plans (intervention group). We only present the most obvious occurrences. The term "quantum object" appeared in almost all lesson plans. Also "preparation" is used by six participants, the wave function in five lesson plans and the differentiation of uncertainty and uncertainty relation is evident in seven teaching concepts. In these own lesson plans many students retreated to the "traditional" way of teaching. Only one teaching unit explicitly addressed quantum cryptography. This could be explained from several reasons: First the students felt at least partly obliged to follow the official curriculum of Saxony which up to now gives no explicit hint to quantum information. Secondly new material has to be internalized before it can be applied. Nevertheless, the students included partly newly learned material.

CONCLUSION

We might deduce from these findings that the approach of offering a seminar with focus on physics education aspects supplementing the lectures on quantum theory and stressing the connection of content and pedagogical content knowledge, enhances the students' content knowledge including quantum cryptography. Extended discussions of superposition, uncertainty and measuring process enables them to develop a deeper understanding of the concepts of quantum physics and to reduce misconceptions. However, the small number of participants requires careful interpretation of results. Nevertheless, such a seminar could contribute to the required special preparation: teacher students learn how to deal with the abstract formalism and to clarify the differences to classical physics.They are encouraged to overcome the strong teaching traditions in quantum physics and know possibilities of facilitating appropriate views by explicitly teaching the quantum perspective. Nevertheless, some of the developed lesson plans show that the future teachers may stay mixed between classical and quantum interpretation (Bailey&Finkelstein 2010). In this respect the seminar has to be optimized.

REFERENCES

Bailey, C., & Finkelstein, N. D. (2010). Teaching and understanding of quantum interpretations in modern physics courses. *Physical Review Special Topics-PER*, *6*(1), 010101.

Borowski, A., Kirschner, S., Liedtke, S., & Fischer, H. E. (2011). Vergleich des Fachwissens von Studierenden, Referendaren und Lehrenden in der Physik. *PhyDid A-Physik und Didaktik in Schule und Hochschule*, *1*(10), 01-09.

Krüger, D., Parchmann, I., & Schecker, H. (2014). *Methoden in der naturwissenschaftsdidaktischen Forschung*. Heidelberg:Springer.

Michelini, M., Santi, L., & Stefanel, A. (2008). Worksheets for pupils involvement in learning quantum mechanics. *Frontiers of Physics Education*, 102-111.

Müller, R. & Wiesner, H., (1998). Vorstellungen von Lehramtsstudenten zur Interpretation der Quantenmechanik - Ergebnisse von Befragungen. In H. Behrendt (Ed.), *Zur Didaktik der Physik und Chemie: Probleme und Perspektiven* (pp. 382-384). Alsbach: Leuchtturmverlag.

Müller, R. (2003). *Quantenphysik in der Schule*. Berlin:Logos-Verlag.

Pospiech, G. (2000). Uncertainty and complementarity: the heart of quantum physics. *Physics education*, *35*(6), 393.

Reinhold, P. (2004). Naturwissenschaftsdidaktische Forschung in der Lehrerausbildung. *Zeitschrift für Didaktik der Naturwissenschaften*, *10*, 117-145.

Riese, J. (2009). *Professionelles Wissen und professionelle Handlungskompetenz von (angehenden) Physiklehrkräften*. Berlin:Logos-Verlag.

Riese, J., & Reinhold, P. (2012). Die professionelle Kompetenz angehender Physiklehrkräfte in verschiedenen Ausbildungsformen. *Zeitschrift für Erziehungswissenschaft*, *15*(1), 111–143.

Ruiz-Primo, M. A., & Shavelson, R. J. (1996). Problems and issues in the use of concept maps in science assessment. *Journal of Research in Science Teaching, 33*(6), 569-600.

Sadaghiani, H. R., (2016). Spin First vs. Position First instructional approaches to teaching introductory quantum mechanics. In L. J. Dyan, Lin Ding & A.Traxler (Ed.), *2016 Physics Education Research Conference Proceedings* (S. 292–295). Compadre.

Schöne, M. (2017). *Die Verbesserung der Lehramtsausbildung in Quantenphysik* (Doctoral dissertation), TU Dresden, Dresden.

Shulman, L. (1987). Knowledge and teaching: Foundations of the new reform. *Harvard educational review*, *57*(1), 1-23.

Van Dijk, E. M., & Kattmann, U. (2007). A research model for the study of science teachers' PCK and improving teacher education. *Teaching and Teacher Education*, *23*(6), 885-897.

Zuccarini, G. (2014). Physics student ideas on quantum state and its formal representations. *Il Nuovo Cimento C*, *37*(4), 273–283.

POST GRADUATE CERTIFICATE IN EDUCATION STUDENTS' TOPIC SPECIFIC PEDAGOGICAL KNOWLEDGE (TSPCK) ON PARTICULATE NATURE OF MATTER

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The study investigates the development of Topic-Specific Pedagogical Content Knowledge (TSPCK) of 97 preservice teachers and how they transform their content knowledge (CK) of the particulate nature of matter into a teachable form, before and after engaging in teaching practice. TSPCK is PCK within a particular topic, is the result of integration of five well-defined interrelated constructs, namely the students' prior knowledge, curricular saliency, what makes a topic easy or difficult to understand, and representation and conceptual teaching strategies. These five components within a particular topic constitute TSPCK. Data was collected using validated instruments for TSPCK before and after teaching practice, as well as a determination of CK instrument after teaching. The findings show that pre-service teachers' TSPCK improved after teaching the topic on the particulate nature of matter during teaching practice. A significant improvement was observed on the following components of the TSPCK-identifying difficult topics and suggesting reasons why the topic was difficult to teach, curricular saliency and representation.

Keywords: particulate nature of matter, TSPCK, pre-service teachers

INTRODUCTION

Research shows that teachers' pedagogical content knowledge (PCK) and the ability to transform content knowledge for teaching, takes years of teaching experience to develop. Given the centrality of CK in PCK, it is self-evident that adequate science content knowledge (CK) is a prerequisite for PCK. The current study concerns a group of pre-service teachers training to teach natural sciences, a combination of four science disciplines, namely, physics, chemistry, earth sciences and life sciences. Most, if not all natural science teachers have insufficient CK in some or all of these disciplines (Davis, Petish, & Smithey, 2006). The pre-service teachers are in training to teach natural sciences but may not necessarily possess adequate prerequisite content knowledge. The requirements of the Post Graduate Certificate in Education (PGCE) programme assume that prospective teachers have acquired all necessary content knowledge to teach at lower grades in their undergraduate degrees. The students enrolled in the PGCE science programme need to have completed two first level courses in either physics, chemistry, life sciences or environmental sciences. As stated earlier, the natural sciences curriculum requires knowledge of several science disciplines, which is not necessarily the case for the pre-service teachers in this study. A particular challenge for the pre-service teachers in this study is their understanding of basic chemistry, in particular the particulate nature of matter, which is central to understanding topics that are more advanced. In this study, we investigate the ability of PGCE students to transform their CK of the particulate nature of matter to teaching practice.

Pedagogical Content Knowledge (PCK) formed the framework for the current study. According to Shulman (1986), PCK bridges the gap between the teachers' knowledge of the subject matter and the transformation of this knowledge into instructional form accessible to learners. It is thus an important component of teacher knowledge. According to Kind (2009), PCK has an elusive nature that is described as tacit and develops through practice. The tacit nature of PCK has led to debates on whether PCK is personal or canonical. Smith and Banilower (2015) claim that PCK exist both as personal and canonical and these feed into other forms in a cyclic manner. In this study, PCK is viewed as topic-specific. This study investigates the canonical PCK for the topic of the particulate nature of matter, known as Topic Specific PCK, or TSPCK, which is PCK within a particular topic (Mavhunga & Rollnick 2013). TSPCK constitutes of five well-defined components, namely students' prior knowledge, curricular saliency, perceptions about what makes a topic easy or difficult to understand, representations and conceptual teaching strategies, which work together when a topic is taught. The model in Figure 1 was chosen because it reflects all the Topic Specific PCK aspects.

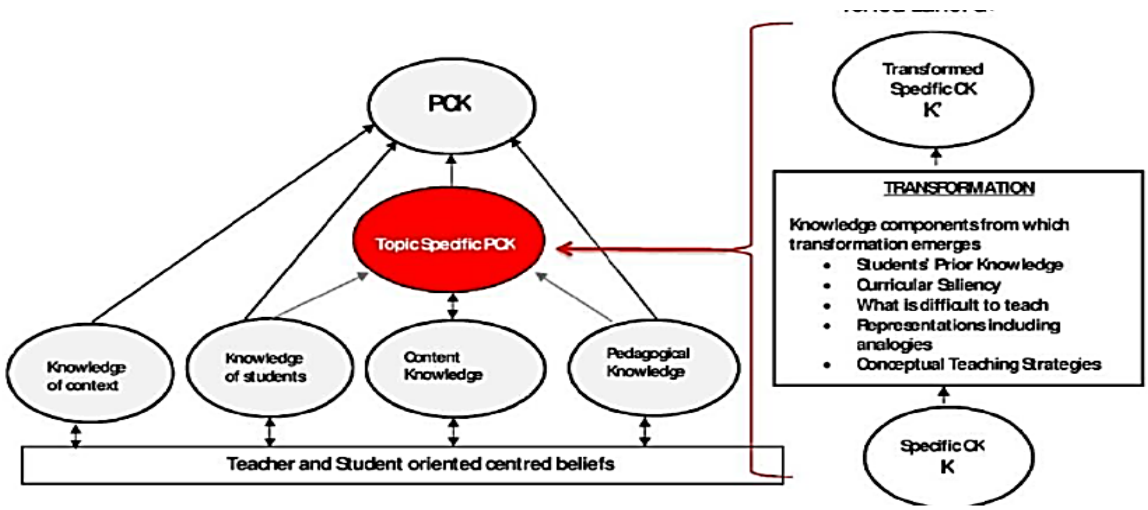

Figure 5: A model for Topic Specific PCK (Mavhunga & Rollnick 2013, p.115)

AIM OF THE STUDY

The aim of this study is to compare the change in TSPCK of PGCE students who taught the topic on the particulate nature of matter as part of their teaching experience with those who did not teach the topic. The paper answers the research question, how does the TSPCK of the particulate nature of matter differ between pre-service teachers who taught the topic to grade 8 and 9 students and those who did not?

METHOD

This paper reports on a mixed methods study located within a pragmatic paradigm (Creswell, 2014) with a group of PGCE students at a South African University. A mixed methods research, involves "mixing or combining quantitative and qualitative research techniques, methods, approaches, concepts or language into a single study" (Johnson & Onwuegbuzie, 2004, p. 17). In this study, priority of analysis was given to quantitative data (Benge, Onwuegbuzie, Burgess, & Mallette, 2010). The research strategy employed is a case study which targeted PGCE students. The PGCE is a one-year programme that consists of 16 weeks of direct teaching and additional 10 weeks in practice teaching.

The Sample

There were 97 PGCE students registered for the one-year PGCE programme at a South African university who completed both a TSPCK pretest and posttest on the topic of the particulate nature of matter. The study sample consisted of 38 male and 59 Female pre-service teachers.

Table 1. Shows the characteristics of participants

Characteristics	%
Grade 12 physics and chemistry	28
No University Chemistry	65
Taught particulate nature of matter in teaching practice	48

In Table 1, it evident that most of the participants did not study chemistry at the university, and only 28% of them had completed Grade 12 physics and chemistry.

DATA COLLECTION

Data was collected through validated instruments testing CK and TSPCK (Pitjeng-Mosabala & Rollnick, 2018). The CK instrument tested knowledge of content matter pertinent to the topic at grade 8 and 9 level while the TSPCK instrument was structured according to the five components of TSPCK, mentioned above. The TSPCK instrument used in this study was modified to suit the junior secondary level, relevant to the teaching of natural sciences. The instruments were administered to the pre-service teachers before and after teaching practice.
No specific instructions were given on the PCK course, but some students taught the topic during their teaching practice while others did not. The process by which they were assigned to teach the topic was determined by the schools where they were placed. Figure 2 below is an example of a TSPCK question, based on the Student Prior Knowledge component:

Water boiling in a kettle

2. When learners were asked to observe and describe what the bubbles are made of when the water in a kettle is boiling, Lwando gave the following written response:

There are large bubbles in the water and these bubbles were made of hydrogen and oxygen because water breaks when boiling to form hydrogen and oxygen.

What response would you write on her script?

Figure 3: Sample Question, Learner prior knowledge (LPK2)

DATA ANALYSIS

The responses to the TSPCK questionnaire were captured on an excel spreadsheet and coded using a validated TSPCK rubric as being limited, (1) basic, (2) developing (3) or exemplary (4). The coded data was analysed using Rasch analysis and the RUMM2030 programme (Andrich, Sheridan, & Luo, 2011).

A one-way analysis of variance available within the RUMM programme was used to establish if there was significant difference between the group of student teachers who taught aspects of the topic on the particulate nature of matter and those who did not. The responses were also analysed qualitatively in order to get an insight into the TSPCK development of PGCE student teachers on the particulate nature of matter.

RESULTS

The ratings determined by the rubric referred to above were checked using inter rater reliability. A posttest was administered to students when they returned from the school teaching experience to compare the performance of those who had taught the topic with those who had not. Racking of the pretest and posttest (labelling equivalent posttest items to their pretest items) was used in order to show the impact of the intervention (teaching experience). Item analysis for pretest and posttest results are shown in Figure 1.

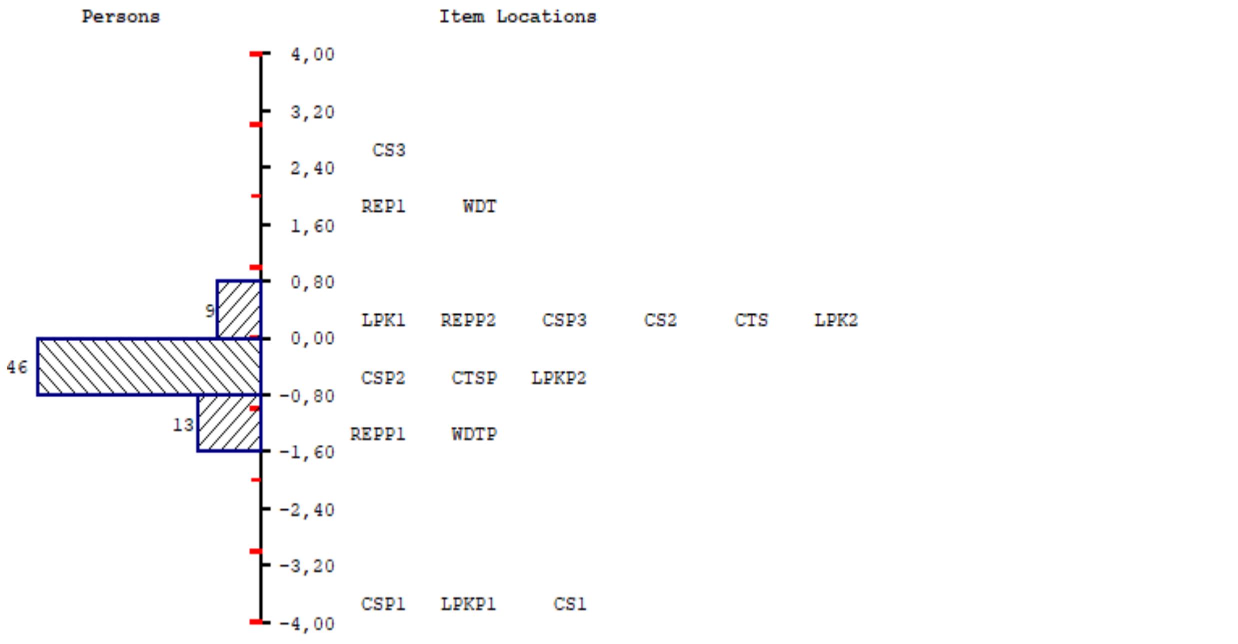

Figure 2: Item-person map of pretest and posttest TSPCK. TSPCK components are abbreviated as follows: CS1, CS2, CS3: curricular saliency, LPK1, LPK2: learners' prior knowledge, REP1, REP2: representations, WDT: What is difficult to teach and CTS: conceptual teaching strategies.

In Figure 1, the Rasch model provided an ordering of the TSPCK items from least to most difficult and this can provide an insight in how PGCE student teachers develop TSPCK in particulate nature of matter. The additional "P" on items identifies an item as a posttest item, for example, the posttest item corresponding to REP1 is REPP1. A comparison between pretest and posttest ranking of items show that CS3 was the most difficult item and three items, CSP1, LPKP1 and CS1 were equally ranked as the easiest items.

When looking at pretest items and their corresponding posttest items, it can be observed that several posttest items were ranked easier than their pretest counterparts (most notably CS3 to CSP3, REP1 to REPP1 and WDT to WTTP). In fact in no case was a posttest item ranked more difficult than a pretest item, demonstrating that the test as a whole was experienced by the PGCE students as easier than the pretest. This finding is confirmed in table 2.

Table 2. One-way Analysis of Variance comparison of those who taught Particulate Nature of Matter to those who did not

Source	Sum of square	df	Mean Square	F	Probability
Between Groups	34,1	1	34,1	90,60889	0,00001
Withon Groups	35,76	95	0,38		
Total	69,86	96			

The one-way ANOVA results show that there was a significant effect between TSPCK and teaching particulate nature of matter during teaching practice ($p < 0.05$) on the development of PCK of pre-service teachers.

There was no significantly link ($p > 0.05$) on completing physics and chemistry in matric, university chemistry course and the development of pre-service teachers PCK.

Qualitative analysis- Learner prior knowledge (LPK2)

Given below are extracts from written responses for both pretest and posttest of five participants.

Table 3.Selected Pre-service teachers' responses on learner prior knowledge question for pretest and post test

Student teacher	Coding Pretest	Responses LPK2 Pretest	Coding Post test	Responses LPK2 Posttest
1.	Limited[1]	It is the bond that joins hydrogen and oxygen that breaks not water. And the evaporation takes place as liquid water changes into gaseous state.	Basic [2]	As water is heated, it changes its form from liquid state to gaseous state. The molecules become loosely packed and bubbles are formed
2	Limited [1]	When the kettle is boiling the substance which is liquid will become gas	Basic[2]	Because the substance is heated the particles gain more kinetic energy, the bonds between particles has become more and more weaker and force of attraction between particles is not present, particle are moving freely from each other
4	Limited[1]	During boiling water is transformed to gas water. Hydrogen and oxygen break and escape as gas H_2.	Developing[3]	When the water molecule gain energy or when the heat is increased, the water molecule gain kinetic energy to overcome the intermolecular forces between them and the molecules move apart changing from liquid phase to gaseous phase
5	Limited[1]	As the water boils, it changes state from liquid to gas rather than a chemical change.	Limited[1]	I would mark her response as correct. However, I would encourage the learner to use scientific terms e.g. When water (H_2O) boils the hydrogen and oxygen covalent bond weakens as the molecules gets kinetic energy. When bonds have weakened, hydrogen and oxygen (no longer covalent bonded) escape to form the observed bubbles.
10	Limited[1]	When water boils, there is a change of state from a liquid to a gas bonds between H_2O breaks to release O_2 and H_2.	Developing[3]	The bubbles there are formed by the change of phase from liquid to gas through heating. There is kinetic energy among the particles and there is boiling which leads to evaporation which means the arrangement of particles move from liquid to gas. The bonds between particles have weakened.

These extracts display evidence of some level of PCK development in the responses of pre-service teachers' on learners' prior knowledge. Only participant 5 provides a response that is in line with the question provided in the instrument, "What response would you write on his script?" The explanation provided by Participant 5 does not illustrate an understanding of any aspects of TSPCK. Participant 10 does demonstrate an understanding of the representation of particles and the role played by kinetic energy.

DISCUSSION AND CONCLUSIONS

The TSPCK knowledge of PGCE natural science students show a level of improvement on TSPCK item on learner prior knowledge (LPK2, Curriculum salience (CS3), Representation (RP2) and conceptual teaching strategies (CST1). The findings also show that there was significant difference ($p < 0.05$) between TSPCK and teaching the particulate nature of matter during teaching practice. These findings which are similar to those of Pitjeng-Mosabala and Rollnick (2018) for a smaller sample of PGCE Teach SA candidates suggests that the experience of teaching a topic at grade 8 has a positive effect on TSPCK. However, the teachers in the above study did undergo a short intervention on a PCK course. The PGCE natural science teachers in the current study experience an intervention in the form of teaching the particulate nature of matter to grade 8 and 9 pupils in schools. There is thus reason to expect better scores in the teachers who have taught the topic (Kind, 2009).

This paper has demonstrated that teaching the topic particulate nature of matter at schools resulted in the improvement of pre-service teachers' TSPCK. The findings show that there was a significant link in the quality of TSPCK development in those who taught the particulate nature of matter in schools ($p = < 0.05$). The implication is that PGCE natural science programmes need to provide pre-service teachers with a platform to practice teaching different topics taught in grades 8 and 9.

Acknowledgement

The national Research Foundation supported this work.

REFERENCES

Andrich, D., Sheridan, B., & Luo, G. (2011). RUMM2030 software and manuals. Perth, Australia: University of Western Australia. In.

Benge, C., Onwuegbuzie, A.J., Mallette, M.H., & Burgess, M.L. (2010). Doctoral students' perceptions of barriers to reading empirical literature: A mixed analysis. International Journal of Doctoral Studies, 5, 55-77.

Creswell, J. W. (2014). A concise introduction to mixed methods research: Sage Publications

Davis, E. A., Petish, D., & Smithey, J. (2006). Challenges new science teachers' face. Review of Educational Research, 76(4), 607-651

Johnson, R. B., & Onwuegbuzie, A. J. (2004). Mixed methods research: A research paradigm whose time has come? Educational Researcher, 33(7), 14-26. doi: 10.3102/0013189X033007014, http://dx.doi.org/10.3102/0013189X033007014

Kind, V. (2009). Pedagogical content knowledge in science education: perspectives and potential for progress. Studies in Science Education, 45(2), 169-204

Mavhunga, E., & Rollnick, M. (2013). Improving PCK of chemical equilibrium in pre-service teachers. African Journal of Research in Mathematics, Science and Technology Education, 17(1-2), 113-125. doi:http://dx.doi.org/10.1080/10288457.2013.828406

Pitjeng-Mosabala, P., & Rollnick, M. (2018). Exploring the development of novice unqualified graduate teachers' topic-specific PCK in teaching the particulate nature of matter in South Africa's classrooms. International Journal of Science Education, 40(7), 742-770. doi:10.1080/09500693.2018.1446569

Shulman, L. S. (1986). Those who understand: knowledge growth in teaching. Educational Researcher, 15(2), 4-14.

Smith, P. S., & Banilower, E. R. (2015). Assessing PCK: A new application of the uncertainty principle. Re-examining pedagogical content knowledge in science education. In A. Berry, P. Friedrichsen, & J. Loughran (Eds.), Re-examining pedagogical content knowledge in science education (pp. 88–103). New York, NY: Routledge.

DEVELOPMENT OF PRE-SERVICE CHEMISTRY TEACHERS' TECHNOLOGICAL PEDAGOGICAL CONTENT KNOWLEDGE

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This study reports the empirical findings of a study that by collecting evidence on the pre-service chemistry teachers' Technological Pedagogical Content Knowledge (TPACK); and correspondingly the effectiveness of a course on the pre-service chemistry teachers' technological pedagogical content knowledge in terms of gender. The course consisted of 14 two class-hour weekly lectures and 13 two class-hour weekly laboratories with 17 pre-service chemistry teachers. The instructor taught explicitly using rich examples from the secondary school chemistry curriculum. During laboratories sections, the pre-service chemistry teachers discussed the pros and cons of the educational technologies in designing lessons in terms of chemistry, teaching strategies, prerequisite knowledge, and alternative conceptions. The instrument was used (in two periods: at the beginning and at the end of the semester) in the study to assess the pre-service teachers' TPACK domains and to measure their development of TPACK over the course of a semester. A mixed between-within subjects analysis of variance analysis was used and it was found that there was a significant main effect for TPACK. The findings of this study revealed that all components improved, indicating the pre-service chemistry teachers' technology content knowledge developed during the semester. Based on these findings, the development of pre-service and in-service chemistry teachers' TPACK is essential for teaching and learning chemistry and teachers should realize the potential of technology in the real-world classroom environment.

Keywords: Technological pedagogical content knowledge (TPACK); Pre-service teachers, Chemistry education

INTRODUCTION

As technology rapidly improves, classrooms are equipped with lots of technological tools (computers, projectors, tablets, etc.). If implemented properly, technology-supported instruction enhances students' learning and understanding (e.g., Dori & Belcher, 2005; Kim & Hannafin, 2011). However, it has been reported that teachers do not integrate technology frequently and efficiently in their classrooms (Bang & Luft, 2013; Harris, Mishra & Koehler, 2009; Kushner Benson, Ward, & Liang, 2015). Some studies (e.g., Angeli & Valanides, 2009; So & Kim, 2009) revealed that teachers had difficulties in integrating educational technologies (such as technological devices or software programs) into their classrooms, in particular in deciding the most appropriate tools for teaching effectively and enhancing student learning. Additionally, teachers sometimes fail to integrate technology effectively into their teaching because of a lack of pedagogical knowledge (Koh, Chai & Tsai, 2013; Kramarski & Michalsky, 2010).

Science issues, in particular chemistry concepts, generally deal with microscopic levels rather than macroscopic levels of perspective. Students often have difficulty understanding and visualizing microscopic concepts such as atoms, molecules, or chemical reactions. Educational technologies such as animations and simulations are quite helpful in visualizing these concepts; chemistry teachers who integrate those educational technologies into the teaching and learning process may support effective learning (Moore, Herzog, & Perkins, 2013; Ryan, 2013). For effective technology integration in instruction, knowledge about technology is not enough; teachers should have different knowledge types content, pedagogical, and technology as well as the ability to integrate these knowledge types (Mishra & Koehler, 2006; Koehler & Mishra, 2009). A technological pedagogical content knowledge (TPACK) framework that explains these knowledge types has been suggested as a requirement for effective technology integration (Mishra & Koehler, 2006). Similarly, in order to graduate pre-service chemistry teachers who use technology effectively in their future instruction, TPACK is essential. Hence, this study examined an intervention implemented to develop the TPACK of pre-service chemistry teachers in a university. The intention is to provide an answer to the question of whether there was a difference between the pre-service chemistry teachers' TPACK was at the beginning of the semester before the course related to educational and instructional technologies and at the end of the semester in terms of gender.

Therefore, the purpose of this study was to:

- trace the development of pre-service chemistry teachers' technological pedagogical content knowledge,
- examine an intervention implemented to develop the pre-service chemistry teachers' TPACK,
- explore whether gender was significant factor in TPACK development.

METHOD

This section consisted of four parts: participants, design of the study, instrument, and description of the instructional technology and material development course.

Participants

This study included 17 pre-service chemistry teachers from the Faculty of Education of a public university. All of the participants were from the department of chemistry education, in the eighth semester of a 10-semester chemistry education program, and they were all involved in the Instructional Technology and Material Development course. All participants in the current study had taken subject matter courses related to chemistry (e.g., General Chemistry, Analytical Chemistry, Organic Chemistry, and Physical Chemistry), general pedagogical courses (e.g., Introduction to Education, Curriculum, Measurement and Evaluation in Education), and subject-specific pedagogical courses (e.g., Theories and Approaches in Teaching and Learning, Methods of Chemistry Teaching) beforehand. Computers and projectors were available in all classroom environments in the university. These participants did not have any school experience in teaching.

Design of the Study

The one-group pretest-posttest design (Fraenkel & Wallen, 2011, p. 269) is used as an experimental design in this study (see Table 1 for research design details).

Table 1. Research Design.

Participants	Pre-test	Intervention	Post-test
Pre-service chemistry teachers	Pre-TPACK	The course related to educational and instructional technologies	Post-TPACK

Instrument

The pre-service Chemistry Teachers' Knowledge of Teaching and Technology Questionnaire (CTKTTQ) was administered in this study to evaluate the pre-service chemistry teachers' TPACK. This questionnaire was developed by Schmidt, Baran and Thompson (2009). The questionnaire covers seven components, which are technological knowledge (TK), content knowledge (CK), pedagogical knowledge (PK), pedagogical content knowledge (PCK), technological content knowledge (TCK), technological pedagogical knowledge (TPK), and technological pedagogical content knowledge (TPCK). However, in this study the items in the questionnaire were restricted to the chemistry discipline (see Table 2). There were 42 items, rated on a 5-point scale. The reliability of the instrument was calculated using Cronbach's alpha coefficient; the scores were .88 for the pre-TPACK and .92 for the post-TPACK.

Table 2. Sample Items for the Components of the TPACK.

Component	Sample Item
Technology Knowledge	I know how to solve my own technical problems.
Technology Content Knowledge	I know about technologies that I can use for understanding and doing chemistry.
Technology Pedagogical Knowledge	I can choose technologies that enhance students' learning for a lesson.
Technology Pedagogical Content Knowledge	I can teach lessons that appropriately combine chemistry, technologies, and teaching approaches.

Description of the Instructional Technology and Material Development Course

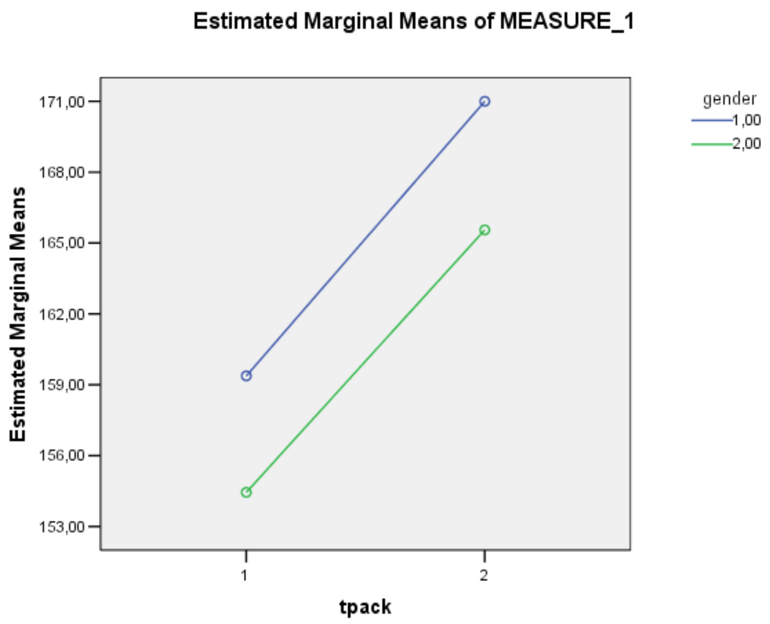
Pre-service chemistry teachers enrolled the Instructional Technology and Material Development (ITMD) course in their fourth year (eighth semester) of the five-year chemistry education program. The purpose of this course was to learn how to integrate simulations, animations, instructional games, data-logging, virtual labs and virtual field trip into chemistry instruction considering factors such as chemistry subjects and their students' possible alternative conceptions or previous chemistry knowledge. This course had two class hour-long theoretical sessions and two class hours-long laboratory sessions each week. While designing the ITMD course, constructivist learning approaches were taken into account in which pre-service chemistry teachers applied their new knowledge of each instructional technology, wrote reflection papers before and after introducing the instructional technology, discussed the importance of alternative conceptions and prerequisite knowledge in chemistry learning, implemented their own materials (such as educational games and posters) to the class, and designed lesson plans considering one of the instructional technologies.

RESULTS

A mixed between-within subjects analysis of variance (Pallant, 2007, p. 236) was conducted to assess the impact of gender on the pre-service chemistry teachers' TPACK across two periods (Table 3). The results indicated that there was no significant interaction between gender and TPACK, Wilks' Lambda= .987, $F(1,13)=.174$, $p=.684$, partial eta squared=.013. There was a substantial main effect for TPACK, Wilks' Lambda= .593, $F(1,13)=8.913$, $p<.05$, partial eta squared=.407; with female and male participants revealed an increase in their overall TPACK scores (see Graph 1).

Table 3. Descriptive Statistics for the TPACK in terms of Gender.

	Gender	Mean	Std. Deviation	N
Pre-total TPACK	1,00	159,3750	13,77303	8
	2,00	154,4444	11,81219	9
	Total	156,7647	12,61710	17
Post-total TPACK	1,00	171,0000	13,36306	8
	2,00	165,5556	6,28711	9
	Total	168,1176	10,28277	17



Graph 1. The change of pre-service teachers' TPACK in terms of gender.

When follow-up analysis was conducted for the components of TK, CK, PK, PCK, TCK, TPK, and TPCK (Table 4), the difference to reach statistical significance for main effects were CK, Wilks' Lambda=.620, F(1,15)=9.191, p=.008, partial eta squared=.380; PK, Wilks' Lambda=.366, F(1,15)=25.991, p=.000, partial eta squared=.634; PCK, Wilks' Lambda=.553, F(1,15)=12.124, p=.003, partial eta squared=.447; and TCK, Wilks' Lambda=.741, F(1,15)=5.251, p=.037, partial eta squared=.259. The largest effect was from PK, indicating approximately 63% of the variance in the pre-service chemistry teachers' TPACK was explained by pedagogical knowledge.

Table 4. Descriptive Statistics of TPACK and Its Components.

	Pre-statistics			Post-statistics		
Variables	Mean	Standard Deviation	Number	Mean	Standard Deviation	Number
TK	23. 94	4.19	17	25.53	3.10	17
CK	46.18	4.99	17	50.18	4.39	17
PK	23.94	3.23	17	28.23	2.19	17
PCK	10.53	1.50	17	11.82	1.24	17
TCK	11. 76	1.30	17	12.77	1.03	17
TPK	20.06	2.01	17	20.12	1.99	17
TPCK	19.77	2.68	17	20.47	1.55	17
Total score (TPACK)	156.81	13.03	17	168.12	10.62	17

DISCUSSION AND CONCLUSIONS

The findings of this study indicated that the pre-service chemistry teachers' TPACK developed and significantly improved during the course. During the semester, the pre-service chemistry teacher participants learned about different educational technologies, discussed how those technologies could be efficiently used during instruction, and applied these technologies during lab sessions. PK is deep knowledge about the processes and practices of teaching and learning, encompassing educational purposes, goals, values, strategies, and more. A teacher with deep PK understands how students construct knowledge and acquire skills in differentiated ways, as well as how they develop habits of mind and dispositions toward learning. PCK covers essential knowledge of teaching and learning content-based curricula, as well as assessment and reporting of that learning. An awareness of students' prior knowledge, alternative teaching strategies in a particular discipline, common content-related alternative conceptions, how to forge links and connections among different content-based ideas, and the flexibility that comes from exploring alternative ways of looking at the same idea or problem, and more, are all expressions of pedagogical content knowledge and are essential to effective teaching.

These discussions were held for each educational technology and they promoted the pre-service chemistry teachers' TPACK, giving them a better understanding of how to teach chemistry using educational technologies for varied chemistry concepts. Therefore, the pre-service chemistry teachers were able to understand the interaction of chemistry, pedagogy, and technology knowledge. These results are consisted with the studies of Koh and Chai (2014) or Li and Tsai (2013). Therefore, the development of pre-service and in-service chemistry teachers' TPACK is essential teachers should realize the potential of technology in the real-world classroom environment.

REFERENCES

Angeli, C., & Valanides, N. (2009). Epistemological and methodological issues for the conceptualization, development, and assessment of ICT-TPCK: advances in technological pedagogical content knowledge (TPCK). *Computers and Education*. 52, 154-168. doi:10.1016/j.compedu.2008.07.006

Bang, E. & Luft, J. (2013). Secondary science teachers' use of technology in the classroom during their first 5 years. *Journal of Digital Learning in Teacher Education, 29*(4), 118-126. doi:10.1080/21532974.2013.10784715

Dori, Y. J., & Belcher, J. (2005). How does technology-enabled active learning affect undergraduate students' understanding of electromagnetism concepts? *The Journal of the Learning Sciences, 14*(2), 243–279.

Fraenkel, J. R., Wallen, N. E., & Hyun, H. (2011). *How to design and evaluate research in education* (8th ed.). The McGraw-Hill Companies, Inc.

Harris, J. B., Mishra, P., & Koehler, M. J. (2009). Teachers' technological pedagogical content knowledge and learning activity types: Curriculum-based technology integration reframed. *Journal of Research on Technology in Education, 41*(4), 393-416. doi: 10.1080/15391523.2009.10782536

Kim, M. C., & Hannafin, M. J. (2011). Scaffolding problem solving in technology-enhanced learning environments (TELEs): Bridging research and theory with practice. *Computers and Education, 56*(2), 403-417. doi:10.1016/j.compedu.2010.08.024

Koehler, M. J., & Mishra, P. (2009). What is technological pedagogical content knowledge? *Contemporary Issues in Technology and Teacher Education (CITE Journal), 9*(1), 60-70.

Koh, J.H.L., & Chai, C.S. (2014). Teacher clusters and their perceptions of technological pedagogical content knowledge (TPACK) development through ICT lesson design. *Computers & Education, 70*, 222–232. doi:10.1016/j.compedu.2013.08.017

Koh, J. H. L., Chai, C. S., & Tsai, C. C. (2013). Examining practicing teachers' perceptions of technological pedagogical content knowledge (TPACK) pathways: A structural equation modeling approach. *Instructional Science*, *41*(4), 793-809.

Kramarski, B., & Michalsky, T. (2010). Preparing preservice teachers for self-regulated learning in the context of technological pedagogical content knowledge. *Learning and Instruction, 20*, 434-447. doi:10.1016/j.learninstruc.2009.05.003

Kushner Benson, S.N., Ward, C.L., & Liang, X. (2015). The essential role of pedagogical knowledge in technology integration for transformative teaching and learning. In C. Angeli and N. Valanides (Eds.), *Technological pedagogical content knowledge exploring, developing, and assessing TPCK* (pp.3-18), New York: Springer Science+Business Media. doi: 10.1007/978-1-4899-8080-9_1

Li, M. C., & Tsai, C. C. (2013). Game-based learning in science education: a review of relevant research. *Journal of Science Education and Technology, 22*, 877-898.

Mishra, P., & Koehler, M.J. (2006). Technological pedagogical content knowledge: A framework for integrating technology in teacher knowledge. *Teachers College Record, 108*(6), 1017-1054.

Moore, E. B., Herzog, T. A., & Perkins, K. K. (2013). Interactive simulations as implicit support for guided-inquiry. *Chemistry Education Research and Practice, 14*, 257-268. doi: 10.1039/C3RP20157K

Pallant, J. (2007). *SPSS Survival Manual: A step by step guide to data analysis using SPSS for windows* (3rd ed.). New York: McGraw Hill, Open University Press.

Schmidt, D.A., Baran, E., Thompson, A.D., Mishra, P., Koehler, M.J., & Shin, T.S. (2009). Technological pedagogical content knowledge (TPACK). *Journal of Research on Technology in Education, 42*(2), 123-149.

So, H.J., & Kim, B. (2009). Learning about problem based learning: Student teachers integrating technology, pedagogy and content knowledge. *Australasian Journal of Educational Technology, 25*(1), 101-116. doi: 10.14742/ajet.1183

ASSESSING STUDENT TEACHERS' SKILLS TO PLAN PHYSICS LESSONS

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A main goal of university teacher education programs is to enable pre-service teachers to provide high quality learning environments. Therefore, theoretical courses focus on imparting professional knowledge, which consists of content knowledge (CK) about the subject to be taught, subject-specific pedagogical content knowledge (PCK) and pedagogical knowledge (PK). In doing so, it is assumed that professional knowledge is used as a resource, especially when planning lessons. In addition, practical courses at the university and a long-term-internship at local schools shall provide practical insights into German teachers' daily routines and enable pre-service teachers to gather first teaching experiences on their own. However, it is not quite clear what makes a teacher good in accomplishing his daily tasks. Especially the effect of professional knowledge (acquired at university courses) on teaching quality in real classroom situations is unclear up to now and could only be shown regarding very specific and narrow aspects of teaching quality. Thus, this study aims to narrow the gap by researching the relationship between pre-service physics teachers' professional knowledge and their performance when planning a certain physics lesson and the development of that performance within a long-term-internship. Therefore, we developed a performance assessment which is used to gather student teachers' skills to plan a physics lesson under standardized conditions. Within the assessment, students have to plan a physics lesson in a hypothetical situation. In addition, we used written tests for CK, PCK and PK to analyse the effect of professional knowledge on the quality of lesson plans. The tests for professional knowledge as well as the performance assessment are administered in a longitudinal study before and after a long-term-internship to student teachers (N=174 individual lesson plans, N=68 longitudinal datasets) at four German universities from three different federal states. Results regarding the test's validity, the effect of the internship and the relation between the skill to plan an lesson and professional knowledge will be presented.

Keywords: Initial Teacher Education (Pre service), Performance Assessment, Professional Development

SUBJECT AND PROBLEM

The creation of highly effective learning environments is a crucial task for every teacher. In doing so, learning environments have to respect students' individual needs as well as prior knowledge and should allow an accessible approach to the content. In order to provide these environments, specific lessons have to be planned and prepared. So skills to plan physics lessons are of vital importance especially for novices, as they cannot fall back on tacit scripts or routines. In science education, teachers' professional knowledge, composed of content knowledge (CK), pedagogical content knowledge (PCK) and pedagogical knowledge (PK; cf. Shulman, 1986; Baumert & Kunter, 2013), has been assumed to be a significant factor affecting teaching quality (e.g. Fischer, Neumann, Labudde, & Viiri, 2014). Nevertheless, it is an open research question whether or not CK, PCK, and PK are the key factors that affect teaching quality - or even if these knowledge areas are relevant at all for teaching (for the domain of physics, see Cauet et al., 2015). Thus, it remains unclear to what extent professional knowledge affects the skill to plan a lesson in particular. The study presented in this paper tries to close the gap by developing a standardized and authentic method that is able to assess skills required to plan physics lessons in a first step. In a second step, the development of skills to plan a physics lesson is examined during a long-term-internship, since this kind of internship appears to be a good opportunity for student teachers to practice and develop those skills. Third, the relationship between those skills and professional knowledge (CK, PCK, PK) is analysed.

THEORETICAL FRAMEWORK AND RESEARCH QUESTIONS

Despite the importance of lesson planning, there is no universal definition of lesson planning. Nevertheless, its importance is stated by many authors, e.g. Rakhkochkine (2011) points out that "*The preparation of instruction is one of the central responsibilities of teachers and can be seen as a focal point of the interaction of theory and practice*" (p.95; cf. also Klafki, 1958). Written lesson plans usually serve two different purposes. On the one hand, teachers shall prepare their actions in order to minimize possible insecurities and to provide action alternatives. One the other hand, especially for student teachers, written lesson plans shall also provide some justifications of the planned lessons, as they are evaluated by teacher trainers (Vogelsang & Riese, 2017). The process of lesson planning itself can be assumed to be a recursive process. Within this process, teachers analyse preconditions, anticipate a certain behavior and reflect their decisions afterwards (Shavelson & Stern, 1981). Even though experienced teachers mostly do not elaborate their lesson plans, as they have scripts and routines to fall back on, student teachers need to plan lessons and reflect on their lessons in order to develop those scripts (Stender, 2014).

When measuring subject-related skills to plan lessons, two different approaches can be found in literature. On the one hand, authentic lesson plans, which were created for teaching real classes, are analysed (e.g. Windt, Hasenkamp, Rau, Lenske & Rumann, 2016; König, Bremerich-Vos, Buchholtz, Fladung & Glutsch, 2019). However, this authenticity comes with the problem of finding a way to compare those lesson plans, since they differ regarding planning schemes, content or learning prerequisites. This is a particular problem if lesson plans are to be analysed holistically. Therefore, often only certain aspects of lesson planning are analysed, for example König et al. (2019) focus on adaptive teaching within the lesson plans, which is the fit between the cognitive preconditions of a learning group and the planned tasks to be worked on in class. On the other hand, more standardized, but less authentic paper-pencil-tests are used. For example, Baer et al. (2011) presented short classroom situations to student teachers, who were asked to apply or reproduce their knowledge about planning. However, a high score within these tests can be achieved without actually planning any lessons, so inferences about the ability to plan lessons should be considered with care.

Our study tries to combine the advantages of both approaches by developing a standardized and authentic *performance assessme*nt in which student teachers need to plan a whole lesson instead of reproducing knowledge about lesson planning. The performance assessment follows Miller's (1990) suggestion, whose domain is medical education. According to him, there is a third kind of assessment between *tests for knowledge*, such as tests used to assess knowledge about planning, and *tests for action*, which are represented by observing professional practice. Miller (1990) proposes a performance assessment to put test persons into real authentic but controlled situations, which represent standard situations test persons will have to face frequently as a professional. This kind of assessment has already been used to assess pre-service teachers' "skill to explain physics", which also represents a standard situation for teachers (cf. Kulgemeyer & Riese, 2018). Since the results showed a positive impact of CK and PCK on the explaining performance, this kind of assessment seems to be a promising way to clarify the relationship between professional knowledge and aspects of teaching quality. As this study aims to develop a performance assessment capable of assessing pre-service teachers' skills to plan a physics lesson, we focused our first research question on criteria for test quality:

RQ1: How far can the developed performance assessment measure the skill to plan a physics lesson validly?

Furthermore, we try to investigate the effect of professional knowledge and the performance shown in the developed assessment within a long-term internship that is part of many MA degree programs in Germany.

RQ2: What development of the skill to plan a physics lesson occurs during a long-term-internship?

RQ3: How does the professional knowledge, especially CK and PCK, affect the skill to plan a physics lesson?

DESIGN

To answer those research questions, a performance assessment has been developed by following Miller's (1990) approach. The paper-pencil instrument puts students in a situation where they have to plan a lesson focusing on Newton's third law. Therefore, a short description of the class and their learning prerequisites are provided and specific learning objectives are determined. The lesson plan has to be documented on a pre-structured planning paper, which suggests some mandatory parts of physics lessons. These parts include an analysis of the physical content, possible student misconceptions, intended experiments and tasks or questions, explanations or justifications, a short conclusion for the blackboard and a lesson draft. By these requirements and the standardized aids, namely copies from three different sources about Newton's third law, these lesson plans allow a higher comparability than completely free lesson plans.

In order to evaluate the quality of lesson plans, we developed a theoretical model, derived from the model of educational reconstruction (Duit, Gropengießer, Kattmann, Komorek & Parchmann, 2012), which revolves around the analysis of the content and the conceptions and affective variables of leaners in order to plan lessons. As a result, the model to evaluate the ability to plan physics lessons contains seven different categories to evaluate:

- Physical content and correctness
- Elementarization

- Presentation and consideration of students‘ perspectives
- Reachability of learning objectives
- Presentation and use of experiments
- Presentation and use of tasks or questions
- Use of examples and contexts

The model was developed by using subject-specific literature and various guidebooks on lesson planning, since theoretical literature seldom goes into detail about planning single lessons. It was also combined with an inductive approach, resulting in a codebook with N=26 two- or three-staged items. However, the rater-agreement was quite low with this stage of the codebook (agreement of 75% for *N*=32 lesson plans), especially for items judging the quality of certain aspects. Consequently, all items were transformed into more detailed and dichotomous item, resulting in a total of *N*=59 items. The codebook contains instruction and examples of whether or not an item is rated one or zero points, an example regarding the presentation of experiments is shown in figure 1.

Experiment - Materials	
Aim: The experiment is described in such a way, that others would be able to prepare the experiment by themselves. Required materials are specified.	
Item solved **(1P)**	Item not solved **(0P)**
Required Materials are specified in description of the experiment or in the lesson draft, e.g.: • *„2 students on separate skateboards, connected with a rope. Both students hold on to one end of the rope. First, only student A pulls in the rope, […]. Can be repeated with force meters attached to the ends of the rope“* • *„Materials: 2 skateboards, 2 students, 1 rope, 2 force meters“* • *“A student is standing on roller skates and has to throw away different balls (tennis ball, basketball, medicine ball) horizontally. The balls and his motion shall be observed”* • …	Important materials are not mentioned, e.g.: • Within the experiment, forces are to be measured, but no force meters are mentioned • Description of experiment not clear • No materials mentioned at all No experiment described

Figure 6. Sample item regarding the presentation of experiments with examples whether the item is solved (1P) or not (0P).

The assessment is administered to students from four German universities both before and after the long-term internship together with tests for professional knowledge, which have been validated in previous projects (for CK: Enkrott, Buschhüter, Borowski & Fischer, 2019; for PCK: Riese, Gramzow & Reinhold, 2017; for PK: Riese, 2009), and questions about the internship. When participating in all assessments, the total testing time amounts 305 minutes per measurement point. In between pre- and post-test are approximately 4.5 months (*M*=139d, *SD*=16d), during which students practice at local schools and have to prepare and hold lessons on their own in physics and their second subject. For that time, they are supervised by experienced teachers with whom they discuss their lesson plans and reflect on their lessons afterwards. In the current state, *N*=174 individual lesson plans have been collected over both measuring points, resulting in *N*=68 sets of pre- and post-tests due to the dropout among students. On average, the 68 students whose longitudinal data is available visited *M*=66 physics lessons (*SD*=34) and held *M*=20 (*SD*=11) physics lessons on their own. At the time of the post-test, they were about M=25.4 years old (SD=4.0) and in their 9th or 10th semester at university.

ANALYSIS AND FINDINGS

In this chapter, we will first discuss some test quality criterial of the developed performance assessment. Following, results regarding the posed research questions will be presented and discussed.

Test quality criteria

After scoring the available *N*=174 lesson plans using the codebook containing 59 test items, all items were analysed. For 14 of these test items the relative probability of solution p was too high (p>0.9), too low (p<0.1) or the item-total correlation r was extremely low (r<0.1). Consequently, those items were discarded for further analysis. The internal consistency for the remaining *N*=45 test items amounts $\alpha_{Cronbach}$=0.81 and the mean total score is *M*=50% (*SD*=15%, min=11%, max=87%). For interrater agreement, *N*=52 lesson plans were double-coded by two independent and trained raters. Their agreement for the *N*=45 items amounted 87.6%, resulting in a Gwet's AC_1 coefficient of 0.83, which indicates substantial agreement (Gwet, 2014). The test items could not be separated empirically into the seven categories, which were used to develop the test items, so there are no sub-scores for the individual categories. Given the mutual dependency of different parts of lesson planning, the lack of separability seems comprehensible, since for example the consideration of leaners' perspectives should affect the selection and use of experiments or tasks to be done, so a strict separation of the seven categories is not necessarily reasonable. However, when using the total test score, the codebook seems to provide an objective and consistent measurement for the ability of lesson planning, which will following be used for further analysis.

Research question 1: Validity of the assessment

To answer RQ1, among others, interviews with three teacher trainers were conducted and their judgements regarding the quality of three selected lesson plans were compared to corresponding results provided by the codebook. The interviewed teacher trainers, who regularly judge student teachers' lesson plans and lessons, have also been practicing as teachers for seven to twelve years at German schools. Prior to the interview, three lesson plans were chosen based on the score provided with the codebook in order to achieve a high variance among the lesson plans. At the start of the interview, the teacher trainers had to judge the lesson plans quality by their own criteria without knowledge of the total score or the codebook, resulting in a school grade. During the interview, the lesson plans were discussed more detailed regarding the seven categories contained in the theoretical model. By the end of the interview, the teacher trainers were asked to judge the lesson plans once again, resulting in a second school grade. To allow a better comparability to the score generated with the codebook, school grades were transformed to percentages, following the German system of grading. As shown in figure 2, the results indicate an agreement among the teacher trainers about the perceived order of quality of those lesson plans as well as an agreement of their mean grades' order to the order of the planning score provided by the codebook.

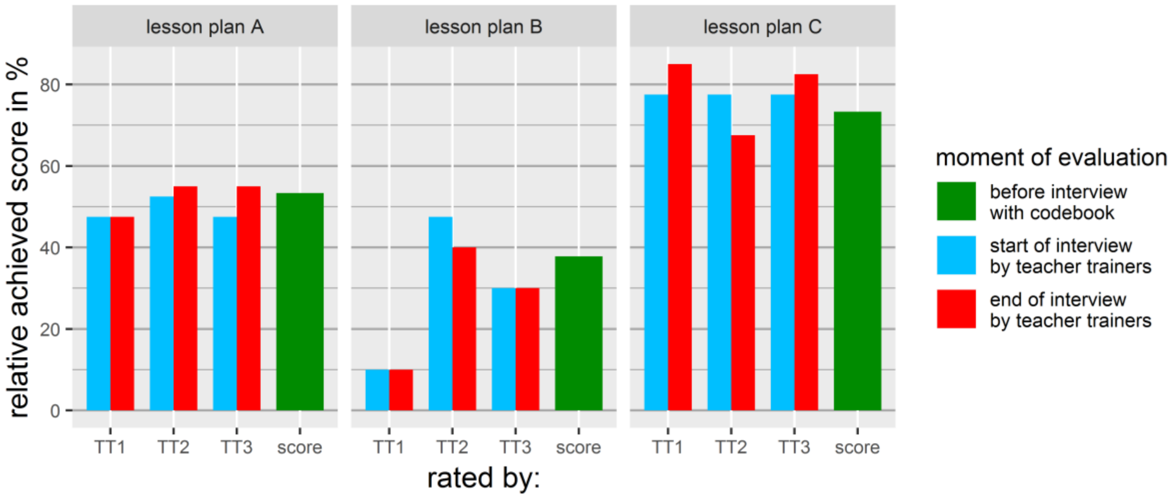

Figure 7. Comparison of three different lesson plans (A, B, C) regarding the plans' quality. Each plan was rated twice by three different teacher trainers (TT) and with the codebook, resulting in the (test-)score. Teacher trainer judgements were transformed to %-values according to the German grading system for higher comparability.

All teacher trainers as well as the codebook evaluate lesson plan C best and plan B worst. Only when looking at the results for lesson plan B, teacher trainer 1 differs considerably from his two colleagues and rates the lesson plan with the worst grade possible. Furthermore, the teacher trainers' judgements shift only slightly during the interview, so knowledge of the seven categories, which were used to score the lesson plans with the codebook, doesn't seem to result in a shift of perceived quality among the teacher trainers. Consequently, we can assume that the perception of lesson plan quality of teacher trainers is similar to that generated with the codebook.

A subset (N=17) of the standardized lesson plans were also compared to real lesson plans, which were created during the internship by the same students. The student teachers taught real classes according to their lesson plans afterwards, so the real plans were prepared for real classes. Due to the diversity among the lesson plans regarding physical content and external conditions, we focused on structural elements and analysed the occurrence and extent of aspects. For this purpose, an independent category system was developed using qualitative content analysis (cf. Mayring, 2015). For example, it was compared if an experiment was described within the lesson plan, how detailed the description was and whether or not the experiment was addressing certain misconceptions. Overall, we found indication of a similar planning behaviour, so the assessment's hypothetical setting does not seem to pose any problems regarding the authenticity.

Research question 2: Development during long-term internship

During the long-term internship, which is mandatory for the teacher education at the participating universities, student teachers visited and held numerous lessons on their own. On average, student teachers held about 20 physics lessons and spent roughly three hours for the preparation of those lessons. As the student teachers are supported by experienced teachers, we can assume that the majority of lesson plans was reviewed by those teachers. After the lesson has been held, student teachers are given the opportunity to reflect on their lessons. On average, student teachers spend about ten minutes talking to their supporting teachers, both before and after holding a lesson. So on the basis of this data, the long-term internships' impact on the ability to plan a physics lesson can be investigated. In table 1 the longitudinal results are summarized, regarding the total score comprised of the N=45 test items.

Table 2. Relative achieved score separated by measurement point and results from a paired t-test.

N=68	Pre-test		Post-test		Paired t-test, t(67)=2.8	
	Mean	SD	Mean	SD	*p*-value	Cohens *d*
Score	48%	14%	53%	15%	0.0075	0.334

When looking at the relative achieved score of those N=68 students in the pre- and post-test, a significant increase of the test score can be observed, but the effect size is small. Still, the long-term internship seems to lead to a slightly higher score in the lesson planning performance assessment among students. These results can be reproduced when using the non-parametric Wilcoxon signed-rank test.

Research question 3: Relation to professional knowledge

As described previously, it remains an open research question to what extent the professional knowledge is related with the ability to plan a lesson respectively the teaching quality in general. Therefore, the professional knowledge was also assessed using written tests for CK, PCK and PK. The correlations (Pearson's r) between the planning score and the total test scores of the three areas of professional knowledge are shown in table 2.

Table 3. Relation between achieved planning score and total score from tests for professional knowledge. Significance levels: Not significant ≙ $p \geq 0.05$ (n.s.), $p < 0.05$ (*), $p < 0.01$ (**).

Bivariate Correlations		CK		PCK		PK	
		r	N	*r*	N	*r*	N
Planning	Pre-tests	0.008 (n.s.)	59	0.318**	74	0.356**	55
	Post-tests	-0.063 (n.s.)	38	0.325**	71	0.247*	71

The case numbers N vary due to the absence of test persons at separate assessments of professional knowledge, especially during the second measurement point. For PCK and PK, small correlations between the test score and achieved lesson planning score can be seen for both pre-test and post-test. However, no correlations between lesson planning score and the test score for CK were found at any measurement point.

DISCUSSION

The results regarding research question 1 seem to provide first evidence that the developed performance assessment is capable of measuring the quality of lesson plans and so the skill to plan a lesson. Interviews with teacher trainers showed exemplary that the perceived quality of lesson plans created within the assessment is similar to the total score generated with the codebook. Furthermore, the hypothetical setting of the assessment doesn't seem to restrict the ecological validity of the test, so the performance assessment appears to be a valid possibility for measuring the skills to plan a physics lesson.

The longitudinal data, which were gathered before and after a long-term internship show a significant increase in the test score along the internship (RQ2), but with a small effect size. It is reasonable to assume that the internship represents an opportunity to increase the ability to plan a lesson, however, given the small effect size, these results should be treated with caution. A possible explanation for the small effect might be that during the internship student teachers are focused on the creation of learning materials and methodological aspects or classroom management, which are not addressed in the performance assessment. Given the demographic data, that was also gathered with the tests for professional knowledge and an additional questionnaire about experiences and the mentoring relationship will allow a more detailed analysis

Regarding research question 3, we can see small correlations between the skill to plan a lesson and the PCK respectively the PK. The correlation between the ability to plan a lesson and the PCK seems more consistent along the internship than the correlation with the PK, which is roughly one third lower after the internship. The correlation with CK could not be shown at all. However, a minimum level of CK appears to be a requirement for a high level of PCK, the connection between lesson planning ability and CK might be included in the correlation with the PCK. It should be noted that we are only considering correlations at this point and not causal aggregations, which we will investigate at a later stage of the project.

ACKNOWLEDGEMENT

The Profile-P+ project is supported by the BMBF-Rahmenprogramm KoKoHs (FKZ 01PK15005A-D).

REFERENCES

Baer, M., Kocher, M., Wyss, C., Guldimann, T., Larcher, S., & Dörr, G. (2011). Lehrerbildung und Praxiserfahrung im ersten Berufsjahr und ihre Wirkung auf die Unterrichtskompetenz von Studierenden und jungen Lehrpersonen im Berufseinstieg. *Zeitschrift für Erziehungswissenschaft* (4), 85-117.

Baumert J., Kunter M. (2013) The COACTIV Model of Teachers' Professional Competence. In M. Kunter, J. Baumert, W. Blum, U. Klusmann, S. Krauss, M. Neubrand (Eds.) *Cognitive Activation in the Mathematics Classroom and Professional Competence of Teachers. Mathematics Teacher Education 8*. Springer, Boston, MA

Cauet, E., Liepertz, S., Kirschner, S., Borowski, A., & Fischer, H.E. (2015). Does it matter what we measure? Domain-specific professional knowledge of physics teachers. *Revue Suisse des sciences de l'education* 37 (3), 462–479.

Duit, R., Gropengießer, H., Kattmann, U., Komorek, M., & Parchmann, I. (2012). The Model of Educational Reconstruction – a Framework for Improving Teaching and Learning Science. In D. Jorde & J. Dillion (Eds.) *Science Education Research and Practice in Europe. Retrospective and Prospective* (13-37). Rotterdam: Sense Publishers.

Enkrott, P., Buschhüter, D., Borowski, A., & Fischer, H.E. (2019). Modellierung und Entwicklung von Fachwissen angehender Physiklehrkräfte. In C. Maurer (Ed.): *Naturwissenschaftliche Bildung als Grundlage für berufliche und gesellschaftliche Teilhabe,* 349-352. Kiel: GDCP Jahrestagung 2018.

Fischer, H., Neumann, K., Labudde, P., & Viiri, J. (Eds.). (2014). *Quality of instruction in physics. Comparing Finland, Germany and Switzerland*. Münster, Germany: Waxmann.

Gwet, K. L. (2014). *Handbook of Inter-Rater Reliability*. (4th ed.). Gaithersburg, MD: Advanced Analytics, LLC.

Klafki, W. (1958). Didaktische Analyse als Kern der Unterrichtsvorbereitung. Die Deutsche Schule, 50, 450-471.

König, J., Bremerich-Vos, A., Buchholtz, C., Fladung, I., Glutsch, N. (2019). Pre-service teachers‘ generic and subject-specific lesson-planning skills: On learning adaptive teaching during initial teacher education. *European Journal of Teacher Education*. https://doi.org/10.1080/02619768.2019.1679115.

Kulgemeyer, C. & Riese, J., (2018). From Professional Knowledge to Professional Performance: The Impact of CK and PCK on Teaching Quality in Explaining Situations. *Journal of Research in Science Teaching* 2018,00: 1-26. https://doi.org/10.1002/tea.21457.

Mayring, P. (2015). *Qualitative Inhaltsanalyse: Grundlagen und Techniken* (12th ed.). Weinheim: Beltz.

Miller, G.E. (1990): The Assessment of Clinical Skills/Competence/Performance. *Academic Medicine* 64 (9), 63-67.

Rakhkochkine, A. (2011). Lesson Planning: Rationales and Strategies for an International Comparison. In K.H. Arnold; T. Bohl; S. Hopmann; B. Hudson; E. Kiel; H. Kiper; B. Koch-Priewe; K. Reusser; N. Seel; K. Zierer (Eds.). *Jahrbuch für allgemeine Didaktik* 2011, (95-107). Baltmannsweiler: Schneider Verlag Hohengehren.

Riese, J. (2009). *Professionelles Wissen und professionelle Handlungskompetenz von (angehenden) Physiklehrkräften*. Berlin: Logos.

Riese, J., Gramzow, Y. & Reinhold, P. (2017). Die Messung fachdidaktischen Wissens bei Anfängern und Fortgeschrittenen im Lehramtsstudiengang Physik. *Zeitschrift für Didaktik der Naturwissenschaften* 23 (1), 99-112.

Shavelson, R.J., & Stern, P. (1981). Research on Teachers' Pedagogical Thoughts, Judgements, Decisions, and Behavior. *Review of Educational Research* 51 (4), 455-498.

Shulman, L. (1986). Those Who Understand: Knowledge Growth in Teaching. *Educational Researcher* 15 (2), 4-14.

Stender, A. (2014). *Unterrichtsplanung: Vom Wissen zum Handeln. Theoretische Entwicklung und empirische Überprüfung des Transformationsmodells der Unterrichtsplanung*. Berlin: Logos.

Vogelsang, C. & Riese, J. (2017): Wann ist eine Unterrichtsplanung ‚gut‘? Planungsperformanz in Praxisratgebern zur Unterrichtsplanung. In S. Wernke & K. Zierer (Eds.): Die Unterrichtsplanung: Ein in Vergessenheit geratener Kompetenzbereich (47-61). Bad Heilbrunn: Klinkhardt.

Windt, A., Hasenkamp, A., Rau, S., Lenske, G., & Rumann, S. (2016). Teaching Abilities of Prospective Teachers at the Beginning of the Practical Phase of Teacher Education. Lavonen, J., Juuti, K., Lampiselkä, J., Uitto, A., Hahl, K. (Eds.), *Science Education Research: Engaging Learners for a Sustainable Future*, 2188-2195.

DEVELOPMENT OF PROSPECTIVE PHYSICS TEACHERS' PEDAGOGICAL CONTENT KNOWLEDGE WHILE PREPARING FOR AN INTERNSHIP

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In recent years, several large-scale studies have researched prospective science teachers' pedagogical content knowledge (PCK) to get findings on how to improve academic teacher education. While a general increase of PCK most often can be found, it is widely unclear how university learning opportunities and other influencing factors affect certain areas of PCK in detail. In this project, the development of prospective physics teachers' PCK and reasons for individual changes in the amount and characteristic of their PCK are researched over a number of months while preparing to a long-term internship. In that time, two subject specific university seminars have to be taken with a focus on methods for planning physics' lessons respectively methods for dealing with students' preconceptions in the physical topics electricity and optics. In methodological terms, in a first step, 24 prospective physics teachers were surveyed with a written quantitative PCK-test in a pre-post design to evaluate the development of their PCK when attending the two seminars. The PCK-test comprises four different areas of PCK (instructional strategies, students' conceptions, adequate use of experiments, physics education concepts) and covers three physical topics (mechanics, optics and electricity). In a second step, guided interviews were conducted with all test persons and analysed by using qualitative content analysis. In the interviews, the prospective physics teachers were individually confronted with changes in their test behaviour (pre-post) as measured by single items of the PCK-test and they were begged to reason why responses differ in the pre-post comparison. Furthermore, the development of PCK in specific areas was related to their individual use of learning opportunities. Thereby we also explore how far the acquisition of PCK depends on a physical topic. First results from the longitudinal part and clues derived from the interviews will be presented.

Keywords: Pedagogical content knowledge, Initial Teacher Education (Pre-service), Professional Development

PROBLEM DEFINITION

Teacher education programs in general as well as introduced innovations in detail should be evaluated with respect to the development of teachers' professional knowledge. Therefore, many studies were conducted to assess certain aspects of science teachers' professional knowledge like pedagogical content knowledge (PCK; Ledermann & Abell, 2014; Shulman, 1986). In the German-speaking research on science teacher knowledge, most studies focus on large-scale methods when researching the development of PCK, so several written PCK-tests have been developed and validated in various projects – especially in the domain of physics (FALKO: Schödel & Göhring, 2017; KiL: Kröger, Neumann & Petersen, 2013; ProfiLe-P: Riese et al., 2015 & Vogelsang et al., 2020; ProWiN: Tepner et al., 2012; QuiP: Olszewski, 2010). Some of those studies found, for example, differences in the amount of PCK (regarding a general total score) depending on the type of teacher education program or the study progress. However, beyond quantitative correlations, there is still a lack of findings how far individual learning opportunities taken at university, learning opportunities taken in daily routines or test-specific and person-specific effects affect becoming teachers' PCK in detail. Those findings would be helpful to explain different development processes of science teachers' PCK in science teacher education programs.

THEORETICAL FRAMEWORK

Pedagogical content knowledge as a part of teachers' professional knowledge

In science teacher education, teachers' professional knowledge has been assumed to be a fundamental factor affecting teaching quality (e.g. Fischer, Neumann, Labudde & Viiri, 2014; Vogelsang et al., 2020). So many studies have been conducted to research teachers' professional knowledge (Ledermann & Abell, 2014). In doing so, most studies refer to Shulman's (1986) fundamental considerations about teachers' professional knowledge, who described seven categories of professional knowledge (content knowledge [CK]; general pedagogical knowledge [PK]; curriculum knowledge; pedagogical content knowledge [PCK]; knowledge of learners and their characteristics; knowledge of educational contexts; and knowledge of educational end, purposes, and values; cf. Shulman, 1987). Recent studies highlight CK, PK and PCK having a great impact on teaching quality (e.g. Baumert et al., 2010; Cauet, Liepertz, Kirschner, Borowski, & Fischer, 2015), where these three domains are sometimes described as including the seven categories. Following those approaches, CK can be understood as subject matter knowledge underlying the content selected for teaching, PK can be described as knowledge of how to act in teaching situations in general and PCK can be regarded as domain-specific knowledge of how to teach the selected content.

Measuring pedagogical content knowledge

Following Shulman (1986), pedagogical content knowledge (PCK) represents a key part of teachers' professional knowledge and comprises knowledge about typical difficulties in teaching a specific topic, knowledge about students pre- and misconceptions and knowledge about representing and formulating a subject to make it comprehensible to others (Hume, Cooper & Borowski, 2019; Park & Oliver, 2008; van Driel & Berry, 2010). Based on those suggestions, several large-scale studies have been conducted in the domain of physics to research (student) teachers' PCK. In doing so, studies usually focus on Topic Specific PCK when measuring PCK to ensure that empirically based subscales can be found within a survey with limited test-time. For example, Fischer et al. (2014) assess certain areas of PCK (e.g. students' misconceptions, difficulties of contents, reactions on students' answers, suitable tasks) only in the physical topic electricity while Gramzow, Riese & Reinhold (2014) and Vogelsang et al. (2020) focus on the physical topic mechanics as students' conceptions in mechanics are well known in science education research. So the approaches chosen in these studies follow the idea that PCK comprises of General PCK, Domain Specific PCK and Topic Specific PCK (Mavhunga, 2014; Veal & MaKinster, 1999). But it is unclear if such an approach allows a representative and valid measurement of physics (student) teachers' PCK when evaluating (parts of) academic teacher education programs or evaluating an intervention with mixed topics, since the role of the physical topic when acquiring Domain Specific PCK is unclear.

AIMS AND RESEARCH QUESTIONS

In order to introduce the research questions, a brief introduction into the structure of typical German teacher education programs is given. In a first step, pre-service teachers usually have to graduate an academic part which lasts five years in most cases. First, in those programs, there is a focus on the acquisition of subject related content knowledge (CK) while the last two years often focus on the acquisition of pedagogical content knowledge (PCK) and a long term internship. In a second step, the academic part is followed by a traineeship with a duration of one to two years where the pre-service teachers receive a wide range of teaching practice at school.

As a first aim, our study presented in this paper evaluates a preparation phase to a long term internship (as mentioned above) at the RWTH Aachen University as a specific part of a typical university teacher education program in Germany. In doing so, the development of physics (student) teachers` PCK is researched by a written PCK-test in a pre-post study design while preparing to the long-term internship. During this time, the student teachers have to take two specific preparatory seminars with a focus on methods for planning physics' lessons and dealing with students' preconceptions in the physical topics electricity and optics. This leads to a first research question:

RQ1: To what extend does physics student teachers' PCK develop in the topics mechanics, electricity and optics while attending those two preparatory seminars?

Moreover, when acquiring PCK, the role of the physical topic is researched:

RQ2: Does the acquisition of PCK independently happen within a distinct physical topic (being taught) or does PCK develop as a whole construct (above different topics)?

Furthermore, more general conclusions about the development of PCK should be drawn. Therefore, the impact of various categories of subject-specific, university learning opportunities as well as other types of influencing factors on prospective teachers` PCK are researched in detail. This leads to two research questions:

RQ3: Which categories of individually taken subject-specific, university learning opportunities facilitate the development of PCK?

RQ4: Which categories of further influencing factors and individual specifics lead to changes in PCK?

METHODS

To answer those research questions, first of all, the development of prospective physics teachers' PCK was measured by a written PCK-test, that was mostly developed and validated in previous projects (Gramzow, 2015; Kulgemeyer & Riese, 2018). In addition to those existing items in mechanics, some more items have been developed in the topics electricity and optics. The test was applied in a pre-post design at the beginning and at the end of those above mentioned two university seminars in the winter semesters 2017/2018 (N = 10) and 2018/2019 (N = 14). With regard to curricular validity, the test considers specifics of the German-speaking teacher education programs and comprises four different areas of PCK (instructional strategies, students' conceptions, adequate use of experiments and physics education concepts), that were empirically verified in previous projects with a four-dimensional Rasch-model (Kulgemeyer & Riese, 2018). The test items were created following a three dimensional model for itemdevelopment as shown in figure 1.

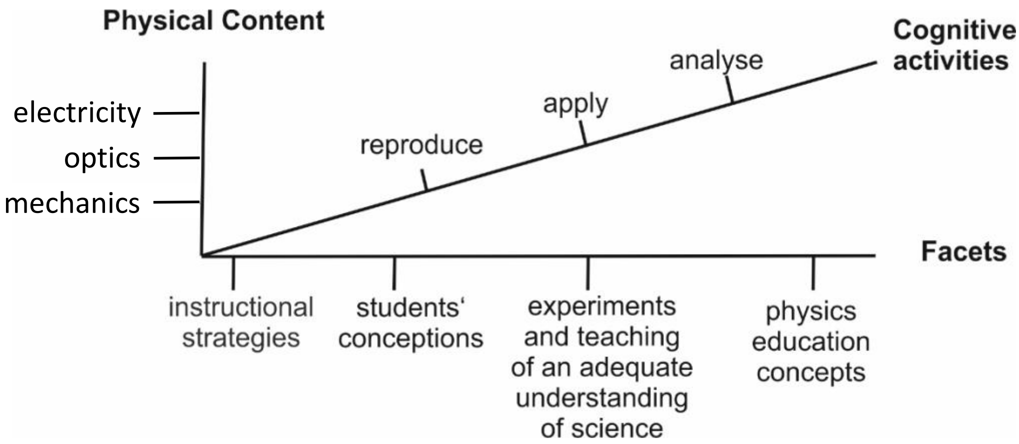
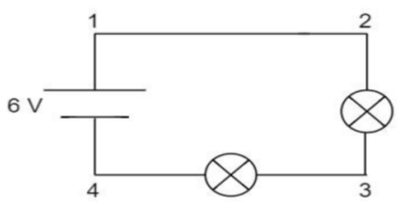


Figure 1. **PCK model for item development modified from Gramzow, Riese & Reinhold (2014, p. 2244).**

Furthermore, the test covers three physical topics (mechanics, electricity and optics), while the physical topic mechanics was not directly addressed in both university seminars. On the whole, the paper-and-pencil test includes 41 items with open situational judgment items as well as multiple-choice items (multiple select). In figure 2, an example of a test item in the physical topic electricity is presented. This sample item is assigned to *electricity*, *student's conceptions* and *analyse* (see figure 1). The testing time for each participating student was limited to 105 minutes.

A student should consider the following electric circuit with two identical lamps:



The student says the following sentence:

"Between all points the same voltage drops and the same current flows."

What wrong conception does the student have?

Figure 2. Sample item in the physical topic electricity.

With regard to research questions 2 to 4, moreover, guided interviews (90 min) were conducted after the post-test with all participants and they were analysed by using qualitative content analysis (Mayring, 2014). In the interviews, the becoming physics teachers were individually confronted with differences (pre-post) in their responses to single test items and they were begged to reason why responses differ in the pre-post comparison. Furthermore, the development of PCK in specific test-items was related to their individual use of different categories of learning opportunities.

ANALYSIS AND FINDINGS

With respect to the pre-post-survey, first results show a statistically significant increase regarding the mean total score of PCK with a medium effect size (table 1). In more detail, the Topic Specific PCK score in electricity also increases with a medium effect size, whereas no increase regarding the Topic Specific PCK score in mechanics can be found at all. The subscore in optics lies within these poles (table 1). These results may indicate that our sample of prospective physics teachers further develop their PCK while attending those two university seminars that prepare to a long-term internship (RQ1). Furthermore, these results lead to the conclusion that there might be an influence of the physical topic being taught when acquiring PCK (RQ2) as the approach of "Topic Specific PCK" (Mavhunga, 2014; Veal & MaKinster, 1999) suggests.

Table 1. Results from dependent t-tests for the PCK total score and corresponding subscores in mechanics and optics (Wilcoxon-test) as well as electricity (each topic: max. 21,5 points, total score: 64,5 points).

dependent t-tests, Wilcoxon-test (optics)				
	Mean	Sd	Sig (2-tailed)	|d| Cohen's d
PCK total score (N=22)	+ 2.16	4.56	0.04	0.47
PCK mechanics (N=24)	- 0.23	3.06	0.72	0.08
PCK optics (N=23)	+ 0.76	2.76	0.30	0.28
PCK electricity (N=22)	+ 1.43	3.30	0.05	0.43

To gather further evidence with respect to research questions RQ3 and RQ4, a more descriptive look at individual changes of the PCK-scores and scores in the three topics mechanics, optics and electricity has been taken to identify test persons with a conspicuous test behaviour. Table 2 presents individual PCK scores of three exemplarily chosen test persons. Regarding the pre-post comparison, it gets obvious that one and the same test person can achieve opposite progressions concerning different topics (e.g. student 1). This result leads to the conclusion that PCK probably does not develop simultaneously in different topics and that the topic is an important factor when acquiring PCK (RQ2).

Table 2. Selected results of individual PCK total scores and scores in the three topics mechanics, optics and electricity in a pre-post comparison. In each of these topics 21,5 points can be achieved (total score: 64,5 points).

Student	PCK **total score** Pre-test	PCK total score Post-test
1	30,0	30,5
2	22,5	28,0
3	18,0	26,0
Student	PCK **mechanics** Pre-test	PCK mechanics Post-test
1	8,0	11,0
2	11,0	11,0
3	12,0	6,0
Student	PCK **optics** Pre-test	PCK optics Post-test
1	8,5	9,0
2	4,0	9,0
3	6,0	11,0
Student	PCK **electricity** Pre-test	PCK electricity Post-test
1	13,5	10,5
2	7,5	8,0
3	0,0	9,0

Having these findings in mind, guided interviews were conducted with all test persons in which the prospective physics teachers were individually confronted with changes in their test behaviour (pre-post) regarding single items of the PCK-test and they were begged to explain their answers respectively the shifting of their answers. To analyse the interview transcripts with qualitative content analysis (Mayring, 2014), first of all, a multilevel category system had been developed which consists of deductive and inductive categories, e.g. effects caused by the test rerun, successfully use of specific learning opportunities, self-made experiences in the students' everyday life or other personal aspects. The category system was proofed by an external rater ($\kappa_{Brennan/Prediger}$=0.69) and by an intrarating ($\kappa_{Brennan/Prediger}$=0.84) which means a substantial resp. almost perfect agreement (Landis & Koch, 1977). Preliminary results from the interviews indicate that personal particularities as well as specific learning opportunities taken at university might affect changes in test behaviour. Individual characteristics of test persons seem to affect their PCK to a rather great extent. For example, the changes in the PCK-scores of student 3 (table 2) can be referred to a different time management in the pre- and post-test. We are going to analyse all 24 interview transcripts to answer RQ3 and RQ4 in detail.

ACKNOWLEDGEMENT

"This project is part of the "Qualitätsoffensive Lehrerbildung", a joint initiative which aims to improve the quality of teacher training. The programme is funded by the Federal Ministry of Education and Research. The authors are responsible for the content of this publication."

REFERENCES

Baumert, J., Kunter, M., Blum, W., Brunner, M., Voss, T., Jordan, A., Klusmann, U., Krauss, S., Neubrand, M. & Tsai, Y.-M. (2010). Teachers' mathematical knowledge, cognitive activation in the classroom, and student progress. *American Educational Research Journal*, *47(1)*, 133-180.

Cauet, E., Liepertz, S., Kirschner, S., Borowski, A. & Fischer, H.E. (2015). Does it matter what we measure? Domainspecific professional knowledge of physics teachers. *Revue Suisse des sciences de l'_education*, *37(3)*, 462–479.

Fischer, H., Neumann, K., Labudde, P., & Viiri, J. (Eds.). (2014). *Quality of instruction in physics Comparing Finland, Switzerland and Germany.* Münster, Germany: Waxmann.

Gramzow, Y. (2015). *Fachdidaktisches Wissen von Lehramtsstudierenden im Fach Physik Modellierung und Testkonstruktion*. Berlin, Germany: Logos Verlag.

Gramzow, Y., Riese, J. & Reinhold, P. (2014). Prospective physics teachers' pedagogical content knowledge – validating a test instrument by using a think aloud study. In C. P. Constantinou, N. Papadouris & A. Hadjigeorgiou (Eds.), *E-Book Proceedings of the ESERA 2013 Conference: Science Education Research For Evidence-based Teaching and Coherence in Learning* (Strand 13, pp. 2242-2249). Nicosia, Cyprus: ESERA.

Hume, A., Cooper, R. & Borowski, A. (Eds.) (2019). *Repositioning Pedagogical Content Knowledge in Teachers' Knowledge for Teaching Science*. Singapore Pte Ltd: Springer Nature.

Kröger, J., Neumann, K. & Petersen, S. (2013). Messung professioneller Kompetenz im Fach Physik. In S. Bernholt (Ed.), *Inquiry-based Learning - Forschendes Lernen* (pp. 533-535). Kiel: IPN, Germany: GDCP.

Kulgemeyer, C. & Riese, J. (2018). From professional knowledge to professional performance: The impact of CK and PCK on teaching quality in explaining situations. *Research in science teaching*, *55*, 1393 – 1418. doi: 10.1002/tea.21457.

Landis, J.R. & Koch, G.G. (1977). The measurement of observer agreement for categorical data. *Biometrics 33*, 159–174.

Ledermann, N.G. & Abell, S.K. (2014). *Handbook of research on science education*, *Volume II*. New York, NY: Routledge.

Mavhunga, E. (2014). Improving PCK and CK in chemistry pre-service teachers. In M. Askew, H. Venkat, M. Rollnick & J. Loughran (Eds.), *Exploring Content Knowledge for Teaching Science and Mathematics: Windows into teacher thinking* (pp. 29-49). Abington, UK: Routledge.

Mayring, P. (2014). *Qualitative content analysis: theoretical foundation, basic procedures and software solution*. Klagenfurt, Austria. https://nbn-resolving.org/urn:nbn:de:0168-ssoar-395173

Olszewski, J. (2010). *The impact of physics teachers' Pedagogical content knowledge on teacher action and student outcomes*. Berlin, Germany: Logos Verlag.

Park, S. & Oliver, J.S. (2008). Revisiting the conceptualisation of pedagogical content knowledge (PCK): PCK as a conceptual tool to understand teachers as professionals. *Research in Science Education*, *38(3)*, 261-284.

Riese, J., Kulgemeyer, C., Zander, S., Borowski, A., Fischer, H., Gramzow, Y., Reinhold, P., Schecker, H. & Tomczyszyn, E. (2015). Modellierung und Messung des Professionswissens in der

Lehramtsausbildung Physik. In S. Blömeke & O. Zlatkin - Troitschanskaia (Eds.), *Kompetenzen von Studierenden: 61. Beiheft der Zeitschrift für Pädagogik* (pp. 55 - 79). Weinheim, Germany: Beltz.

Schödl, A. & Göhring, A. (2017). FALKO-P: Fachspezifische Lehrerkompetenzen im Fach Physik. In Krauss, S., Lindl, A., Schilcher, A., Fricke, M., Göhring, A., Hofmann, B., Kirchhoff, P. & Mulder, R. H. (Hrsg.): *FALKO: Fachspezifische Lehrerkompetenzen. Konzeption von Professionswissenstests in den Fächern Deutsch, Englisch, Latein, Physik, Musik, Evangelische Religion und Pädagogik* (S. 201-244). Münster: Waxmann.

Shulman, L. (1987). Knowledge and teaching: Foundations of the new reform. *Harvard Education Review*, *57(1)*, 1–22.

Shulman, L. (1986). Those who understand: Knowledge growth in teaching. *Educational Researcher*, *15(2)*, 4-14.

Tepner, O., Borowski, A., Dollny, S., Fischer, H. E., Jüttner, M., Kirschner, S., Leutner, D., Neuhaus, B. J., Sandmann, A., Sumfleth, E., Thillmannn, H. & Wirth, J. (2012). Modell zur Entwicklung von Testitems zur Erfassung des Professionswissens von Lehrkräften in den Naturwissenschaften. *ZfDN (Zeitschrift für Didaktik der Naturwissenschaften)*, *18*, 7–28.

Van Driel, J.H. & Berry, A. (2010). The Teacher Education Knowledge Base: Pedagogical Content Knowledge. In B. McGraw, P.L. Peterson & E. Baker (Eds.), *International Encyclopedia of Education, 3rd edition*, *Vol. 7* (pp. 656-661). Oxford: Elsevier.

Veal, W.R. & MaKinster, J.G. (1999). Pedagogical Content Knowledge Taxonomies. *Electronic Journal of Science Education*, *3 (4)*.

Vogelsang, C., Borowski, A., Kulgemeyer, C., Riese, J., Buschhüter, D., Enkrott, P., Kempin, M., Reinhold, P., Schecker, H. & Schröder, J. (2020). Development of prospective physics teachers' professional knowledge and skills during a one-semester school internship. In O. Zlatkin-Troitschanskaia, H.A. Pant, M. Toepper & C. Lautenbach (Eds.) (2020). *Student Learning in German Higher Education: Innovative Measurement Approaches and Research Results* (pp. 105-123). Wiesbaden, Germany: Springer.

TEACHING CHEMISTRY INCLUSIVELY – ARE WE PREPARED?

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Related to the ratification of the Convention on the Rights of People with Disabilities, school teachers are faced with new challenges in chemistry lessons. Due to the increasing students' diversity, appropriate learning environments which are able to support learners according to their individual learning, development and cognitive abilities are needed. Important criteria for an appropriate perception and handling of heterogeneous learning groups in the sense of adapted class design are teachers' competences and attitudes towards inclusive chemistry education. Based on these requirements, the project aims at supporting pre-service chemistry teachers in acquiring central inclusive competences as well as reasonable attitudes towards inclusion during university education. The results of the explorative preliminary study show that teacher students' attitudes as well as their skills and knowledge deviate from the demands desirable for inclusive education. Taking these findings into account, it is necessary to offer appropriate courses at university. Thus, a course was planned, conducted and evaluated in order to detect a possible way to prepare prospective chemistry teachers adequately. The course aims at provoking them to reflect upon their attitudes towards inclusion and discovering how they can be enabled to work with learners' diverse abilities, interests and needs (both perceived and real) in inclusive chemistry lessons. To gain insights into their individual processes, questionnaires and process-portfolios had been used to collect data which were analysed by means of qualitative content analysis. In addition, validated scales were used to evaluate prospective chemistry teachers' inclusive attitudes and competences before and after the intervention. The paper will outline first results of the main study and will illustrate potential shifts of pre-service teachers attitudes and competences before and after attending the course.

Keywords: Inclusion, Initial Teacher Education (Pre-service), Teacher Preparation

INTRODUCTION

There is a general consensus that inclusion and consequently, inclusive chemistry education is a complex issue and its realization requires various changes at different levels (i.a. UNESCO, 2005; Rouse, 2008; Florian & Black-Hawkins, 2011). Aggravating this situation, inclusion is often discussed with regards to ethics and norms and therefore causes uncertainty among (pre-service) teachers, not least, because of a missing practical definition and missing underlying inclusive didactics. However, to successfully implement inclusion at all levels of (chemistry) education, it is necessary that (pre-service) chemistry teachers acquire appropriate competences and accept their responsibility for the learning process and development of all students (Booth & Ainscow, 2002), which has been shown in several research studies (Gross & Reiners, 2012; Abels, 2015). Thus, the role perception of teachers plays a significant role in promoting students' equal participation and individual development in inclusive chemistry education (Saloviita, 2015). Particularly with regard to secondary school teachers it also means that they see their role as chemistry teachers as transformers of knowledge rather than as educators (Rouse, 2008). However, numerous studies show that many teachers feel challenged educating students with and without special educational needs simultaneously for several reasons: either they do not feel safe enough for inclusive teaching, have made negative experiences in dealing either with challenging students and/or the required cooperation partners or they simply do not feel responsible because of their own role perception (i.e. Forlin, 2001; Gavish, 2017).

TEACHERS AS CRUCIAL PREDICTORS FOR SUCCESSFUL INCLUSION

Trying to focus on every student's needs, the educational work of teachers is gradually gaining more and more importance and is no longer limited to the transfer of knowledge anymore. In order to implement inclusive education successfully, students' content and social learning must be combined. Learning has to be based on positive student-teacher-relationships and a respective feedback culture. Therefore, cooperative and activating forms of learning must be employed within a flexible and (goal-) differentiated setting (Booth & Ainscow, 2002). Such learning arrangements require professional competences of teachers based on positive attitudes towards and mind-sets supporting inclusion (Florian & Black-Hawkins, 2011). Relevant literature claims that the attitudes towards heterogeneity and inclusion as well as the teachers' competences are of major importance when dealing with the heterogeneity faced in (chemistry) lessons (i.e. UNESCO, 2005; Lindsay, 2007). Exploring day-to-day lessons, it becomes obvious that although teachers are familiar with particular strategies for adaptive chemistry education, they do not adopt these strategies in their teaching. There might be various different reasons for not doing so, but obviously there are certain decisive factors for teachers whether or not they act according to their theoretical knowledge. According to the Theory of Planned Behaviour, attitudes as well as perceived behavioural control strongly influence behavioural intention and consequently determine the actual performance of a certain behaviour (Fishbein & Ajzen, 1975; Ajzen, 1991). Attitudes can basically be defined as a person's willingness to evaluate a certain set of behavioural beliefs positively or negatively, based on feelings, affections as well as opinions and perceptions (Bierhoff, 2000). Whether intended behaviour leads to actual behaviour, depends on the perceived behavioural control though: the more a person feels capable of carrying out a certain type of behaviour and feels like being able to control this behavioural pattern, the stronger are the intentions to engage in the behaviour in question. The significant influence of behavioural control on a person's actual behaviour is also considered in the concept of self-efficacy, which is based on Bandura's Social-Cognitive Theory. In order to carry out intended behaviour, it is of major importance how confident a person is with their own skills. A person is more likely to perform intended behaviour, if he/she feels certain to successfully master a complex or challenging situation based on competences or qualities like effort and endurance (self-efficacy expectation, (Schwarzer & Jerusalem, 2002)). Besides the person-related self-efficacy and efficacy expectations, the relationship between an action set and the expected result, i.e. the outcome expectancy, plays an important role when engaging in certain behaviour. Consequently, the actual realization of a certain behavioural pattern strongly depends on the person's expectations.

With regard to inclusive chemistry education these theories show, that the teachers' competence is relevant, but not sufficient for actually teaching chemistry in an inclusive and learner-centred way. Moreover, teachers' positive attitudes towards inclusion as well as their confidence in their own competences and self-efficacy, and therefore their perceived capability of satisfying the diverse needs of heterogeneous learner groups, are crucial factors for engaging in certain behaviour.

Based on Dlugosch (2010) the following two aspects are significant for realizing successful inclusive education: ideally teachers have positive attitudes towards inclusion and corresponding role perceptions. They see themselves as responsible for every student and their expectations towards the performances and achievements of every single student are positive. Moreover, they have a high self-efficacy expectation and they are convinced to be able to teach effectively in an inclusive learning environment (Dlugosch, 2010). Jordan et al. (2009) also claim that not only the normative values of a school, but also the attitudes of teachers towards their own roles in the process of inclusive education are fundamental for effective teaching that motivates and fosters students and finally leads to successful learning. Teachers' willingness to take responsibility for all students as well as accepting whatever special educational needs they have („teacher P-I beliefs") and their self-efficacy expectations („teacher efficacy") are crucial for successful inclusive education. (Jordan, Schwartz & McGhie-Richmond, 2009). In summary it can be said that teachers' professional handling of inclusive learning environments requires a high amount of self-regulative skills, such as regulation of emotion and willpower. They are even stronger if a teacher's self-efficacy expectation is high. Furthermore, professional teaching is strongly influenced by teachers' assumptions about and attitudes towards inclusive chemistry education, which sometimes might appear rather contradictory (Baumert & Kunter, 2006).

In order to promote teachers' professional action, it is necessary to provide courses for pre-service chemistry teachers at university, in which they learn how to deal with inclusive classes and reflect upon their opportunities and challenges (i.e. Meijer, 2010). Schlüter & Melle could show that preparing pre-service chemistry teachers for inclusive education in the course of their university education led to a positive change of attitudes, opinions and self-efficacy towards inclusive education (Schlüter & Melle, 2018).

OVERVIEW OF THE PROJECT

Based on the training units from Rouse (2008) ("Apprenticeship of the head, of the hand of the heart") the project aims at exploring how theoretical basic knowledge (head: knowing), practical knowledge (hand: doing) and a positive attitude (heart: believing) can be developed for prospective chemistry teachers in order to reduce individual preconceptions about inclusive chemistry education step by step. Moreover, the question arises whether and to what extend pre-service teachers are able to develop competences and positive attitudes which meet the demands of inclusive education as early as at university.

For this reason, a preliminary study enquiring pre-service teachers' pre-experiences, pre-conditions and pre-conceptions concerning inclusive chemistry education was conducted qualitatively. Based on the results of this study, a course focussing on the particular needs of pre-service teachers regarding inclusive chemistry education, combining theoretical aspects of special (needs) education and practical methodological skills, was designed. The course included and combined elements of promoting theoretical knowledge, practical procedural knowledge and (self-) reflective knowledge (see table 1, and Rouse, 2008).

Table 1. Elements of the course "Inclusive Chemistry Education – Opportunity or Challenge?!".

Knowing	**Develop basic theoretical knowledge** • Particularities of inclusion/ inclusive chemistry lessons; characteristics of chemistry teaching; pragmatic know-how for inclusive chemistry lessons
Doing	**Develop pragmatic and content-related knowledge** • Design and implementation of actual hands-on opportunities for inclusive chemistry education
Believing	**Perceive and reflect upon the different perspectives of inclusion:** • Individual examination of personal experiences and attitudes towards inclusive chemistry education • Experiments in labs with different handicaps, pre-service teachers taking different roles

The main focus of the course was on stimulating active, reflective theoretical discussion and getting practical experience in order to familiarize pre-service teachers with opportunities and limitations of inclusion. Therefore, their attitudes and opinions (self-reflection and self-perception) on the one hand and chemical particularities (reflection upon chemical topics) were discussed. In order to be able to take the individual requirements and pre-requisites of the participating students into account appropriately, the topics were pre-selected and modified according to the needs and aims of the participating pre-service teachers. Additionally, all the topics discussed were dealt with in the context of chemistry education, as only this approach allowed for the pre-service teachers to gain insights into the particular challenges of teaching chemistry in inclusive learning environments and to acquire the respective relevant competences. In this regard the course offered pre-service teachers the opportunity to reduce personal barriers and discover strategies dealing with inclusion. The pre-service chemistry teachers were able to acquire and reflect upon these strategies autonomously and topic-related and could increase their awareness for their newly-acquired skills.

Kopmann & Zeinz (2016) emphasize the importance of being conscious of and reflecting upon existing teacher student beliefs. In combination with the integration of newly acquired knowledge and practicing alternative strategies of action this can lead to effective, sustainable changes in attitude (Kopmann & Zeinz, 2006). In their empirical studies on teacher students' and teachers' attitudes and self-efficacy beliefs Hecht, Niedermaier & Feyerer (2016) found out that university education can provide comprehensive knowledge of and a positive view on inclusion and should therefore create opportunities for gaining experience with inclusion, so teacher students can develop self-efficacy in this respect (Hecht, Niedermaier & Feyerer, 2016). In order to do so, they particularly highlight the necessity of acquiring competences in the fields of diagnosis, differentiation and individualized learning. Additionally, the teacher students should be given opportunities to experience what it means to have special needs as well as time and place to discuss and reflect upon these experiences in order to be able to teach in an innovative and demand-oriented way.

The course has already been conducted three times at two different universities in the course of the master studies programme ($N_{Master\ students}$=57) and has been evaluated with regards to the following superordinate research question: How does a demand- and target-oriented course-setting influence chemistry teacher students' competences with regard to inclusive education? The superordinate research question had to be concretized into the following two research questions:

RQ1 In what way can the course address chemistry teacher students' needs and can consequently lead to the development of key competences?

RQ2 How does the course strengthen chemistry teacher students' confidence to teach chemistry in an inclusive way, work collaboratively when necessary and deal with behavioural disorders?

METHODOLOGY

The long-term aim of the project is to evaluate in what way and to what extent pre-service chemistry teachers are able to develop competences and appropriate attitudes towards inclusive chemistry education at university. Therefore, a mixed-methods research design (Döring, Bortz & Pöschl, 2016) was planned, of which the course is the central element (see fig. 1).

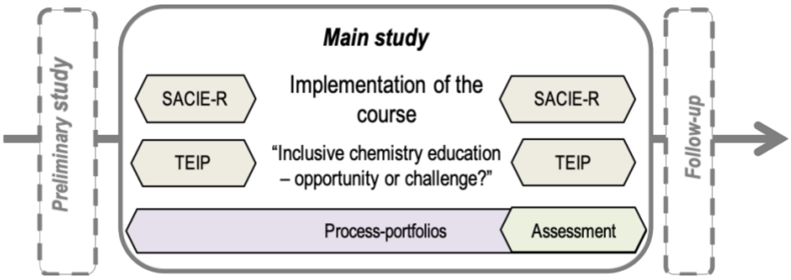

Figure 1. Overview of the research design of the project with research elements and research tools.

In order to develop a demand- and target-oriented course-setting and to be able to answer the research questions, it was necessary to evaluate the needs of pre-service chemistry teachers in advance and to compare those to general research findings (preliminary study). To gain insight into teacher students' needs semi-structured interviews and questionnaires were conducted (*N*=15). Based on these findings a course was developed and conducted (see table 1). The didactic structure of the course took the following aspects into account to the same extent: the aims of teaching chemistry inclusively based on (content-specific) research findings and teacher students' individual preconditions about inclusive chemistry education. The issues that teacher students raised as well as chemical content were considered in each course session in terms of an iterative and reflexive process. The course was qualitatively analysed and evaluated employing process-portfolios which the participants put together during the course. This approach gave teacher students the opportunity to construct, reflect and extend their personal knowledge and attitudes towards inclusion (structuring content analysis, Mayring, 2014). Moreover, before and after the intervention the validated SACIE-R-scale ("The Sentiments, Attitudes and Concerns about Inclusive Education Revised (SACIE-R) scale", 3 subscales with a four-level Likert scale (0-4), Forlin et al., 2011) as well as the validated TEIP-scale ("Teacher Efficacy for Inclusive Practices", three subscales with a six-level Likert scale (0-6), Sharma, Loreman & Forlin, 2012) were used to gain deeper insight into teacher students' shifts of perspectives on inclusive education (see fig. 2). In a follow-up study the acquired competences of the teacher students will be evaluated and analysed with regard to their application in inclusive chemistry lessons.

In the following section the results of the main study shall be presented in more detail. All in all, 57 master students studying at two different universities took part in the main study. 38 participants put together a process portfolio. Concerning the pre-post-questionnaires 42 students filled in the SACIE-R-scale whereas 39 filled in the TEIP-scale. On average the students were 23,5 years old. 52% of them were female. 81% of the participants had no or hardly any experience teaching students with special needs and 60% said that the amount of training they received in teaching students with special needs was limited or very limited.

FINDINGS

The results of the process-portfolios show that pre-service chemistry teachers' knowledge increased in all three dimensions (see table 2): the students gained essential theoretical knowledge about inclusive chemistry education (see K1). Furthermore, the professionalization process was target-oriented as the students had stated that the experiment belonged to every chemistry lesson, no matter how heterogeneous the learning group was. Particularly the pre-service chemistry teachers' self-experience in the lab, taking the role of students with special needs using devices to simulate these demands, allowed them to gain fundamental insights into the design of inclusive chemistry lessons and to improve their teaching (see K3).

Table 2. Excerpt from the categories for the evaluation of the process portfolios (*N*=38).

Categories	Results (anchor statements)
K1 Theoretical basic knowledge *(Knowing)*	"For me, an inclusive chemistry lesson includes four aspects: content learning, social learning, conducting experiments and ensuring safety. [...] Thus, inclusive learning can be ensured by the experiment" [MK, 17;19]
K2 Pragmatic and content-related knowledge *(Doing)*	"The highlight was the practical implementation of the chemistry lesson we designed ourselves. [...] We had difficulties realizing the lesson but this made our insights and impressions even more sustainable." [SE, 08] "For me, particularly the practical examples showed what we had to learn: they showed me which aspects I have to focus on when teaching [students with special needs] […], I am still convinced that experimenting and doing something practically is most important to learn new content." [SK, 40;42]
K3 Self-reflective knowledge *(Believing)*	"Especially the experiences in the lab when I took another role deliberately, gave me safety and new insight into conducting an experiment with different handicaps." [CS, 46] "I feel definitely [...] better prepared now. I also became aware of [...] how important it is to actively reflect and examine the personal role as a chemistry teacher when designing an inclusive chemistry lesson. My focus is on the students' resources and I see myself as a teacher who values and considers heterogeneity and who wants to teach in an unbiased way." [CH, 32]

Based on the newly acquired basic theoretical knowledge, the students were able to build up practical skills (see K2), which in turn changed their views of inclusive education positively and helped them to comprehend their own role as a chemistry teacher in inclusive classes (see K3). This brief insight into the results of the qualitative content analysis of the process portfolios already showed, that the pre-service chemistry teachers could acquire necessary competences for the successful realisation of inclusive chemistry education due to the particular course design. Both, the practical elements and the theoretical discussion of potentials and challenges of inclusive chemistry education positively affected the pre-service chemistry teachers' perception of teaching chemistry inclusively as well as their awareness of their role as teachers. This is also made explicit in the following statement of a participating teacher student: *"[...] The course provided a lot of new experiences, which allowed me to develop new ideas. [...] I learned new approaches towards inclusive chemistry teaching [...]. Experiments are an important part of chemistry lessons and all students, regardless of their limitations, should be encouraged in this field. [...]. The practical experience in the laboratory was helpful as my empathy and my understanding for students with special needs, as well as my self-confidence in differentiating and foster all students in an inclusive environment has grown [...]"* [NM, 23].

The pre-post-test survey about sentiments, attitudes and concerns about inclusive chemistry education (SACIE-R-scale) shows that the pre-service chemistry teachers' attitudes towards inclusion (1st subscale SACIE-R, α=.79) have already been quite positive (M=3,02) and have become even better (M=3,06) after they have taken part in the course. It has to be mentioned though that the visible growth, cannot account for a significant transformation of attitudes (*N*=42, Z=-0.529, *p*=.597). On the other hand, teacher students' sentiments (2nd subscale SACIE-R, α=.62) have already been low (M=1,94) before the course, but have minimally increased (M=1,98) after the course, not significantly though (*N*=42, Z= 0.385, *p*=.700).

In contrast, the subscale "concerns" shows a mediocre effect concerning the reduction of teacher students' concerns (3rd subscale SACIE-R, α=.52) about inclusive chemistry education (*N*=42, M_{pre}=2.87, M_{post}=2,60, Z=-2.816, *p*=.005, r=0.307). Figure 2 shows that particularly those concerns in relation to items 2 and 5 could be reduced (see fig. 2). Before the course, students said they were worried about not being able to give the attention needed to all the learners in an inclusive classroom (item 2) and not having the knowledge and skills required to teach students with disability (item 5). Both concerns could be reduced after attending the course.

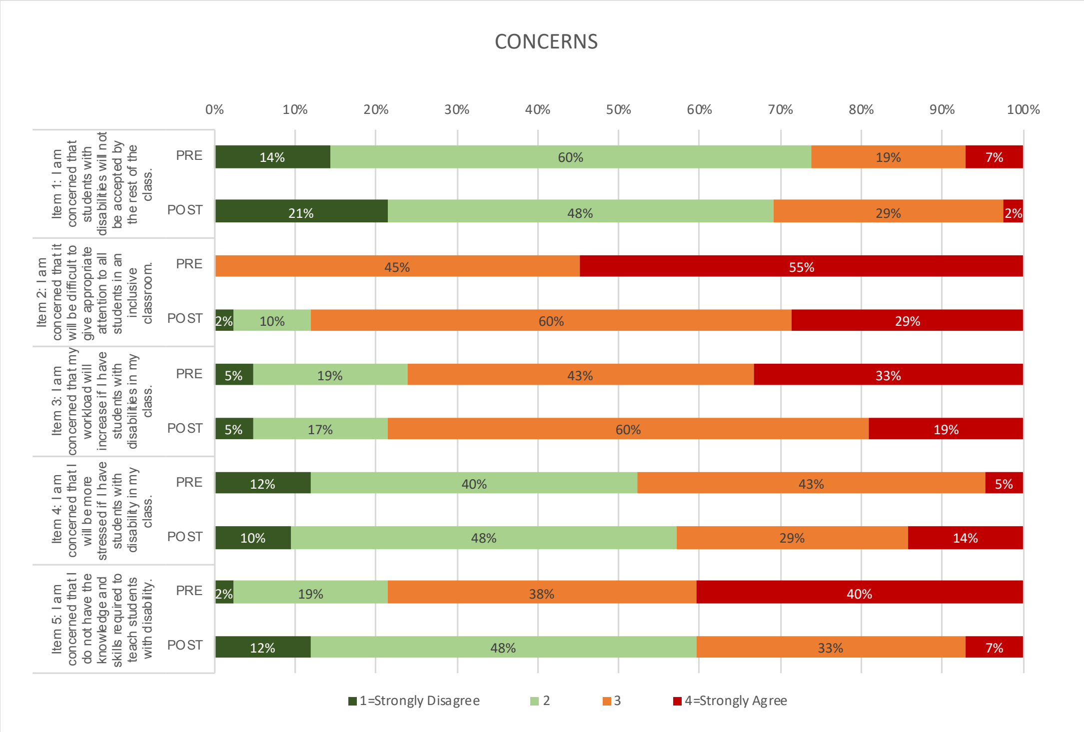

Figure 2. Results of the individual items of the subscale "concerns".

The pre-post-test survey on the pre-service teachers' efficacy for inclusive practice (TEIP-Skala) shows that the teacher students' confidence in their ability to design inclusive chemistry lessons as well as their efficacy to teach chemistry inclusively improved significantly (1st subscale TEIP, α=.71) in the statistics (N=39, M_{pre}=4,44, M_{post}=4,71, t=-3.560, p<.001, d=0.51).

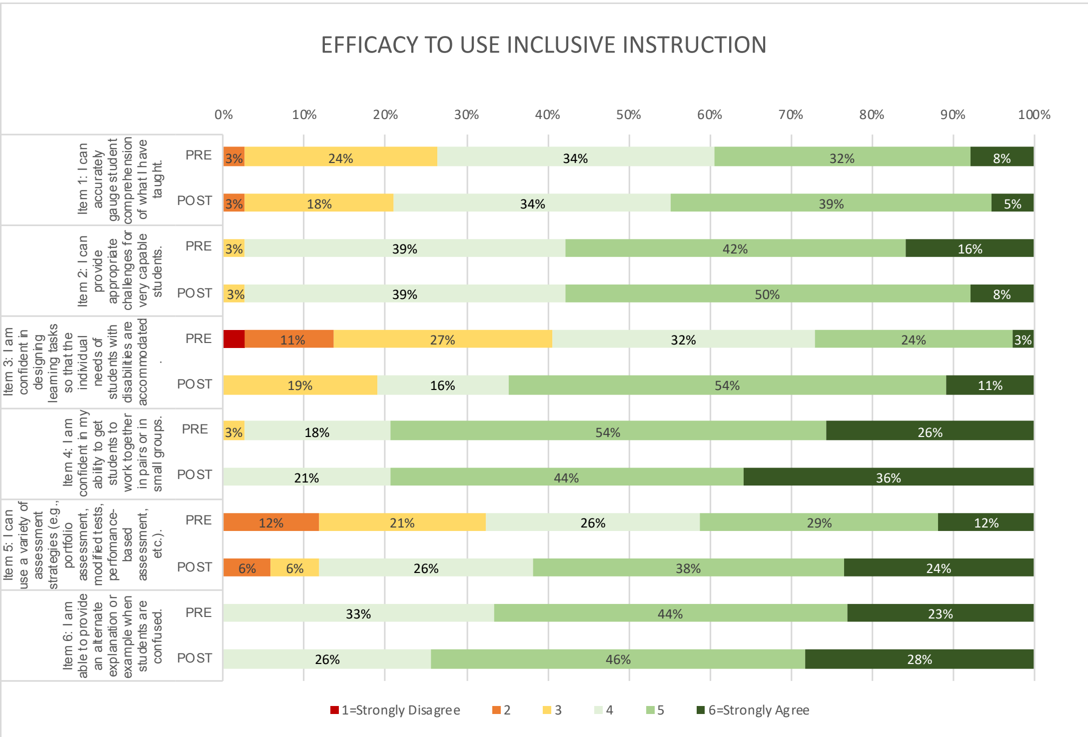

Figure 3. Results of the individual items of the subscale "efficacy to use inclusive instructions".

Breaking down the subscale into individual items shows that the teacher students could particularly gain confidence in designing learning tasks that consider the individual needs of students (item 3) and in using various assessment strategies (item 5, see fig. 3). This increase of self-efficacy when teaching chemistry in an inclusive setting, might be a reason why the pre-service teachers' concerns have decreased significantly (see fig. 2). Additionally, it can be observed that teacher students' efficacy in interdisciplinary collaboration (2nd subscale TEIP, α=.88) has increased significantly (N=39, M_{pre}=4,17, M_{post}=4,58, t=-3.481, p<.001, d=0.56) after attending the course. Furthermore, the analysis of the sample generally shows a rise in pre-service teachers' estimation of their efficacy in managing disruptive behaviour (3rd subscale TEIP, α=.83) after attending the course, to a statistically not relevant degree though (N=39, M_{pre}=4,53, M_{post}=4,64), t=-1.572, p=.124).

CONCLUSION

The results of the study show that through participating in the course pre-service chemistry teachers learned new approaches and gained insights into planning and teaching chemistry in an inclusive way. They were also able to develop a positive attitude towards inclusive chemistry education as well as towards their own roles as instructors in this process (i.e. Schlüter & Melle, 2018). As the sample was rather small, the quantitative data has to be interpreted carefully and it is necessary to link it closely to the results of the qualitative data in order to be able to evaluate the actual effectiveness of the course or parts of the course. Although the students have studied chemistry-related challenges of inclusive chemistry intensively during the course, their practical knowledge and competences are limited to the safe and protected environment of university education. Therefore, further studies must evaluate whether and how students can implement these competences and attitudes they have acquired at university in real, day-to-day situations when teaching chemistry in an inclusive way. Finally, the results and consequences of the whole project must be transferred to other universities in terms of multiplier-trend. Thus, this project may be seen as a relevant step towards inclusive chemistry didactics.

REFERENCES

Abels, S. (2015). Scaffolding inquiry-based science and chemistry education in inclusive classrooms. In N.L. Yates (Ed.), *New Developments in Science Education Research* (pp. 77-95). Hauppauge: Nova science publisher.

Baumert, J. & Kunter, M. (2006). Stichwort: Professionelle Kompetenz von Lehrkräften. *Zeitschrift für Erziehungswissenschaft, 9*(4), 469-520.

Bierhoff, H.W. (2000). *Sozialpsychologie. Ein Lehrbuch*. Stuttgart: Kohlhammer.

Booth, T. & Ainscow, M. (2002). *Index for Inclusion. Developing Learning and Participation in Schools.* Bristol: CSIE.

Dlugosch, A. (2010). Haltung ist nicht alles, aber ohne Haltung ist alles nichts?. *Gemeinsam leben, 18*(4), 195-202.

Döring, N., Bortz, J. & Pöschl, S. (2016). *Forschungsmethoden und Evaluation in den Sozial- und Humanwissenschaften.* Berlin: Springer.

Florian, L. & Black-Hawkins, K. (2011). Exploring inclusive pedagogy. *British Educational Research Journal, 37*(5), 813-828.

Forlin, C. (2001). Inclusion: identifying potential stressors for regular class teachers. *Educational Research, 43*(3), 235-245.

Forlin, C., Earle, C., Loreman, T. & Sharma, U. (2011). The Sentiments, Attitudes and Concerns about Inclusive Education Revised (SACIE-R) scale for measuring pre-service teachers' perceptions about inclusion. *Exceptionality Education International, 21*(3), 50-65.

Gavish, B. (2017). Four profiles of inclusive supportive teachers: Perceptions of their status and role in implementing inclusion of students with special needs in general classrooms. *Teaching and Teacher Education, 61*, 37-46.

Gross, K. & Reiners, Ch.S. (2012). Alternative Documentations of Experiments – A Differentiation and Diagnosis Tool in Chemistry Lessons?. *CnS – La chimicia nella Scuola. Proceedings ICCE-ECRICE, XXXIV*, 141-144.

Hecht, P., Niedermair, C., Feyerer, E. (2016). Einstellungen und inklusionsbezogene Selbstwirksamkeitsüberzeugungen von Lehramtsstudierenden und Lehrpersonen im Berufseinstieg – Messverfahren und Befunde aus einem Mixed-Methods-Design. *Empirische Sonderpädagogik, 1*, 86-102.

Jordan, A., Schwartz, E., McGhie-Richmond, D. (2009). Preparing teachers for inclusive classrooms. *Teaching and Teacher Education, 25*, 535-542.

Kopmann, H. & Zeinz, H. (2016). Lehramtsstudierende und Inklusion. *Zeitschrift für Pädagogik, 62*(2), 263-281.

Lindsay, G. (2007). Educational psychology and the effectiveness of inclusive education/mainstreaming. *British Journal of Educational Psychology, 77*, 1-24.

Mayring, P. (2014). *Qualitative content analysis: theoretical foundation, basic procedures and software solution*. Klagenfurt, Retrieved from http://nbn-resolving.de/urn:nbn:de:0168-ssoar-395173.

Meijer, C.J.W. (2010). Special Needs Education in Europe: Inclusive Policies and Practices. *Zeitschrift für Inklusion, 4*(2), Retrieved from https://www.inklusion-online.net/index.php/inklusion-online/article/view/136/136.

Rouse, M. (2008). Developing Inclusive Practice: A Role for Teachers and Teacher Education?. *Education in the North, 16*, 6-11.

Saloviita, T. (2015). Measuring pre-service teacher's attitudes towards inclusive education: Psychometric properties of the TAIS scale. *Teaching and Teacher Education, 52*, 66-72.

Schlüter, A.-K. & Melle, I. (2018). Professionalization of Future Chemistry Teachers for Teaching in Inclusive Classrooms. In O. E. Finlayson, E. McLoughlin, S. Erduran & P. Childs (Eds.), *Electronic Proceedings of the ESERA 2017 Conference. Research, Practice and Collaboration in Science Education, Part 13* (co-ed. M. Evagorou & M. Michelini), (pp. 1709-1720). Dublin, Ireland: Dublin City University.

Schwarzer, R., Jerusalem, M. (2002). Das Konzept der Selbstwirksamkeit. In: M. Jerusalem, D. Hopf (Hrsg.). *Selbstwirksamkeit und Motivationsprozesse in Bildungsinstitutionen*. Zeitschrift für Pädagogik, Beiheft 44, 28-53.

Sharma, U., Loreman, T. & Forlin, C. (2012). Measuring teacher efficacy to implement inclusive practices. *Journal of Research in Special Education Needs, 12*(1), 12-21.

UNESCO (2005). *Guidelines for Inclusion: Ensuring Access to Education for All*. Retrieved from http://unesdoc.unesco.org/images/0014/001402/140224e.pdf.

ARE WE PREPARING TEACHERS FOR INTERDISCIPLINARY PRACTICE? A LOOK TO THE PRESERVICE CHEMISTRY TEACHER EDUCATION IN BRAZIL

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The official documents regarding secondary and higher education in Brazil outline the importance of practices related to contextualization and interdisciplinarity in initial teacher education. In this scenario, formative activities have been implemented in the curricular structure of the initial teacher education that aims to approach specific contents, teaching practices, and aspects related to contextualization and interdisciplinarity. One of the primary curricular changes involves the implementation of the so-called Practice as a Curricular Component (PCC), to articulate knowledge and to provide the transposition of the pedagogical knowledge to teaching-learning situations. In this work, a survey was made of how actions related to practices associated with contextualization and interdisciplinarity have been implemented, to recognize in which context these actions are developed. We verified that most of the activities occur in non-curricular practices. Also, the PCC is practically absent about contextualized and interdisciplinary training proposals.

Keywords: Context-based Learning, Preservice Teacher Education, Science Education Policy

INTRODUCTION

There are several ways to approach the concepts of interdisciplinarity and contextualization in teaching, and there is no consensus on its definition. For interdisciplinarity, Lenoir and Hasni (2004) point out the existence of different concepts: francophone, oriented to a work of epistemological reflection; the anglophone American, which has an instrumental perspective ("know-how") and the Brazilian concept with a subjective logic and privileges the human and affective dimensions. The contextualization considers education as one that promotes critical thinking so that students can use the scientific knowledge to understand reality, to transform it, and, in this way, an education that promotes citizen participation in decision-making.

The official documents related to education in Brazil reflect the importance of the theme. About the teachers in training, the profile of the graduate students must be "...based on principles of interdisciplinarity, contextualization, democratization, pertinence and social relevance ..." (Brasil, 2015, p.7).

In this perspective, public policies have been implemented through teaching training programs and curricular changes to favor the development of professional knowledge. These include two proposals: PIBID (Institutional Program for Teaching Initiation Scholarships) and PCC (Practices as a Curricular Component) and these are practices that enable a contextualized and interdisciplinary work.

The first offers teaching initiation scholarships to undergraduate students who, under the guidance of a university teacher and the supervision of a secondary teacher, are dedicated to teaching and teaching-related activities in public schools. Although this program was implemented in 2008, it is intermittent, and each implementation lasts years and a half on average.

The second is part of the curriculum of undergraduate courses, corresponding to a total of 400 hours, and its goal is to articulate different practices to provide the transposition of specific knowledge for teaching-learning situations. The PCC may occur throughout the training course and may be applied from the first semester and distributed into specific subjects or subjects designed for this purpose. As part of the curriculum of all courses, this program includes all undergraduate students.

Considering different practices that exist in teacher training courses and that it is a viable path for the development of contextualized and interdisciplinary activities, the present work seeks to raise data and interpretations of how the contextualization and interdisciplinarity are present in the initial training courses of chemistry teachers of Brazilian Educational Institutions. For this, we analyzed the works on the subject, published in congresses and journals on teaching science in the Brazilian scenario.

METHODOLOGY

This paper presents itself as a qualitative research (Bogdan & Biiklen, 1994) and was carried out from the reading and categorization of papers presented in two Brazilian congresses (National Meeting of Science Education Research and National Meeting of Chemistry Teaching) and six journals whose theme is science or chemistry teaching (Electronic Journal of Science, Science and Education, Journal Essay, Research in Science Teaching, New Chemistry at School and Brazilian Journal of Science Education Research).

The research was implemented using the keywords contextualization, interdisciplinarity, and practice as a curricular component, for works published from 2013 to 2018. After searching for the keywords, we proceeded to read the abstracts, and the articles dealing with contextualized or interdisciplinary practices in the initial training courses of chemistry were read in full. The analytical treatment of the information was the categorization of the texts. Text Categorization consists of classifying texts by thematic categories based on a predefined set, and it is possible to incorporate new classifications throughout the analysis (Sebastiani, 2002).

RESULTS AND DISCUSSION

As noted earlier, a literature review was performed, which resulted in a total of 297 works. As an initial filter, we selected the works related to the initial formation of chemistry teachers. For categorization, we decided for mixed categorization, with a priori and a posteriori categories. The categorization resulted in 55 papers related to interdisciplinary or contextualized practices developed in the initial teacher training course of chemistry.

Table 1 shows the defined categories and the number of related works. It is noteworthy that the categories came from the curricular structure of the training courses, which subdivide the course into specific disciplines (chemistry in this case), pedagogical disciplines, practicum, training programs, or policies – PIBID, and practices developed in the PCC. Throughout the analysis, we noticed a set of works that were developed by research groups in the initial formation in different ambiances, defining this as a posteriori category.

Table 1. Works related to contextualized/interdisciplinary activities developed in the initial formation of chemistry graduates.

ACTIVITY	number of works
PIBID	27
Practicum	13
Research/study groups/workshops	9
Pedagogical disciplines	3
PCC	2
Not informed	1
Chemistry disciplines	0
Total	**55**

The results show that 27 (49%) of the papers presented refer to contextualized/interdisciplinary practices in PIBID, 13 (23.6%) in practicum, 9 (16.3%) in research groups, and 2 (3.6%) in the PCC. Surprisingly, we found no reports of work developed in the specific disciplines of the undergraduate chemistry course.

The largest number of published works refers to the activities developed in the PIBID, which is part of the National Teacher Training Policy of the Ministry of Education and aims to allow the students to experience the pedagogical practice in the school context in the first half of the course.

Among the 27 works that are part of this research, there are examples of using PIBID to develop contextualized practices with undergraduates, such as Maciel et al. (2017), who used the jigsaw cooperative learning technique to study the chocolate. The undergraduates studied various aspects related to the theme, such as cocoa and chocolate composition, its history, and production.

Some works aim to develop professional knowledge necessary for the contextualized work in the undergraduates. Silva et al. (2016) developed with the students a contextualized didactic sequence about oil for the teaching of hydrocarbons. The sequence was applied to the secondary students by the undergraduates. They also wrote a diary with considerations about the development of the work, in which they reflected on the stages of the process, from the planning to the reflection on the teaching practice.

Nogueira and Fernandez (2019) conducted a “state-of-the-art” study of papers presented in journals and dissertation and theses about PIBID, and report that the participation of undergraduates in the program “influenced the professional choice, contact with various teaching methodologies and the perception that the chemical contents should be appropriate to the school context” (p.10). Also have enabled “a critical and reflective training on the teaching practice, besides emphasizing that the studies directed to the structuring of the classes were fundamental for their development as students” (p.10).

From the quantity and content of the works, it is possible to infer that PIBID has been established as an important teacher training program in Brazil since its implementation in 2008, and contributes significantly to the development of the professional knowledge of undergraduates. However, the program does not include all undergraduate students, since the granting of scholarships depends on federal government-sponsored edicts and budget allocation, varying with the country's political and economic situation.

The second category with the largest number of works is the practicum, which constitutes a broad possibility for the development of interdisciplinary and contextualized activities since they are related to the intervention and performance of the future teacher in the real classroom setting. As they are compulsory subjects of the degree course, they include all undergraduates. Thus, the existence of works related to this category is considered positive.

As an example, Pena and Quadros (2016) used the practicum to develop didactic sequences with the undergraduates based on a textbook considered innovative and that uses generating themes, as opposed to traditional textbooks. The students prepared didactic sequences about water and the environment and had the opportunity to teach secondary students. The authors report that the discussions during the elaboration of the sequences generated conflict in the undergraduates due to the different proposals. However, these discussions have somehow influenced the practice of these undergraduates during the immersion to teaching and were important to their development.

Despite being a privileged opportunity for contextualized and interdisciplinary work, practicum depends fundamentally on teacher involvement, both on the part of the teacher educator at the university and the supervising professor at the school where the graduate will work. Thus, not all experiences achieve the expected result, which is the development of the professional knowledge of undergraduates.

Lopes and Falcomer (2015) report that some of the problems pointed out by students refers to the school structure that suppresses the availability of supervising teachers to work with undergraduate students. The secondary curriculum structure, which is fragmented, makes it difficult for teachers from different areas to work together and leads to a lack of willingness on the part of teachers to carry out contextualized or interdisciplinary work.

Regarding the PCCs, there is a low number of contextualized/interdisciplinary works, a fact that can be contradictory, since such practices enable the development of this type of activity, and, as a part of the curriculum, it involves all students. Its development can take place within specific chemistry disciplines or as a discipline that integrates others, such as pedagogical disciplines.

In this sense, the activities of PCC would enable the integration between pedagogical, chemical and other knowledge areas, in addition to knowledge related to teaching chemistry in basic education, thus promoting the reflective process in the undergraduate student, surpassing the model based on the segregation between specific and pedagogical knowledge, whose character was too theoretical (Saviani, 2009). It is observed, however, that although the reformulation was implemented in 2002, there is still a great difficulty for its effectiveness.

When discussing the training of higher education teachers, Pereira and Mohr (2017) observe that the majority of teacher educators feel unprepared for teaching and the development of PCC activities, since their training took place to privilege specific knowledge over the integration of theory and practice, present in the current model.

The PCC involves a clear intersection between specific content and pedagogical content, which means that it must be conducted by professionals who can work in these two spheres of professional knowledge. Thus, for its implementation, the teacher training process must be stimulated, so that they can develop in students the professional knowledge necessary for their performance when they become teachers.

In the Brazilian scenario, in general, the teachers responsible for the pedagogical disciplines have training in pedagogy or similar areas and may not have the theoretical framework of the specific discipline to carry out this articulation. On the other hand, teachers responsible for chemistry subjects often lack pedagogical training and, therefore, are not formally prepared to carry out this articulation (Viveiro & Campos, 2011). On the other hand, some reformulations in the guidelines have been carried out in several undergraduate courses to address this issue, and, in several courses, subjects such as an internship or other subjects of a pedagogical nature have already been taught by teachers with specific training.

Although all articles have highlighted the importance of contextualized work, the scenario chosen for its development is almost always dissociated from the specific subjects of the course, and pedagogical subjects. The task of interdisciplinary and contextualized work is delegated to the practicum or non-curricular proposals such as PIBID and study groups, and not to specific chemistry subjects. As an example, most works with this characteristic occur in activities not related to the course curriculum (65.3%) - PIBID, study groups, and thematic workshops.

Among the few works developed in pedagogical or specific disciplines, Sampaio, Bernardo, and Amaral (2016) bring an interesting proposal to the contextualized work in which the authors used the methodology of the study cases with undergraduate chemistry students in the discipline of pedagogical practices. The topic studied was the implementation of a thermoelectric plant, which was in vogue at the time in the State of Pernambuco, where the university stays. The authors point out that students understood the various scientific concepts related to the theme, such as combustion, energy conversion, physical transformations, environmental issues, among others. Also, they developed argumentative and critical skills when positioning for or against the installation of the plant.

Another example is the work developed by Barros, Bittencourt, and Volpato (2016) in which they discussed why different soils present different colors. They used bond theories as theoretical support. They discussed the limitations of the Valence Bond Theory and the applicability of the Crystal Field Theory to explain soil colors since the colorful minerals have a metallic center in their structure.

The authors noted that there was an increase in students' understanding of the topic and reported students' satisfaction in working with the concept in a contextualized way. One caveat of the authors regarding the work done was the lack of time to accomplish activities such as reading texts and carrying out experiments, which could contribute even more to the learning of the theme.

This approach uses an everyday theme (color of different soils) to work on complex concepts (Valence Bond Theory and Crystal Field Theory), and allows, in addition to theoretical classes, experimental activities. Thus, it could be used in the specific discipline of the course in which these bonding theories are taught; however, it was carried out in a study group with a small number of undergraduate students.

Reading the selected articles shows that none of the works proposed contextualization as a part of the specific subjects of the course (General, Organic, Inorganic, Analytical, Physical Chemistry, or Biochemistry). The closest to this scenario involves collaborative work between different teachers, including technical and pedagogical disciplines. This fact highlights the difficulties of educators themselves about working with contextualized chemistry classes, which is reflected in the reproduction of technical classroom models (Viveiro & Campos, 2011).

CONCLUSIONS

The official documents of basic and higher education in Brazil point out the importance of teacher training with a focus on interdisciplinary and contextualized work. All the works analyzed consider these aspects important. However, the development of activities rarely occurs in the chemistry disciplines, and most of the works delegate the task of interdisciplinary and contextualized work to the disciplines of practicum and extracurricular proposals.

The insertion of the PCC in the initial training courses represents a (theoretical) progress regarding the previous model and a possibility for the promotion of contextualized and interdisciplinary actions. We emphasize, however, that there is a need to better structure this training component, especially about the educators (teachers who work developing the PCC).

In principle, it is necessary to implement the practice as a curricular component within the scope of specific disciplines. Subsequently, proposals related to contextualization and interdisciplinarity in these same disciplines must be incorporated.

The change in the curricula of undergraduate courses represented a major advance in the initial training of teachers. It is now up to the teachers the challenge of overcoming their limitations, promoting meaningful learning for undergraduate students. Also, it is necessary to overcome the model for implementing innovative proposals only in activities different from specific disciplines.

There are already programs, albeit incipient, for the pedagogical training of teacher educators (initial and continuing education) at Brazilian universities. It is necessary to improve these actions, as well as the investigation of their impacts. Also, it is possible to implement joint actions between teachers in the field of education and the field of chemistry, expanding the scope of knowledge of teachers.

The impacts of new regulations and programs on education must be investigated in the long term. Although there are gaps to be addressed, an increase in proposals that involve interdisciplinarity in Brazilian secondary education has been observed in the literature (Lamego & Santos, 2017). Thus, investing in new teacher training actions can further contribute to the expansion of these proposals.

ACKNOWLEDGEMENT

F.O thanks IFSP for permitting time-off from work to accomplish her doctorate.

The authors thank the Chemistry Institute of the University of Campinas and the research group PEmCie.

REFERENCES

Barros, M. R., Bittencourt, O. R., & Volpato, H. A. M. (2016). Cores da Terra: Uma Temática para o Ensino de Química Inorgânica na Formação Inicial de Professores [Colors of the Earth: A Theme for Teaching Inorganic Chemistry in Initial Teacher Education]. Presented at the Encontro Nacional de Ensino de Química, Florianópolis, Brasil. Retrieved from http://www.eneq2016.ufsc.br/anais/resumos/R0707-1.pdf

Lamego, C. R. S., & Santos, M. C. F. (2107). Interdisciplinaridade e educação em ciências: uma pesquisa bibliográfica nos Anais do I - X ENPEC (1997 – 2015) [Interdisciplinarity and science education: bibliographic research in the Annals of I - X ENPEC (1997 - 2015)]. Presented at the X Encontro Nacional de Pesquisa em Educação em Ciências, Florianópolis, Brasil. Retrieved from http://www.abrapecnet.org.br/enpec/xi-enpec/anais/resumos/R1317-1.pdf

Lenoir, Y., & Hasni, A. (2004). La interdisciplinaridad: por un matrimonio abierto de la razón, de la mano y del corazón. [Interdisciplinarity: for an open marriage of reason, hand and heart]. Revista Ibero-Americana De Educación, (35), 167-185. Retrieved from https://rieoei.org/historico/documentos/rie35a09.htm

Lopes, E. A. M., & Falcomer, V. A. S. (2015). Praticando interdisciplinaridade durante o estágio supervisionado em ensino de ciências naturais [Practicing interdisciplinarity during the supervised practicum in natural science teaching]. Presented at the Encontro Nacional de Pesquisa em Educação em Ciências, Águas de Lindóia, Brasil. Retrieved from http://www.abrapecnet.org.br/enpec/x-enpec/anais2015/resumos/R2023-1.PDF

Nogueira, K. S. C., & Fernandez, C. (2019). Estado da arte sobre o Pibid como espaço de formação de professores no contexto do ensino de química [State of the art on Pibid as a space for teacher training in the context of chemistry teaching]. *Ensaio Pesquisa Em Educação Em Ciências* , *21*, 1–27. https://doi.org/10.1590/1983-21172019210128

Oliveira, B. R. M., Kiouranis, N. M. M., Eichler, M. L., & Queiroz, S. L. (2017). Chocoquímica: construindo conhecimentos acerca do chocolate por meio do método de aprendizagem cooperativa Jigsaw [Chocochemistry: building knowledge about chocolate through the Jigsaw cooperative learning method]. *Química Nova Na Escola*, *39*(3), 277–285. https://doi.org/10.21577/0104-8899.20160085

Pena, D. M. B., & Quadros, A. L. A. (2016). A prática docente de professores em formação em Química: a lida com um material didático “inovador” [The teaching practice of teachers in Chemistry training: dealing with “innovative” teaching material]. Presented at the Encontro Nacional de Ensino de Química, Florianópolis, Brasil. Retrieved from http://www.eneq2016.ufsc.br/anais/resumos/R0816-1.pdf

Pereira, B., & Mohr, A. (2017). Prática como Componente Curricular: que novidade é essa 15 anos depois? [Practice as a Curricular Component: what's new 15 years later?] (1st ed., pp. 193-210). Florianópolis: UFSC-CED-NUP.

Sampaio, A. A. M., Bernardo, D. L., & Amaral, E. M. R. (2016). Análise de Uma Estratégia de Estudo de Caso Vivenciada por Licenciandos de Química [Analysis of a Study Case Strategy Experienced by Chemistry Graduates]. *Química Nova Na Escola*, *38*(2), 173–180. https://doi.org/10.5935/0104-8899.20160023

Saviani, D. (2009). Formação de professores: aspectos históricos e teóricos do problema no contexto brasileiro. [Initial teacher training: historical and theoretical aspects of the problem in the Brazilian context] Revista Brasileira De Educação, 14(40), 143-155. Retrieved from http://www.scielo.br/pdf/rbedu/v14n40/v14n40a12.pdf

Sebastiani, F. (2002) Machine Learning in Automated Text Categorization. ACM Computing Surveys, 34, 1-47. Shulman, L. (1987). Knowledge and Teaching: Foundations of the New Reform. Harvard Educational Review, 57(1), 1-23. doi: 10.17763/haer.57.1.j463w79r56455411

Silva, F. C. S., Oliveira, T. A. L., Matos, F. I., Silva, M. S., & Silveira, M. P. (2016). Reflexões de um grupo de bolsistas do Pibid Química UEM sobre o processo de elaboração de uma Sequência Didática [Reflections by a group of scholarship holders from Pibid Química UEM on the process of preparing a Didactic Sequence]. Presented at the Encontro Nacional de Ensino de Química, Florianópolis, Brasil. Retrieved from http://www.eneq2016.ufsc.br/anais/resumos/R0970-1.pdf

Viveiro, A. A., & Campos, L. M. L. (2011). Um olhar sobre os docentes de área específica em um curso de licenciatura em ciências: reflexos na formação inicial de professores [A look at teachers in a specific area in a science degree course: reflections on initial teacher education]. Presented at the Encontro Nacional de Pesquisa em Educação em Ciências, Campinas, Brasil. Retrieved from http://abrapecnet.org.br/atas_enpec/viiienpec/resumos/R0220-2.html

EXAMINATION OF PRE-SERVICE PHYSICS TEACHERS' PROBLEM SCOPING IN ENGINEERING DESIGN PROCESS OF A STEM PROJECT

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STEM is an interdisciplinary field of science, technology, engineering and mathematics. Engineering design process has a crucial role to integrate STEM effectively because it supports many opportunities for the students. It includes a real-world context for learning science and maths by using high-level thinking and problem-solving skills. STEM student competencies are key elements in the engineering design process. One of these STEM student competencies is problem scoping. Problem scoping is a skill that designers need to learn and practice to be effective. The aim of this study was to examine pre-service physics teachers' problem scoping in Roller Coaster STEM activity. For this purpose, STEM approach was conducted with a total of 16 pre-service physics teachers in a state university during one semester. Multiple case study design was carried out for this research. Activity papers and project presentation video records of the pre-service physics teachers were analyzed. Findings showed that they highly focused on the materials to be used in the activity. Most of the pre-service physics teachers did not focus on energy conservation equations on problem scoping and they jumped to the solution of the problem or prototyping.

Keywords: Engineering design process, STEM, pre-service teachers.

INTRODUCTION

Nowadays, STEM education is one of the most intriguing educational movements (Sanders, 2009). It is an interdisciplinary field of science, technology, engineering and mathematics (Bybee, 2013). "STEM education" has become a commonly-used term in K-12 education and there are some definitions of STEM based on the content. Bybee (2013) points out that STEM education integrates all the four disciplines and engineering design process to promote problem solving and innovation. Another definition of STEM education belongs to Moore and his colleagues (2014). In their opinion, integrated STEM education is a curriculum design that combines all or some of the STEM disciplines into the lesson by using real-world problems. On the other hand, Kelley and Knowles (2016) argue that integrated STEM education is an approach to teaching STEM from two or more STEM disciplines through an authentic context.

Engineering is a challenging situation for integration for many science teachers. A lack of knowledge about engineering confines teachers' and pre-service teachers' efforts to integrate engineering in to their science teaching (Guzey et al., 2014). Guzey and colleagues (2019) suggest that more research is required to identify effective examples of integrated engineering design process. According to Purzer and Shelley (2018), STEM competencies are key elements in the engineering design process. These competencies are problem scoping, evidence-based decision making, idea fluency, engineering ethics, process awareness, and technical communication and teamwork.

The current study presents findings from pre-service physics teachers' problem scoping in engineering design process. The research question guiding this study was as follows: How do pre-service physics teachers refine a problem as a problem scoping competency in engineering design process?

Problem scoping means developing a problem statement from the perspectives of stakeholders and refining the problem statement as additional information found through the process of design (Purzer and Shelley, 2018). Because engineering design problems are complex and problem scoping can be a key factor for a better understanding of the engineering design process. Atman and colleagues (2009) created a model in their work to better understand the design process. In this model, as shown in Table 1, there are definitions for design activities and stages. According to this model, the problem scoping includes the process of defining the problem and gathering the information necessary for the solution of the problem.

Table 1. Definitions for design activities and stages. (Atman, Deibel and Parnell, 2009)

Stage	**Activities Involved**
Problem Scoping (SC)	Problem Definition, Gathering Information
Designing Alternative Solutions (DAS)	Generating Ideas, Modeling, Feasibility Analysis, Evaluation
Project Realization (PR)	Decision, Communication
Design Activities	
Activity	**Definition**
Problem Definition (PD)	Defining the details of the problem
Gathering Information (GATH)	Collecting information needed to solve the problem
Generating Ideas (GEN)	Thinking up potential solutions (or partial solutions)
Modeling (MOD)	Detailing how to build a solution or parts of a solution
Feasibility Analysis (FEAS)	Assessing possible or planned solutions
Evaluation (EVAL)	Comparing two or more solutions within constraints
Decision (DEC)	Selecting one idea or solution
Communication (COM)	Revealing and explaining design elements to others

In detail, problem scoping occurs both at the beginning of the design process, when designers do not have specific solutions in their minds and when they redefine the problem while developing the solution. According to Watkins and her colleagues (2014), problem scoping includes more than listing criteria and information, it includes prioritizing and integrating different aspects of the problem so they argue for the importance of attending to the following features in students' problem scoping:

1. Naming: Identifiying the different constraints, criteria and pieces of information in a problem
2. Setting the context: Considering interactions among problem requirements and prioritizing different components in a problem
3. Reflecting: Acknowledging and evaluating the problem in detail.

Although research in the literature explains what needs to be done to determine the problem scoping in the design process, there is still a comprehensive question that needs to be addressed:

In what ways do pre-service physics teachers evaluate the problem scoping? How do they make this evaluation individually and in groups?

METHODOLOGY

Document analysis, a qualitative research method, was used in the process of examining the problem scoping of physics teacher candidates. Bowen (2009) defines this research method as the researchers interpreting and making sense of the documents related to the study systematically. According to Bowen (2009), this method includes thematic coding of the content of the document as in the analysis of the interview copies. In this study, STEM activity papers were used as data collection tool. Activity papers include the daily life problem as well as what should be known to solve this problem and what resources should be used to solve the problem. The answers given by pre-service teachers to the questions on the activity sheet were coded by open coding method and thematic frames were created. Frequencies and percentages of the categories were calculated based on the responses of the participants. The answers of all participants were coded and compared by another researcher. The researchers agreed about 90%, and the agreed results were shared after the differences of opinion were clarified by the method of mutual discussion. In Table 2, all categories of problem scoping of physics teacher candidates are presented. In Table 3, the problem scoping processes of physics teacher candidates in individual and group are presented in more detail. The participants were 16 pre-service physics teachers enrolling in a state university and all of them were female. The participants experienced engineering design based challenges and STEM design challenges by doing the following activities: making the highest tower with spaghettis, my soup does not get cold, my egg does not break, cars that are made with balloons. For the last activity, pre-service physics teachers were asked to design a safe and fast roller coaster with at least two loops with using one-meter long foam insulation track, two different marbles, masking tapes, timer, and metric ruler. In the activity, the problem was to design a roller coaster section that would allow a coaster car (marble) to travel at a high speed without going off the track. The pre- service physics teachers were expected to investigate the roles of both kinetic and potential energy in determining the speed that the roller coaster cars could travel and experiment to determine the effect of the starting hill height and loop diameter on the performance of the roller coaster. When viewed in the all process, the participants identified the problem, defined what was given in the problem, produced possible solutions, developed a prototype to show their solutions, and received feedback from their classmates.

To examine their problem scoping process, K-W-S (What I **K**now- What I **W**ant to Know- What **S**ource I Need) chart was used for each participant from their documents. Findings are composed by comparing these K-W-S charts in individual or in group. Firstly, the pre-service teachers filled K-W-S charts individually after explained the daily life problem situation. They stated what they knew about the problem, what they wanted to know and the method of research for problem solving. They repeated the same procedure after discussing with their group peers. They presented their processes as a group.

RESULTS

In this study, which aimed to determine the problem scoping in the engineering design process of the physics teacher candidates and to reveal the differences of individual and group work in creating a problem scoping, the K-W-S charts were examined. By comparing all K-W-S charts, 175 codes were determined and linked to the related frames. The results of coding were shown in Table 2 with their frequencies and percentages in response to the first research question. A coding scheme of six frames was developed to characterize the extent of the design problem scoping. The definition of each frame was made as shown in Table 2. For example, the design frame included engineering and design related words and decisions about having design. Considering the determined the frames and their percentage, design was the second lowest value among other values for the pre-service teachers. This issue may show us that teacher candidates needed to gain a designer perspective. On the other hand, the participants ignored the limitations, although one of the most important points for solving the given problem was to consider limitations. They solved the problem by trying over and over again.

Materials frame was related to prototype materials that could be used to solve the problem. The pre-service teachers focused on what the materials of the problem were, but not on the properties of the materials or the differences of the materials. Because prospective teachers examined sample STEM projects on the internet, they focused on whether the materials in that project existed. For example, marbles with two different surfaces were used in the STEM activity. One of them had a rougher surface and the other one had a more slippery surface. They noticed that these marbles had different surfaces in the testing section of the engineering design process. This issue was also one of the limitations in the solution of the problem. Teacher candidates were expected to create at least two loops and to travel safely with two different marbles in STEM activity. For this reason, teacher candidates should be enabled to focus on their own materials and problems.

In the process of problem scoping of teacher candidates, physics concepts were the most mentioned 43.29% in K-W-S charts of activity. These concepts were energy (kinetic and potential), velocity, acceleration, friction and centripetal force respectively. But unfortunately, most of the pre-service physics teachers did not focus on energy conservation equations on problem scoping and they jumped to the solution of the problem or prototyping.

Although safety was part of the design, it was considered as a separate frame. The pre-service physics teachers made many attempts to reach a solid or strong structure. Finally, resource of their research frame was formed by utilizing the section I in the K-W-S chart. In order to solve the problem, the pre-service physics teachers identified the use of resources as searching the internet, collaborating with friends, looking at exemplary STEM studies, reasoning, applying mathematical modeling and applying trial and error method. However, attention should be paid on resource use. Doing internet research limited creativity and it brought limited use of the material. Because teacher candidates focused on the materials of exemplary projects they saw on the internet.

Table 2. Definitions of frames, descriptions, frequency and percentage used during the coding process.

Frame	Description	Frequency	Percentage %
Design	Engineering vocabulary, design issues, decisions about having design.	14	8
Materials	Prototype materials to be used to solve the problem	15	8.57
Physical Concepts	Emphasizing the concepts of physics such as velocity, friction, centripetal force and acceleration etc.	74	43.29
Safety	Durability of the structure or track.	24	13.71
Awareness of Limitation	Be aware of restrictions such as number of loops, velocity of the marble etc.	6	3.43
Resource of their research	Determination of resources of the research to find the solution of the problem.	42	23

Table 3 provides more detail about pre-service physics teachers' problem scoping. This table was prepared for the answer to the second research question. With this table, it is tried to reveal the way of the pre-service teachers' creating problem scoping as individual and in a group.

For instance; P-1 (Pre-service physics teacher-1) stated that she needed to minimize the friction force in relation to the daily life problem and she had to ensure the safety of the ball. She wanted to know how to guide the balls. She emphasized that she would conduct relevant research on the Internet. After talking with her group friends, she stated that she would solve the problem by taking into account the friction force. The P-1 and her group mates did not solve the problem for the two different marbles because they thought that the friction force should be low in their problem scoping process. They noticed this situation in the testing process and they made corrections in the evaluation process. Furthermore, P-1 and her group peers did not have any calculation for the roller coaster by using energy conservation equations. They used only trial and error method. If we evaluate the process over the codes, it is seen that P-1 first focused on the concepts of physics and then safety issues. In setting the context, the same participant only considered the design. However, at the end of the group study after the individual study, this participant took into consideration physics concepts, design and safety issues in reflecting period and turned the focus of design as well as the material to solve this problem. The processes of the other participants were presented in the table as in the logic of coding.

There are two issues that are appropriate to address. When we look at the participants of P-3 and P-10, while taking AL (awareness of limitations) individually into consideration, it was not included in the problem scoping in group work. In addition, the participants of P-10, P-11 and P-14 ignored the design in the group work while individually adding the design to the problem scoping. In other words, when it came to group work, some individually conceivable points can be bypassed. The teacher candidates may not have been able to defend what they thought individually.

Table 3. Pre-service Physics Teachers' Frames for Problem Scoping in K-W-S Charts.

Participant	Individual (What I Know)- Naming	Individual (What I Want to Know)- Setting the Context	Individual (What Source I Need)- Setting the Context	Group (What I Know)- Reflecting	Group (What I Want to Know)- Reflecting	Group (What Source I Need)- Reflecting
P-1	PC-S	D	RM-RM	PC-D-S	M-D	RM
P-2	S-D	M	RM	PC- D-S	M-D	RM
P-3	PC-M- AL	PC- M- D- S	RM	PC-S- D	M- D	RM
P-4	PC	PC	RM –RM	S -PC	PC	RM- RM
P-5	-	M	RM	S -PC	PC	RM -RM
P-6	PC- PC	PC	RM -RM	PC -S	PC	RM –RM
P-7	PC -PC	PC	RM	PC -PC	PC -S	RM
P-8	PC	PC- S	RM	PC -PC	PC -S	RM
P-9	PC	D	RM	PC -PC	S	RM
P-10	PC-D-S-S-	PC -PC	RM	PC -PC- S	PC- M -S	RM –RM
P-11	PC- S -D	PC	RM	PC -PC	PC -M -S	RM -RM
P-12	PC- PC- PC	S- PC	RM	PC- PC	PC- M -S	RM- RM
P-13	PC- PC -S	PC -PC	RM	PC- PC- S	PC -MS	RM-RM
P-14	PC- D -D	PC- M	RM	PC –PC	PC- M	RM
P-15	PC -PC	PC	RM	PC –PC	PC- M	RM
P-16	PC –PC- PC	PC	RM	PC- PC	PC- M	RM

Abbreviations in the table are as follows; PC= Physical Concepts, S= Safety, D= Design, M= Materials, AL= Awareness of Limitations, RM= Resource of Research

CONCLUSION AND IMPLICATION

It is thought that providing students with engineering design problems involving multiple disciplines and integrating different disciplines is one of the most critical points of STEM education (Wang, Moore, Roehrig & Park, 2011). Engineering design problems are tools for learning science and mathematics knowledge in STEM education and require an in-depth analysis of these problems (Kolodner, 2002). As stated by Guzey et al. (2014), design process is a challenging situation for integrated STEM for many science teachers. A lack of knowledge about engineering confines teachers' and pre-service teachers' efforts to integrate engineering into their science teaching. In STEM, we need such studies to understand the problem solving in the design process. For this reason, this study was carried out to examine the problem scoping of the prospective physics teachers in the STEM project and to determine their problem scoping in the individual and group work. As a result of these inferences, teachers can effectively integrate STEM into their lessons. Besides, students can use physics concepts to encourage different problem solving methods.

More than half of the pre-service teachers did not use physics concepts when describing the problem and they focused more on the engineering design process. However, it is recommended that engineering should be integrated with science, not as a separate design (Wang et al., 2011). However, this focus is mostly on the prototyping part of the engineering design process. This finding is not compatible with Capobianco and Rupp (2014)'s study. Because they argue that teachers devote most of their time to problem definition, linking with daily life, and solution suggestions, which are the first steps of the engineering design process.

On the other hand, collaboration is important in problem-based learning environments. Because each group member contributes to the process by generating different ideas for understanding and solving the problem (Hung, 2009). In this process, it may be appropriate to consider the different ideas of each of the students. As the existing steps in the individual studies of the students disappeared after the group work, individual activities can be done in addition to group work in STEM activities. Dayton (Ohio) Regional STEM Center (2011) published a framework for quality of STEM education and this framework includes ten components. One of the components of this framework is individual accountability in a collaborative culture. This component explains that quality STEM learning experiences often require students to work and learn independently and in collaboration with others using effective interpersonal skills. Individual accountability is a belief that each member of group is responsible for his/her performance (Laal et al., 2013). As Johnson et al. (1991) suggests, individual accountability is one of the five key elements of collaborative learning. Therefore, students can develop their belief that they are responsible for their work by working individually in STEM activities. In addition, pre-service teachers and in-service teachers can be given argument training to defend their own thoughts.

REFERENCES

Atman, C. J., Deibel, K., & Borgford-Parnell, J. (2009). The process of engineering design: A comparison of three representations. In *DS 58-1: Proceedings of ICED 09, the 17th International Conference on Engineering Design, Vol. 1, Design Processes, Palo Alto, CA, USA, 24.-27.08. 2009* (pp. 483-494).

Bowen, G.A. (2009). Document analysis as a qualitative research method. Qualitative Research Journal, 9 (2),27-40.

Bybee, R. W. (2013). *The case for STEM education: Challenges and opportunities*. NSTA press.

Capobianco, B. M., & Rupp, M. (2014). STEM teachers' planned and enacted attempts at implementing engineering design-based instruction. *School science and mathematics*, *114*(6), 258-270.

Guzey, S. S., Tank, K., Wang, H. H., Roehrig, G., & Moore, T. (2014). A high-quality professional development for teachers of grades 3–6 for implementing engineering into classrooms. *School science and mathematics*, *114*(3), 139-149.

Guzey, S. S., Ring-Whalen, E. A., Harwell, M., & Peralta, Y. (2019). Life STEM: A case study of life science learning through engineering design. *International Journal of Science and Mathematics Education*, *17*(1), 23-42.

Hung, W. (2009). The 9-step problem design process for problem-based learning: Application of the 3C3R model. *Educational Research Review*, *4*(2), 118-141.

Johnson, D.W., Johnson, R.T., & Smith, K. (1991). Active Learning: Cooperation in the College Classroom. Edina, MI: Interaction Book Company.

Kelley, T. R., & Knowles, J. G. (2016). A conceptual framework for integrated STEM education. *International Journal of STEM Education*, *3*(1), 11.

Kolodner, J. L. (2002). Facilitating the learning of design practices: Lessons learned from an inquiry into science education. Journal of Industrial Teacher Education, 39(3), 9-40.

Laal, M., Geranpaye, L., & Daemi, M. (2013). Individual accountability in collaborative learning. *Procedia-Social and Behavioral Sciences*, *93*, 286-289.

Moore, T. J., Stohlmann, M. S., Wang, H. H., Tank, K. M., Glancy, A. W., & Roehrig, G. H. (2014). Implementation and integration of engineering in K-12 STEM education. In *Engineering in pre-college settings: Synthesizing research, policy, and practices*. Purdue University Press.

Purzer, S., & Shelley, M.(2018). *Research Highlights in STEM Education.* ISRES Publishing.

Sanders, M. (2009). Integrative STEM education: primer. *The Technology Teacher*, *68*(4), 20-26.

STEM Education Quality Framework. (2011). Dayton Ohio Regional STEM Center http://daytonregionalstemcenter.org/wp-content/uploads/2012/07/STEM-Framework-Background.pdf

Wang, H. H., Moore, T. J., Roehrig, G. H., & Park, M. S. (2011). STEM integration: Teacher perceptions and practice. *Journal of Pre-College Engineering Education Research (J-PEER)*, *1*(2), 2.

Watkins, J., Spencer, K., & Hammer, D. (2014). Examining young students' problem scoping in engineering design. *Journal of Pre-College Engineering Education Research (J-PEER)*, *4*(1), 5.

WHAT IT TAKES TO BE A GOOD SCIENCE TEACHER? PROJECT-BASED LEARNING AS AN IMPETUS FOR STUDENT-TEACHERS' PROFESSIONAL GROWTH

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This study examines the way in which PBL contributes to the professional-identity development of novice science teachers, and the role of emotional experiences in this process. More specifically, we examine the science student teachers' expectations and emotionally intense experiences as well as the connection between the former and the latter. The data were obtained from the student-teachers' reflective reports (n=32) and were analysed utilising linguistic and non-parametric statistical analyses. The study points out that introducing the PBL approach in a pedagogical course may expose student-teachers to positive emotional experiences and leads to optimistic expectations, which tend to nurture the students' growing confidence as teaching professionals, and, consequently, enhances the development of students' professional identity creating a sense of professional self-efficacy.

Keywords: Teacher education, project-based learning, reflection

INTRODUCTION

The constant search for the best teaching methods by which to promote the development of science student- teachers' professional identity has always been a central issue when discussing teacher-education programs (Caires, Almeida, & Vieira, 2012). One of the most promising approaches is the integration of Project-Based Learning (PBL) into pedagogy and disciplinary courses (Marshall, Petrosino, & Martin 2010; Kokotsaki, Menzies, & Wiggins 2016).

The PBL approach has the potential to positively influence the development of student teachers' professional identity (Tsybulsky & Oz, 2019; Tsybulsky & Muchnik-Rozanov, 2019; Tsybulsky, Gateneo-Kalush, Abuganem, & Grobgeld, 2020). Positive and negative emotionally intense experiences during PBL process play an important role in student-teachers' development of professional identity (Tsybulsky & Muchnik-Rozanov, 2019; Timoštšuk & Ugaste 2012). Another significant yet largely neglected aspect of teacher identity development involves a future dimension of reflective discourse–student teacher expectations. Ursua and Vasquez (2008) view future-projected talk as an essential part of the identity-shaping process that student-teachers undergo. Such projective reflections tend to describe their personal perceptions of how the future events will possibly unfold, based on their current emotions and their professional knowledge and beliefs (Debreli, 2011).

The current study investigats student teachers' perceptions regarding their experiences accumulated while learning about the PBL approach and how these perceptions influenced the development of their professional identity. We focused on the following research question: is there a connection between emotionally intense experiences and student teachers' expectations.

We hypothesized that the greater the number of instances of positively perceived emotionally intense experiences, the greater would be the number of positive expectations and the fewer the number of negative expectations reported by the student teachers. Should our hypothesis be confirmed, we interpret the correlation as an indication that student teachers gained confidence and a sense of professional empowerment, as they began to perceive themselves as more professional and knowledgeable teachers, compared to heir self-perception at the beginning of the PBL. Hence, confirmation of this hypothesis would also provide an indication of the significant role that the PBL process has in stimulating the development of student teachers' professional identity.

METHODOLOGY

Context of the study

The participants of the study were 16 Jewish and Bedouin student teachers in their first year of studies towards the B.Ed. degree with a specialization in teaching sciences at the elementary school level. The sample consisted of men and women between the ages of 20 and 24 years, who resided in the country's southern region and came from a low-to-mid-level socioeconomic background.

The student teachers participated in a yearlong (two semesters) PBL process, which was experienced in the framework of a first-year pedagogical course, consisting of four weekly hours (a total of 121 hours over the course of the year). In addition, during the second semester, student teachers were enrolled in a practicum module, which took place in schools, for a total of six weekly hours (a total of 84 hours for the entire semester). The practicum presented them with the opportunity to implement what they had studied.

Research tools and data collection

The data were obtained from the student teachers' reflective reports submitted at the end of both the first and the second semesters, Overall, a total of 32 reports were analyzed. Participants were instructed to write their reflections in a completely free manner, without any guidance or structure, and to describe, their learning and teaching experiences, as they saw fit, while noting what they found significant, what they felt and thought during the learning process, the difficulties encountered, what they learned from the process, and what they would implement in their professional lives.

Data analysis

Data were analyzed utilizing a multi-level approach integrating linguistic analysis and quantitative non-parametric statistical analyses. Student-teachers' perceived experiences were grouped according to the following categories: (1) positive or negative emotional experiences; (2) prospective reflections conveying expectations.

(1) Experiences Perceived as Positive or Negative

The instances of positively perceived experiences were coded when the student-teachers' descriptions --of either their experiences teaching science classes using a PBL approach or their expectations regarding their professional future-- contained expressions (mainly clauses) using words with a clearly positive connotation. In the context of the present study, a positive connotation refers to positive associations and subjective feelings evoked by a particular word (i.e. an associative, subjective, or affective meaning attributed to a word). A negative connotation refers to an undoubtedly negative feeling evoked through the associative, subjective, or affective meaning attributed to a word. Instances of positively perceived experiences were observed when the student-teachers wrote. “I liked learning”, “I learned a lot about myself”, “I was able to cope well with the study materials”, “I'm feeling very optimistic”, “That's extremely encouraging”, “I'm already able to work much more independently”, etc. Instances of negatively perceived experiences were observed when the student-teachers wrote: “I feel like I'm trying but still not succeeding”, “I found it difficult to answer the question”, “I felt like there were instances in which I began to feel stressed and sometimes I lost my sense of direction”, “Sometimes I felt a bit frustrated', etc.”.

Based on the systemic functional linguistic theory, certain adverbs indicate higher or lower intensity and may convey intensification by emphasising quality of experience. Such intensifiers may be “interpersonally” neutral (e.g., very, much, quite, really, completely, utterly, almost, etc.) or “ derive from some interpersonally significant scale (amazingly, awfully, unbelievably, perfectly, etc.)” (Halliday and Matthiessen 2004, p. 356). The effect of intensification can also be achieved through lexical reiteration, i.e. repetition of a particular lexical item in order to emphasise a given point (Halliday and Matthiessen 2004). We viewed the use of intensifiers as a means of expressing the student teaches’ emotions in reflective narrative as well as the markers of more emotional experiences than those described without the intensifiers. Descriptions were coded as conveying more emotional experiences (both positive and negative) when any intensifier was used regardless of its interpersonal quality, or when certain lexical items were repeated within a span of five adjacent clauses. When the description of perceived experiences did not include intensifiers or lexical reiterations, these instances were coded as unmarked emotional experiences. For example, instances of experiences perceived as more emotional were identified when the students wrote words such as *terribly*, *very, most, much, really, even more, indeed, a lot, so much, amazingly, plenty*, *more (than anticipated*), and *I can*. The following phrases demonstrate various types of intensifiers: “Each day I was happy to be a part of the school… In other words, my confidence and desire to be a teacher grew stronger from one day to the next” (the underlined phrase exemplifies the use of lexical reiteration to emphasize a point); “I am certain that I can stand in front of the class and I am absolutely certain that I chose the right profession” (the intensification via lexical reiteration as well as the use of the intensifier *absolutely*).

(2) Prospective reflections that convey expectations

Following Ursua and Vasquez (2008) we drew a distinction between retrospective reflection (a teacher’s reflection on a certain past action) and prospective reflection, which is seen as reflecting on an intended action. From Throughout the reflective reports, students' descriptions were coded as expectations of future experiences either when the future form of the verb was used (in Hebrew, these forms are characterised by inflectional morphology) or the present tense was used to convey a sense of something to come. The following are examples of phrases coded as expectations of future experiences: “My positive feelings will increase”, “I will continue to face challenges”, “I have no intention of being easy on myself”, “Pedagogy lessons will continue to provide me with tools", "I will be able to conduct a lesson in the classroom", "I will enjoy myself as much as possible", etc.

The frequency of the variables examined was calculated using Spearman's one-tailed correlation test. In particular, correlations were tested between the number of positive/negative emotionally intense perceived experiences (i.e., Working on this project was a *very significant* part of the deep understanding gained of this fascinating profession and therefore ,it opened up a very broad perspective for me'), and the number of positive/negative expectations (i.e.,'I'll continue to face challenges successfully, I'm not going to give up, the pedagogy lessons are going to provide me with various tools').

RESULTS AND DISCUSSION

Reports and descriptions of emotional experiences included both positively and negatively perceived experiences. It was found that emotional experiences (both with and without the intensification) were mostly viewed as positive (88% in the middle of the year, and 92% in the year's end). Table 1 contains a summary of the types of perceived experiences and examples excerpted from the collected data.

Table 1. Examples of Positive and Negative Emotional Experiences.

Emotional Experiences	**Examples with Intensification via Adverbs**	**Examples with Intensification via Lexical Repetitions (reiterations)**
Perceived as Positive. Midyear: 88%. End of the year: 92%	Working on this project was a *very significant* part of the deep understanding gained of this fascinating profession and therefore ,it opened up a very broad perspective for me. (Natalie) There's no doubt that as the year continued, this course contributed *a great deal* to my pedagogical knowledge and was enriching .But more than anything, I found an answer to the question: what does it mean to be an excellent teacher? (Valerie)	*I felt* that the atmosphere in the classroom had changed and *it felt* much better! *I feel* that my confidence is higher after the course: despite having come to realize just how complicated this profession is, *I feel* that I have received numerous tools for coping. (Shira)
Perceived as Negative Midyear: 12%	Before I began studying, I had *lots of* fear, for example: how would I manage to stand in front of the class? (Hanina)	I *was terribly afraid* that I would fail; I *was afraid* that I would not manage to cope in front of an entire class of

End of the year: 8%	students and managed to convey the lesson properly. (Eden)

Findings indicated that student-teachers described mostly positive expectations regarding their professional future, both at the midyear point (72%) and at the end of the year (85%). Their positive expectations, conveyed both through the content of the narrative and by means of linguistic markers, concerned their desire to continue studying and developing on their way to becoming educators in the meaningful sense. Negative expectations were related mostly to anxiety regarding the challenges they would encounter in the classroom and how they would manage the students. Table 2 includes descriptions of positive and negative expectations.

Table 2. Examples of positive and negative expectations.

Prospective Reflections that Convey Expectations	**Examples**
Positive	I want to continue to study and develop, so I can *become* an excellent teacher. (Eden)
Midyear: 72%.	The course's helped me acquire skills that I will continue to *apply* in the. (Iman)
End-of-the-year: 85%	I expect to *continue* learning new things, to acquire additional tools for coping with issues that are important to emphasize in teaching and in forming my professional persona. (Inna)
	I am certain that everything I have learned in this course *will provide* numerous advantages in the following years and in the future. (Natalie)
Negative	I'm afraid that I *won't be able to handle* the students in terms of discipline. (Ya'ara)
Midyear: 28 %.	I am anxious because --what if I *don't succeed* in becoming a significant teacher? (Valerie)
End-of-the-year: 15 %	I worry that I *won't find the time* to prepare the lessons and about how I will perform in classroom. So far only a student of education who still doesn't have all of the tools. (Jabri)

Our findings revealed a significant correlation ($p < .01$) between described emotionally intense experiences and positive expectations. In particular, the high frequency (88% and 92%) of the positively perceived emotionally intense experiences correlated with a higher frequency (72% and 85%) of positive expectations. Thus, also the third hypothesis was confirmed. Moreover, a significant negative correlation ($p < .01$) was found between positively perceived emotionally intense experiences and negative pessimistic expectations. In other words, the high frequency (88% and 92%) of the positively perceived emotionally intense experiences correlated with a lower frequency (28% and 15%) of pessimistic expectations. These correlations were found at the midyear point, as well as at the end of the academic year.

A major implication of this finding is that the high number of emotionally intense experiences that student teachers garnered throughout the process of PBL learning contributed to more optimistic and positive feelings regarding their own future as teachers and reflected a better understanding of just how meaningful PBL process may be for the learners. This way, feeling more hopeful towards the completion of the PBL process points to student teachers' gains in confidence and a sense of professional empowerment, as they start perceiving themselves as professional and knowledgeable teachers. Moreover, relying on the existing literature, positive emotions tend to be associated with implementing more effective pedagogical methods (Ruthig et al., 2007; Trigwell, Ellis & Han, 2012). As our findings revealed, implementing PBL pedagogy, one of the most promising methods in teacher education, resulted in student teachers' positive perceptions of the learning process they underwent.

It should be mentioned that only recently has professional research begun to focus on student teachers' emotional experiences (Anttila et al. 2016) and only a few studies have examined this aspect in the context of shaping professional identity through project-based learning of pedagogical courses (Tsybulsky & Oz, 2019; Tsybulsky & Muchnik-Rozanov, 2019). The current study sheds light on the emotional aspect of the perceptions of the PBL-related experiences and its impact on the student teachers' professional identity. Our findings can contribute to current and future studies on the process of preparing preservice teachers through student-centered, inquiry-based learning approaches such as the PBL. We suggest that this process has the potential to expose student teachers to positive emotional experiences, which are linked to the kind of optimistic expectations that tend to underlie the students' growing confidence as teaching professionals. In turn, these gains in self-confidence reflect the shaping of the student teachers' professional identity, as they learn to view themselves as increasingly confident and knowledgeable teachers. It appears that investigating student teachers' emotional experiences is worthwhile, particularly in the context of understanding student teachers' identity construction and, hence, it is recommended as a direction for further research.

REFERENCES

Anttila, H., Pyhältö, K., Soini, T., & Pietarinen, J. (2016). How does it feel to become a teacher? Emotions in teacher education. *Social Psychology of Education*, *19*(3), 451-473.

Caires, S., Almeida, L., & Vieira, D. (2012). Becoming a teacher: Student teachers' experiences and perceptions about teaching practice. *European Journal of Teacher Education, 35*(2), 163-178.

Debreli, E. (2011). "Use of diaries to investigate and track pre-service teachers' beliefs about teaching and learning English as a foreign language throughout a pre-service training program." *Procedia-Social and Behavioral Sciences*, *15*, 60-65.

Halliday, M. A. K., & Matthiessen, C. (2004). *An introduction to functional grammar*. London: Routledge.

Kokotsaki, D., Menzies, V., & Wiggins, A. (2016). Project-based learning: A review of the literature. *Improving Schools, 19*(3), 267-277.

Marshall, J. A., Petrosino, A. J., & Martin, T. (2010). Preservice teachers' conceptions and enactments of project-based instruction. *Journal of Science Education and Technology*, *19*(4), 370-386.

Meijer, P. C., De Graaf, G., & Meirink, J. (2011). Key experiences in student teachers' development. *Teachers and Teaching: Theory and Practice*, *17*(1), 115-129.

Ruthig, J. C., Haynes, T. L., Perry, R. P., & Chipperfield, J. G. (2007). Academic optimistic bias: Implications for college student performance and well-being. *Social Psychology of Education*, *10*(1), 115-137.

Schepens, A., Aelterman, A., & Vlerick, P. (2009). Student teachers' professional identity formation: Between being born as a teacher and becoming one. *Educational Studies*, *35*(4), 361-378.

Sutton, R. E., & Wheatley, K. F. (2003). Teachers' emotions and teaching: A review of the literature and directions for future research. *Educational psychology review*, *15*(4), 327-358.

Trigwell, K., Ellis, R. A., & Han, F. (2012). Relations between students' approaches to learning, experienced emotions and outcomes of learning. *Studies in Higher Education*, *37*(7), 811-824.

Tsybulsky, D. & Muchnik-Rozanov, Y. (2019). The development of student-teachers' professional identity while team-teaching science classes using a project-based learning approach: a multi-level analysis. *Teaching and Teacher Education*, *79*, 48-59.

Tsybulsky, D. & Oz, A. (2019). From frustration to insights: experiences, attitudes and pedagogical practices of pre-service science teachers implementing PBL in elementary school. *Journal of Science Teacher Education*, *30*(3), 259-279.

Tsybulsky, D., Gateneo-Kalush, M., Abuganem, M. & Grobgeld, E. (2020). Experiences of preservice teachers exposed to project-based learning. *European Journal of Teacher Education*. http://dx.doi.org/10.1080/02619768.2019.1711052.

Ursúa, A., & Vásquez, C. (2008). "Reflection and professional identity in teachers' future-oriented discourse." *Teaching and Teacher Education*, *24*(7), 1935-1946.

BECOMING A CHEMISTRY TEACHER – EXPECTATIONS FOR CHEMISTRY EDUCATION COURSES

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The development of professional competence is of major importance for each education student and ultimately, for the entire education system. Therefore, optimising the learning processes of these students is a goal of professional development at the university level. Learning processes are influenced by the prior knowledge, beliefs and expectations individuals hold. Gaining insights into student beliefs and expectations should provide an opportunity to optimise their university courses. To acquire insights in these beliefs and expectations, we used a questionnaire with open questions. We developed a category system based on the COACTIV model of professional competence, with which we categorised all statements given on the questionnaire by the 168 students (BA/MA). The students assume the most important influence on their future profession is whether they have self-related ability cognitions, but they do not expect to develop such cognitions in their university courses. As a consequence of the results, the Division of Chemistry Education is now offering students authentic learning situations with real pupils. This approach provides the chance for the students to try out the teacher role and reflect upon their first teaching experiences. They can revise their image of this role and obtain a realistic view concerning their future profession.

Keywords: professional competence, chemistry education at university

INTRODUCTION

When young, in-service teachers retrospectively reflect on their university studies, a majority expresses a lack of adequate preparation through their courses for the job of teaching chemistry. Education students often experience chemistry (content knowledge, CK), science education (pedagogical content knowledge, PCK) and pedagogy (pedagogical knowledge, PK) as distinct areas in their studies – but the interaction of these areas is of major importance in supporting and enhancing their professionalism as future teachers (Shulman, 1986). The Division of Chemistry Education at FU Berlin tries to work against such student estimations: Firstly, by acquiring insights into the expectations and beliefs students have regarding their future profession and their science education courses. Secondly, by considering these expectations and beliefs in the science education courses to come and – if necessary – fostering a more realistic view of the future profession. Thirdly, by optimising the chemistry education courses to find a balance between subject, education, and the needs of the students (Streller & Bolte, 2018). In this contribution, we focus specifically on these student expectations.

Theoretical Background

In Germany, school education and teacher training is based on standards (KMK, 2004), which are important for study regulations at university. The standards define requirements to be met by teachers, the most important of which being: “Teachers are experts of teaching and learning. Their core task is the specific and scientifically reasoned design and reflection of teaching and learning processes. They should perform their educational role properly, undertake advisory and assessment tasks, and develop their skills continuously” (KMK, 2004, 6). In addition to these general tasks, more specific requirements for each subject in teacher education are described; in chemistry: basic knowledge in organic chemistry, inorganic chemistry, physical chemistry and biochemistry, as well as knowledge in chemistry education and practical teaching skills (KMK, 2008, 12). Finally, the standards describe an enormous catalogue of knowledge, skills, and motivational orientations teacher need to possess.

Beside the normative requirements teachers must meet, educational research about professional development investigates different factors trying to find effective ways to improve (science) education courses. Empirical educational research has investigated various aspects of the teaching profession to improve teacher recruitment and training (EC, 2013; Baumert & Kunter, 2013, 25). In the project COACTIV a model combining findings from various research perspectives was developed and empirically tested.

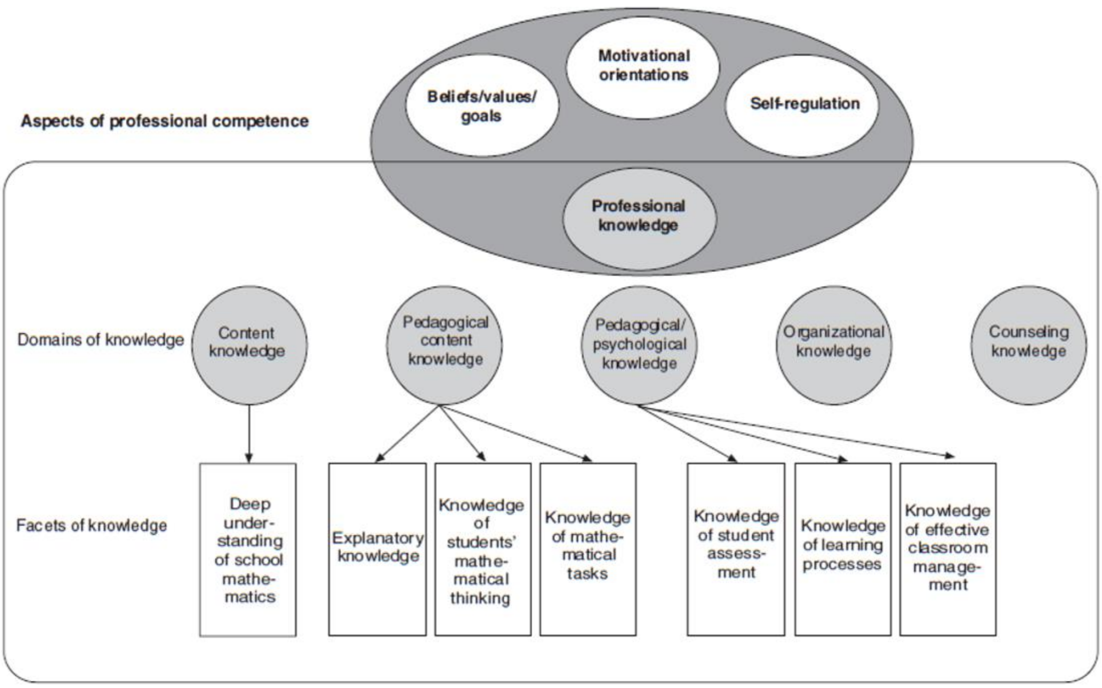

Figure 1. COACTIV model of professional competence in the context of teaching (Baumert & Kunter, 2013, 29)

This non-hierarchical model contains aspects, domains and facets of professional competence (such as knowledge and skills) in the context of teaching; the different facets (Figure 1) are operationalised by concrete indicators (Baumert & Kunter, 2013, 28). For example, an indicator in the domain of pedagogical content knowledge (PCK) and the facet of knowledge of tasks is knowledge of the cognitive demands and the prior knowledge that they implicitly require (Baumert & Kunter, 2013, 33).

Focusing on effective professional development research there are aspects like prior knowledge, beliefs and expectations of learners which have to be known as a starting point and basis for developmental processes because these influence each learning process. Professional development is no exception, but, *"too often the cognitive research on learning is forgotten when it comes to designing teacher's training"* (Loucks-Horsley et al. 2010, 53).

Research Goal

In our study, we wanted to find out what expectations and beliefs our students express regarding their future profession as teacher and what expectation they have for their chemistry education courses. Since learning processes are influenced by beliefs and expectations, we pursue the long goal, to optimise our chemistry education courses by taking into account the results of this study.

METHOD

To get an insight into the aforementioned beliefs and expectations, the university students were asked two questions in an open questionnaire:

1. What do you think is expected of you as a teacher?
2. What do you expect from your studies, especially from your chemistry education courses?

Since winter term 2012/13 168 students of the BA and MA programme took part in this study (table 1).

Table 1. Sample (number of students).

	Students				
	2012/13	2013/14	2014/15	2015/16	2016/17
Bachelor	37	26	18	29	-
Master	-	16	-	23	19

To categorize the answers we developed a category system based on the COACTIV model (Figure 1). The category system contains all aspects, domains and facets as well as the concrete indicators to operationalize the facets. The domains and facet form superordinate categories and for the sub-categories we mainly recourse to the indicators which specify the facets (table 3). We added sub-categories coming from the list of teachers' competence compiled by the European Commission (EC, 2013, 45f.) to differentiate the 1. facet of *knowledge of tasks* (practical skills), 2. aspect of *beliefs/values/goal* (disposition to team-working, commitment to promoting the learning of all students, critical reflection to one's own teaching), 3. aspect of *motivational orientation* (disposition to ongoing professional improvement). Furthermore, we added knowledge of experiments as a sub-category to knowledge of tasks. Experiments represent a special type of tasks in science lessons and should reflected in a separate categorie. Finally, our system contains 50 categories for question one and 53 for question two. The categorization proceeds with the program MaxQDA by at least two people to ascertain the inter-rater reliability (Cohens κ).

RESULTS

Both questions were answered usually detailed by the 168 students; 821 statements could be used for analysis of question 1 and 550 statements are the data source to investigate question 2 (Table 2). We will consider the results for both questions separately below.

Table 2. Number of statements (differentiated by question 1 and 2)

	Number of statements (question 1 and *2*)									
	2012/13		2013/14		2014/15		2015/16		2016/17	
Bachelor	182	*110*	123	*80*	72	*48*	153	*114*		
Master			79	*55*			123	*81*	89	*62*

Results regarding question 1 – expectations: teachers' role

530 statements of BA and 291 statements of MA students could be used for analysis (Table 2). Two people coded the statements to ascertain the inter-rater reliability; the value of Cohen's kappa is .79.

Table 3. Summarised overview of BA and MA students' statements reg. question 1: What do you think is expected of you as a teacher?

Aspect	**domain**	**facet**	**BA N_{St}=530**		**MA N_{St}=291**	
			Σ St	**%**	**Σ St**	**%**
knowledge	content knowledge (CK)		**48**	9.06	**24**	8.25
	pedagogical/psychological knowledge (PPK)		**8**	1.51	**5**	1.72
		general pedagogical knowledge of instructional planning	**26**	4.91	**18**	6.18
		knowledge of effective classroom management and orchestration	**56**	10.56	**27**	9.28
		knowledge of learning processes	**96**	18.11	**61**	20.96
		knowledge of student assessment	**22**	4.15	**14**	4.81
		prof. behavior in school context	**2**	0.38	**4**	1.37
	pedagogical content knowledge (PCK)		**7**	1.32	**4**	1.37
		explanatory knowledge	**80**	15.09	**27**	9.28
		knowledge of students thinking	**3**	0.57	**1**	0.34
		knowledge of tasks	**40**	7.55	**25**	8.59
		knowledge of experiments	**0**		**0**	
	organisational knowledge		**1**	0.19	**4**	1.37
	counseling knowledge		**9**	1.70	**10**	3.34
beliefs/values/goals			**99**	18.68	**47**	16.15
motivational orientation			**21**	3.96	**16**	5.50
self-regulation			**3**	0.57	**1**	0.34
global statements			**9**	1.70	**3**	1.03

Table 3 shows the distribution of the statements. Most statements of the BA students were assigned to the categories *beliefs/values/goals*, *knowledge of learning processes*, and *explanatory knowledge*. Most of the statements of the MA students were assigned to *knowledge of learning processes* and *beliefs/values/goals*. The greatest difference between both groups of students we find in the category *explanatory knowledge* (Δ = 5.81%).

Because so many statements were coded in the category *beliefs/values/goals* we provide a closer insight into this category (Figure 2).

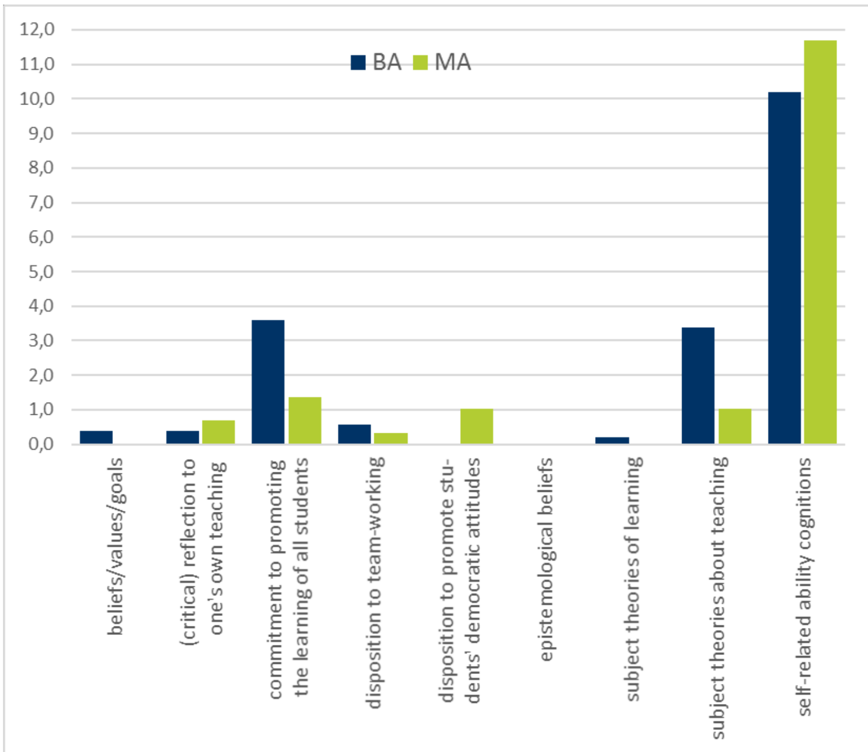

Figure 2. Aspect beliefs/values/goals – differentiated description in percent (N_{BA}=99, N_{MA}=47).

More than 10% of the statements (Table 3) belonging to the category *beliefs/values/goals* are coded in the sub-category self-related ability cognitions. Students express many attributions, such as: as a teacher I have to be patient, punctual, polite, a role model, industrious, always fair, likeable.

Results regarding question 2 – expectations: chemistry education

In light of the data, the category system for question 2 was adjusted accordingly by three categories (last three rows in Table 4). 352 statements of BA and 198 statements of MA students could be used for analysis (Table 2). Regarding question 2 the number of statements is less than for question 1 (550 < 821). Once more, the inter-rater reliability for this classification system was calculated, κ .68.

Most statements of the BA students were assigned to the categories *general pedagogical knowledge of instructional planning*, *explanatory knowledge,* and *knowledge of effective classroom management and orchestration*. Most statements of the MA students were assigned to the categories *requests on design/methods of seminars* and *general pedagogical knowledge* *of instructional planning.* Primarily MA students express particular wishes on the design of seminars. Regarding this aspect, we find the maximum difference between both groups of students (see Table 4). Altogether, the answers of MA students are more balanced over all categories (see Table 4). Both BA and MA students express their expectation to become familiar with a selection of feasible experiments and safety regulations although they do not mention experiments at all regarding question 1 (Table 3 and 4)

Table 4. Summarised overview of BA and MA students' statements reg. question 2: What do you expect from your studies, especially from your chemistry education courses?

aspect	domain	facet	BA N_{St}=352		MA N_{St}=198	
			Σ St	**%**	**Σ St**	**%**
knowledge	content knowledge (CK)		**3**	0.85	**4**	2.02
knowledge	pedagogical/psychological knowledge (PPK)		**8**	2.27	**5**	2.52
knowledge		general pedagogical knowledge of instructional planning	**54**	15.34	**25**	12.63
knowledge		knowledge of effective classroom management and orchestration	**42**	11.93	**16**	8.08
knowledge		knowledge of learning processes	**39**	11.08	**13**	6.56
knowledge		knowledge of student assessment	**9**	2.56	**1**	1.01
knowledge		professional behavior in school context	**16**	4.54	**7**	3.53
knowledge	pedagogical content knowledge (PCK)		**9**	2.56	**10**	5.05
knowledge		explanatory knowledge	**48**	13.63	**18**	9.09
knowledge		knowledge of students thinking	**4**	1.14	**10**	5.05
knowledge		knowledge of tasks	**27**	7.67	**11**	5.55
knowledge		knowledge of experiments	**26**	7.39	**11**	5.55
knowledge	organisational knowledge		**15**	4.26	**9**	4.55
knowledge	counseling knowledge		**3**	0.85	**2**	1.01
beliefs/values/goals			**13**	3.69	**4**	2.02
motivational orientation			**2**	0.57	**2**	1.01
self-regulation			**3**	0.85	**8**	4.04
global statements			**3**	0.85	**1**	1.01
requests on design/methods of seminars			**27**	7.67	**34**	17.17
overview of sources (how to get material)			**1**	0.28	**5**	2.52
insights of current state of research			**0**		**2**	1.01

DISCUSSION AND CONCLUSIONS

The category system is suitable to analyse the students' answers; Cohens kappa is satisfactory ($\kappa 1$ .79; $\kappa 2$ .68). Surprising for us is that students of both groups assume the most important influence on their future profession are self-related ability cognitions. In contrast, they do not expect to develop such cognitions in the university courses.

Both groups of students expect to learn from their science education courses primarily how to plan a lesson and to acquire explanatory knowledge. BA students want to be able to equip pupils with this knowledge of chemistry in an effective, creative, and fascinating way using various methods and teaching styles. A traditional view of learning arises out of these assumptions, the constructivist perspective on learning seems to be unknown to them. This view is also expressed in the expectations students have on their training courses in chemistry education. Here, they wish to be equipped with a catalogue of practical examples of how to acquire the tools and techniques for lesson planning, which help them to facilitate knowledge and instruct them on how to plan a lesson. This traditional view on teaching seems to shift during the study. For example, the MA students also want to know more about learning processes, but in their statements we find changes in perspectives from a teacher-centred view towards a more pupils-centred view: 'How can I promote a pupil' instead of 'how can I transfer knowledge.'

A central aspect of chemistry education courses was nearly totally left out by all of the participating students: The aspect of research into science education and its importance for teachers was not even mentioned once in the sample of the BA students. These results introduce a task for us as science education researchers and educators. We have to introduce students to science education research and to present this discipline as a practically-based and research-intensive counterargument to the simplified traditional beliefs of students. The answers of the students show how important it is to stress the impact of science education research in the university courses.

MA students express detailed requests regarding the organisation and designing of the university courses. They want to have contact to schools and pupils during their studies and want to discuss authentic examples and situations they may have to face in school. As expected, MA students have a more differentiated view on their studies (balanced answers). They are experienced and have a broader view on diverse aspects of (chemistry) education courses. Nevertheless, even for MA students educational research seems to play a minor part.

In our opinion, it is incredibly important to consider these results as we move forward. Firstly, we are now able to consider their wishes in the courses and secondly we can avoid misunderstanding and disappointment regarding the university courses. In our chemistry education courses we have started to focus explicitly on the areas of chemistry, chemistry education and pedagogy with students in authentic learning situations. This means, in an early stage of the bachelor programme, the students get the opportunity to teach pupils in class to attain a more realistic view on their future profession. Furthermore, we already introduce students in the bachelor programme to science education research and present this discipline as an important part of professional knowledge and in this way as a sturdy foundation for their future as science teachers.

ACKNOWLEDGEMENT

We thank all the participating students and in particular Michelle Kube for her support in the evaluation of the questionnaires.

REFERENCES

BAUMERT, J., KUNTER, M. (2013). THE COACTIV MODEL OF TEACHERS' PROFESSIONAL COMPETENCE. IN M. KUNTER ET AL. (EDS.), *COGNITIVE ACTIVATION IN THE MATHEMATICS CLASSROOM AND PROFESSIONAL COMPETENCE OF TEACHERS* (25-48). NEW YORK: SPRINGER.

European Commission (2013; Ed.). Supporting teacher competence development. *ec.europa.eu/dgs/education_culture/.../teachercomp_en.pdf*

Loucks-Horsley, S., Stiles, K. E., Mundry, S., Love, N., & P. W. Hewson (2010). *Designing professional development for teachers of science and mathematics*. Corwin, Thousand Oaks, California, 3rd ed.

Schumacher, K., Lind, G. (2000). Praxisbezug im Lehramtsstudium. Bericht einer Befragung von Konstanzer LehrerInnen und Lehramtsstudierenden. Uni Konstanz.

Shulman, L. (1986). Those who understand. Knowledge growth in teaching. *Educational researcher 15*(2), 4-14.

KMK - Standing Conference of the Ministers of Education and Cultural Affairs (2004). Standards for teaching and teacher education. https://www.kmk.org/fileadmin/Dateien/veroeffentlichungen_beschluesse/2004/2004_12_16-Standards-Lehrerbildung-Bildungswissenschaften.pdf

KMK - Standing Conference of the Ministers of Education and Cultural Affairs (2008). Requirements for subjects and subject education in teacher education. http://www.kmk.org/fileadmin/veroeffentlichungen_beschluesse/2008/2008_10_16_Fachprofile-Lehrerbildung.pdf

Streller, S., Bolte, C. (2013). Translating university chemistry for the classroom. *Chemistry in Action!* Issue 101, 20-26.

Streller, S., Bolte, C. (2018): Becoming a Chemistry Teacher. NorDiNa, Vol. 14, No. 2, 125-137.

SELF-REFLECTION OF A CHEMISTRY TEACHER

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The methods of self-reflection are e.g. a self-monitoring, audio and video recording, a feedback from students, knowing the learning success of students (students' grades), inspection in classes and using the pedagogical diary. This contribution deals with the importance of self-reflection in a teacher's work. An integration of self-reflection program into the pregradual training of chemistry teachers is presented, especially in relation to Didactics of Chemistry (a university subject for future teachers) and the pedagogical practice. The main aim is to demonstrate a specific tool that can be used by a university student – future teacher (pre-service teacher), during his/her pedagogical practice to reflect and develop his/her self-reflection abilities.

Keywords: Evaluation, Reflection, Self-Regulation, Education, Chemistry teacher

THEORETICAL BACKGROUND

The efficacy and quality of process of education is not accidental. It mainly depends on teacher, his/her approach to work and students. The self-reflection of a teacher can be considered the basic determinant to affect this efficacy and quality. It leads teacher to his/her internal dialog with himself/herself (Hupková & Petlák, 2004). Only a teacher who performs its own self-reflection can improve himself/herself. No successful teacher can get along without self-reflection of his/her own educational activities, it is not possible to develop his/her teaching profession without it.

Self-reflection is not only about evaluating the abilities and opportunities of a person. The main point of self-reflection is to conclude findings for further personality development. It is one of indicators of person's responsibility to see and assess himself from outside, in broader cultural and social context. It moves on individual activities and broadens horizons in which one is able to discover the sense of his performances and also to understand the actions of the other people. However, the self-reflection is performed only in case of teacher's personal need (Körkkö, Kyrö-Ämmälä & Turunen, 2016). Self-reflection can be perceived as an act in which the thinking is returning back to itself in order to deepen its analysis. It can also be perceived as a mental process based on a tendency of reshaping and restructuring our experiences, views and knowledge.

The need for existence of reflection has come in two kinds of rationality that can only be linked through reflection. These are the rationalities:

Cognition as epistéme – PLATON – conceptual knowledge:

- theoretical, general, timeless, relatively constant,
- is ruled by principles, rules, laws,
- cognitive insight, intellectual forms, description.

Cognition as phronesis – ARISTOTELES – perceptual knowledge, practical wisdom

- understanding of particular cases and ambiguous situations;
- flexible, responsive to situations, ready for unexpected surprises, unclarity of practical, inventive in improvisation,
- long-term experience, assessments, choices, confrontation with consequences.

One of the functions of self-reflection is to help teachers realize their mental structures, to revise them and reshape them if needed. Well-known functions are: cognitive, feed-back, preventive, developing and relaxing.

In addition to the concept of *competency* also the other concept - *professional knowledge in education* - is important for self-regulation and self-reflection. *Knowledge* is a final integrated information with an indication of its practical usage. The professional knowledge in education can be classified as follows:

- *theoretical knowledge* – scientific knowledge transformed didactically (planning of the education),
- *acting knowledge* – knowledge enriched by experience obtained in practice (realization of education),
- *context knowledge* – the relations between theory and practice through reflection, confronting the practical experience with the theoretical schemes (evaluation and improving the education).

In fact, a teacher can use only a specific part of the theory that is directly connected to its practical usage. A self-reflection become a mirror of his practice (Hatton & Smith, 1995).

The most frequently used methods for teacher's self-reflection in educational practice are: (i) *self-monitoring*, (ii) *audio and video recording*, (iii) *feedback from students*, (iv) *students' grades*, (v) *observing (inspections) by the other teachers* and (vi) *pedagogical diary*. However, in order to provide teachers to be able to realize and interpret their own self-reflection, they have to be taught how to do that (Beatty, 2000).

The issue of self-reflection, its importance in the existence of man, in the context not only of his professional growth but of his general existence, is part of many studies in the field of pedagogy, psychology and social sciences. However, the fact is that self-reflection, the need to get feedback and reflect on it, is not part of many relevant documents, statements or scientific studies. The OECD states in its report that 21st-century employees need to have information-processing skills, including reading literacy, mathematical literacy and problem-solving skills. Besides, they must also have 'generic' skills, such as interpersonal communication, autonomy and ability to learn. (OECD, 2013). According to economists Hanushek and Woesmann (2008), skills related to thinking and learning, such as critical thinking and problem solving, play a significant role in the economic growth of countries. Nor is self-reflection included in the content of defined skills by the European Commission (2011). The term "competence" has become a phenomenon over the last 20 years, which was considered by many researchers as an element in education that provides an alternative to traditional education. Competences, competency models have become a means of obtaining a quality, a means of measuring and evaluating performance. Based on an analysis of the 21st-century competence framework review by Voogt and Roblin (2012) based on documents from organizations supporting the development and assessment of skills for the current century or by recommendations from international organizations supporting the development of education, economic growth and technology, perceived as skill or competence. The critical competencies recommended by the European Parliament and the Council of Europe are intended for all individuals for their well-being and development, active citizenship, social inclusion and employment (European Commission, 2007). There are 8 of these competencies, but neither describes in its description the need for self-reflection, for its implementation and its reflection.

METHODOLOGY

The nature of self-reflection mentioned above and acquisition of knowledge and competencies in the work of future teachers declares that a pre-service teacher can reflect his/her potential to become a successful teacher by performing a pedagogical practice. Moreover, the study of university subjects in which so-called *reflexive program* is included, can be another field for training self-reflection skills. In our university, such program for pre-service teachers is arranged even before their real pedagogical practice at secondary and high schools. This training is realized within the didactical subjects like (i) *Didactics of Chemistry*, (ii) *Technique and Didactics of School Experiments,* (iii) *Computer in Learning Chemistry*, (iv) *Computer based experiments* and another optional subjects according to students' choice. The pre-service teachers have also opportunity to teach Chemistry in simulated classes (at university classrooms) within an obligatory subject called a *Special Didactics of Chemistry* where their classmates represent the simulated secondary or high school students. The duration of such simulated classes covers a standard class-time as well. The pre-service teachers endeavor to lead the simulated lessons as if they acted at real classes with the real students. The university teacher supervising the class and the classmates (simulated students at the same time) take notes about the process of simulated education in order to subsequent analysis in more detail. Such a reflexive training program provides pre-service teachers a real insight into their work as future teachers of Chemistry. The emphasis is placed on the development of competencies related to professional growth which are then validated and developed even before entering to the real conditions of a genuine school. Performing the simulated classes, the pre-service teachers go through the following single phases of a reflection cycle: (i) *action*, (ii) *feedback on action*, (iii) *realizing the fundamental aspects*, (iv) *creating alternatives* and (v) *examining*. Within these phases, the cognitive characteristics (e.g. pre-concept, describing, self-dialogue, viewpoints, finding links, experience in the specific situations) and emotional connections (e.g. feelings, attitudes, motivation, personal interest, relation to change or resistance) are applied.

As stated before, performing self-reflection and self-evaluation is an important element of the pedagogical practice of a pre-service teacher. At the end of the pedagogical practice training, a pre-service teacher is evaluated by a hosting in-service teacher and a supervising university teacher. However, they also take into account the self-evaluation of a pre-service teacher provided in writing in a specific evaluation sheet (Table 1-4). The evaluation sheet consists of a set of professional competencies and qualities of a pre-service teacher, where the ranking itself is aligned on a 5-point scale, from 1 – insufficient to 5 – excellent. There is a special field in the sheet for self-evaluation to be filled in by a pre-service teacher according to his/her self-reflection. Among other things, the pre-service teacher is expected to provide reasoning and the ways of his/her farther professional development. The knowledge presented in the sheet is categorized according to the following teacher's activities:

1. Planning and preparing of the teaching process (Table 1); *2. Implementation of teaching* (Table 2) (Verbal and non-verbal communication, Educational climate, Social climate, Discipline, Management of the teaching process, Evaluation of a student); *3. Post part of teaching* (Table 3) (Reflection of education, Evaluation and professional development); *4. Context of education* (Table 4).

The planning and preparation of the teaching process section focuses on the student's ability to conceptually and systematically plan and optimize teaching. This part (Table 1) of the evaluation sheet also includes the specifics of the chemistry subject, such as the preparation and implementation of a chemical experiment.

Table 1. Part 1 of the evaluation sheet (Planning and preparing of the teaching process).

Pre-Service Teacher's Knowledge	**Scoring** 1 – insufficient 5 – excellent
1 Planning and preparing of the teaching process	
University Student (Pre-service teacher): • He/she plans the teaching process conceptually and systematically concerning the objectives set out in the state and school education program and the individual possibilities and needs of students. The preparation for teaching includes outputs following the content and performance educational standards of chemistry for the respective level and year of education.	
• In the context of the educational objectives, the nature of the curriculum, the needs and possibilities of students and the educational climate, the optimizes the scope and content of chemical terms.	
• In the context of the educational objectives, the nature of the curriculum, the needs and possibilities of students and the educational climate, he/she chooses the appropriate concept and approaches to education, especially those based on constructivism and developing students' research abilities (problem-based learning, concept based on research).	
• In the context of the educational objectives, the nature of the curriculum, the needs and possibilities of students and the educational climate, he chooses appropriate methods and organizational forms of teaching, appropriate content and reflects logical continuity, complexity and interconnection of curriculum, including in-subject and inter-subject relations and connection to the practice itself. He/she plans to work with unique texts, textbooks, by which he develops reading literacy, especially the level of readability and readability of particular professional text.	
• In the context of educational objectives, the nature of the curriculum, the needs and possibilities of students and the educational climate, he/she chooses the appropriate material means - teaching aids (including models), technical equipment, etc. He/she chooses the optimal inclusion of digital technologies in the classroom, taking into account the digital content used.	
• In the context of the educational objectives, the nature of the curriculum, the needs and possibilities of students and the educational climate, he/she chooses the	

appropriate selection and integration of the school chemistry experiment concerning the curriculum content also focusing on the safety when working. He/she correctly integrates the school experiment into the teaching unit in terms of its classification according to the form of teaching, from the gnoseological point of view, as well as from work accuracy (e.g., quantitative school experiments in connection with using a computer).	
• In the context of the educational objectives, the nature of the curriculum, the needs and possibilities of the students and the educational climate, he plans the students to work with quantitative and qualitative information; graphs, dependencies, diagrams, tables, diagrams, schemes.	
• He/she plans ways of getting feedback for both the student and the teacher. Concerning the student, he/she has a well-thought-out system of questions and tasks, their integration into individual phases of teaching. He/she has elaborated models of problem-solving, through which it leads the student to the right solution and reveals the "mistakes" that the student can make in understanding the curriculum and thus the level of his understanding of the curriculum and ability to solve tasks.	
Self-evaluation, arguments, ways of further development	

The second part of the evaluation sheet (Table 2) is focused on the actual implementation of teaching. It consists of three sublevels containing teaching indicators, namely: verbal and non-verbal communication, educational and social climate, discipline, teaching process management and diagnostics and assessment of the student. In this part of the sheet, it is clear that the teacher needs to evaluate the student only after the student has given his self-assessment. For example, an indicator of the level of control and correct interpretation of scientific discipline knowledge is evaluated here. It is an indicator that is not directly related to the preparation and implementation of teaching by the student; therefore, the student has no direct influence on this level. Therefore, an interesting finding is the mutual consistency of the testimony of the evaluation of this indicator to students and teacher in training.

Table 2. Part 2 of the evaluation sheet (Implementation of teaching, Performing education).

Pre-Service Teacher's Knowledge	**Scoring** 1 – insufficient 5 – excellent
2 Implementation of teaching (Performing education)	
2.1 Communication and conditions in the classroom	
University Student (Pre-service teacher): • He/she uses standard Slovak language during the class. He/she expresses himself in a language that is comprehensible to the student.	
• He/she appropriately uses nonverbal communication means (smile, eye contact, friendly and helpful gestures, movement around the classroom, respect for the personal space zone). He/she uses the correct demonstration techniques and procedures to conduct non-verbal education while doing the experiments.	
• He/she creates sufficient communication space for all students, strives for balanced communication interaction. He/she creates opportunities for thinking, confronting different opinions and ideas of students, leading them to reason. He/she creates	

opportunities for mutual communication among students. He/she leads students to express their understanding of the topic and reflect on the learning process.	
• He/she handles discipline well in the classroom, adherence to the agreed system and rules of coexistence and behavior in the classroom. He responds adequately to the behaviors of disturbing and annoying behavior and ensures that they are minimized. He creates an environment of mutual respect and honesty.	
• He/she includes in the classroom the activities, concepts and approaches that help to develop collaboration, positive classroom relationships and better integration with students that are isolated, rejected by other classmates, and so on.	
• He/she plans ways of getting feedback for both the student and the teacher. Concerning the student, he/she has a well-thought-out system of questions and tasks, their integration into individual phases of teaching. He/she has elaborated models of problem-solving, through which it leads the student to the right solution and reveals the "mistakes" that the student can make in understanding the curriculum and thus the level of his understanding of the curriculum and ability to solve tasks.	
Self-evaluation, arguments, ways of further development	
2.2 Management of the teaching process (management of education)	
• He/she carries out the training according to the preparation, at the same time he reacts to the development of the situation and the needs and possibilities of the students, but does not lose the connection to the set goals; he uses time effectively.	
• He/she knows and interprets the knowledge of the scientific discipline of chemistry, understands the technical terms, events and relations between them. He/she interprets the symbolic and formal language of chemistry correctly and appropriately.	
• He/she individualizes the support of students' learning process concerning their possibilities (e.g., differentiates curriculum and demands, respects individual pace of learning, takes into account integrated students in the classroom and their content and degree of integration, modifies working methods, criteria and assessment methods).	
• He/she supports activity and inner motivation of students to learn - he raises curiosity, interest in learning and knowledge of new things. He asks open questions that activate higher levels of thought and require a more coherent student's speech (Why? What would happen if... What do you predict? Try to formulate the assumption of the upcoming trend and the result of the experiment. How would you explain that .... . What is your opinion .....?). He encourages students to ask questions and appreciates their interest and willingness to ask questions.	
• He/she creates learning situations requiring the cooperation of students, using self-learning practices and frontal forms of learning as needed. He/she teaches students to use effective self-learning strategies (metacognitive strategies).	
• He/she detects students' preconceptions, analyzes them mutually with them, and directs them to learn and interpret it correctly. He/she uses students' acquired knowledge, ideas and experience in their learning. He/she identifies misconceptions associated primarily with misconceptions about chemical concepts and chemical reactions.	
• Through the teaching of chemistry, he/she develops natural science literacy and abstract thinking of students. He/she develops abstract thinking, ability to predict, observe, analyze, draw conclusions and interpret.	
Self-evaluation, arguments, ways of further development	

2.3 Evaluation of a student	
• He/she provides students with assessment criteria (students know what is being evaluated and what weight each criterion weighs in the overall assessment) or allows them to participate in the development of these criteria.	
• He/she evaluates learning processes - provides continuous feedback on learning activities and student behavior in descriptive languages, assesses progress, effort, interest, level of cooperation, suggests strategies for improvement (what and how to change, improve), works with mistakes of students as an opportunity to further improvement.	
• In addition to the level of acquired knowledge, he/she also evaluates the level of acquired skills in the implementation of school experiments, the ability to predict, observe, analyze, draw conclusions, argue and interpret.	
• He/she assesses students' performance in terms of individual possibilities and prerequisites and appreciates individual progress of students.	
Self-evaluation, arguments, ways of further development	

The post-teaching part (Table 3) is a space for introducing a comprehensive reflection of the students, as well as evaluating the ability of self-evaluation and planning the further professional development of the student.

Table 3. Part 3 of the evaluation sheet (Post part of teaching - Reflection of education, Evaluation and professional development).

Pre-Service Teacher's Knowledge	**Scoring** 1 – insufficient 5 – excellent
3 Post part of teaching	
University Student (Pre-service teacher): • After each taught unit, he/she evaluates the selected strategies, methods and organization of teaching concerning the teaching plan, the set goals but also to their achievement.	
• On the basis of self-reflection, he/she plans to further increase his professional qualities.	
Self-evaluation, arguments, ways of further development	

The above-mentioned reflective program tool is designed for the evaluation of a student in the context of the implementation of continuous teaching practice (Table 4), which lasts 2 months at primary or secondary school. The student works in the school environment, whose determinants are not only the student and the teacher but also the parent. Therefore, the last part of the evaluation sheet is the part named Context of Teaching, which focuses on the ability of the student to adapt in the school environment, on the degree of his flexibility towards school activities and his cooperation with parents.

Table 4. Part 4 of the evaluation sheet (Context of education).

Pre-Service Teacher's Knowledge	**Scoring** 1 – insufficient 5 – excellent
4 Context of education	
University Student (Pre-service teacher): • participates in the school life, participates in school activities and projects, attends school meetings, attends meetings of a subject commission, attends the meetings with parents etc.	
• comprehends the school curricula and is aware of its fundamental parts, is able to describe the school philosophy.	
• is interested in the ways of cooperation between teachers and parents.	
• develops skills of communication with parents.	
Self-evaluation, arguments, ways of further development	

CONCLUSION

Since 1990s, the trends of professional training and performance of teachers in the Central European context have identified several dominating tendencies which determine the structure and priorities related to teacher's competencies. The acquisition and validating of these competencies is realized during pregradual education for the first time (Nezvalová, 2000). Therefore, it is necessary to pay attention to the conceptual framework and implementation of reflexive program to the university training of future chemistry teachers.

ACKNOWLEDGEMENT

We acknowledge The National Project No. ITMS 312011F057, *IT Academy – Education for the 21. Century*.

REFERENCES

Beatty, B. R. (2000). Teachers leading their own professional growth: self-directed reflection and collaboration and changes in perception of self and work in secondary school teachers. *Journal of In-Service Education*, 26(1), 73-97.

European Commission. (2007). *Kľúčové kompetencie pre celoživotné vzdelávanie – Európsky referenčný rámec* [Key competencies for Long-life Learning – European Reference Framework] Retrieved from http://www.edutest.sk/wp-content/uploads/2015/05/KK_podla_EU.pdf

European Commission Directorate-General 5, Employment and Social Affairs. (2011). *Transferability of Skills across Economic Sectors: Role and Importance for Employment at European Level*. EUR-OP. Retrieved from https://europa.eu/european-union

Hanushek, E. A. & L. Woessmann, L. (2008). The Role of Cognitive Skills in Economic Development. *Journal of Economic Literature*, 46(3), 607-668.

Hatton, N. & Smith, D. (1995). Reflection in teacher education: Towards definition and implementation. *Teaching and Teacher Education*, 11(1), 33-49.

Hupková, M. & Petlák, E. (2004). *Sebareflexia a kompetencie v práci učiteľa* [Self-reflection and competencies in a teacher's work]. Bratislava: Iris.

Körkkö, M., Kyrö-Ämmälä, O., & Turunen, T. (2016). Professional development through reflection in teacher education. *Teaching and Teacher Education*, 55, 198-206.

Nezvalová, D. (2000). *Reflexe v pregraduální přípravě učitele* [Reflection in pregradual teacher training]. Olomouc: Palacky University.

OECD (2013). *OECD Skills Outlook 2013: First Results from the Survey of Adult Skills*. OECD Publishing, Paris, Retrieved from https://doi.org/10.1787/9789264204256-en

Voogt, J., & Roblin, N. P. (2012). A comparative analysis of international frameworks for 21st century competences: Implications for national curriculum policies. *Journal of curriculum studies*, 44(3), 299-321.

PART 14: STRAND 14

In-service Science Teacher Education, Continued Professional Development

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CONTENTS

STRAND 14: INTRODUCTION

IN-SERVICE SCIENCE TEACHER EDUCATION, CONTINUED PROFESSIONAL DEVELOPMENT

Strand 14 of ESERA addresses an internationally increasingly recognized complex field of science education research: in-service teacher education and continued professional development of science teachers. It is obvious that the value and success of any educational system strongly corresponds with the quality of its teachers' competences and practices. In this sense, it is not surprising that the strand on in-service science teacher education is always one of the most active strands of ESERA. Compared to the last ESERA conference proceedings, the number of papers presented in this strand was growing from 10 to 32 pieces.

Again, this edition of the ESERA conference proceedings portrays a singular, interesting array of research pieces addressing actual problems of science teacher education and continued professional development from sometimes similar, but quite often very different theoretical and methodological frameworks. Compared to previous editions of Strand 14 of the ESERA proceedings, we probably find here the most diverse representation in terms of internationalization. The 32 papers included in this section, come from all over the world. There is, on the one hand, a strong European presence with papers coming from research institutions in Austria, Germany, Greece, Ireland, Israel, Italy, Portugal, Sweden, Switzerland and UK. On the other hand, non-European, international presence and collaboration becomes visible by papers from South Africa, South-America (Brazil and Chile), Asia (Japan), Oceania (New Zealand). This collection forms a truly international character and confirms the fact that including research pieces from all over the world is a trend that is gaining momentum in each ESERA edition. We think, the ESERA community will strongly benefit from this global exchange of ideas. The visible internationality and number of papers underlines the increased worldwide relevance of this field of science education research and the need of common work on often similar problems.

Looking at the contents and approaches of studies we can find an interesting spectrum. There are theoretical studies as well as empirical ones, but also studies connected to innovations concerning specific course developments and applications including the investigation of its effects and the possibilities of evaluation of science teaching. That variety demonstrates very well, how the complexity of in-service science teacher education and continued professional development is scientifically approached by the ESERA community.

The theoretical studies at the beginning of this chapter, for instance, investigate and discuss the actual situation of science teaching and teacher education in the mirror of already existing studies and results by examining theoretical standards, focusing the linkage of PCK and practical teaching experiences in STEM teacher education. They investigate competencies required by teachers to ensure progression and continuity in students' learning.

Empirical studies to be found in this chapter deal with the professionalization processes of teachers in all phases of their careers. They look at needs, challenges and possibilities for individual support, in order to ensure progression and continuity including the potential of professional learning communities. In addition, structural challenges in the field of science teacher education are tackled. A number of empirical papers investigate effects of innovative teacher training courses for instance concerning the integration of ICT, and the development of teacher knowledge, beliefs and attitudes toward teaching science.

A larger number of papers communicates developmental activities. In the focus of interest are innovative courses and the investigation of specific variables and effects while applying these courses, mainly looking at teachers' competences and learning communities. The innovations presented comprise for example the initiation and investigation of collaboration between teachers and scientists or the implementation of learning communities.
Another group of studies deals with the transformation of pedagogical practices from didactic to dialogic teaching. There are training ideas addressing the use of experiments and the teaching argumentation.

The last (but not least) part of the chapter presents papers dealing with the development and application of methods and tools of evaluation.

Looking at the selection of papers one will find that the ESERA community within strand 14 tackles important issues in order to support improvement of in-service teacher education and continued professional development of science teachers all over the world.

Manuela Welzel-Breuer & Claudio Fazio

LINKING PEDAGICAL CONTENT KNWOLEDGE AND PRACTICAL TEACHING EXPERIENCES IN STEM TEACHER EDUCATION: A SYSTEMATIC REVIEW OF THE LITERATURE

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Teachers' professional knowledge is considered central to improving students' learning outcomes in science, technology, engineering, and mathematics (STEM) subjects (Abell, 2007; Magnusson, Krajcik, & Borko, 1999). Pedagogical content knowledge (PCK), introduced by Shulman (1986) as a very specific dimension of teachers' professional knowledge, is now a well-established construct in STEM education research. Findings in this research field suggest that teachers with well-developed PCK for teaching STEM subjects are more able to provide effective instruction, and professional development to enhance teachers' PCK in STEM education is now advocated (van Driel & Berry, 2012). Research also shows that teachers' PCK development hinges on professional practical experiences, e.g., classroom teaching (Carlson et al., 2019), inferring that provision of practical experiences in teacher education, which are linked to teachers' PCK can help prospective teachers to expand their professional knowledge (Carlson et al., 2019). However, while PCK features in many studies in STEM education research, empirical evidence that establishes a link between PCK and teaching practice in STEM is ambiguous because these studies conceptualise PCK and practical experiences inconsistently (Wilson, Borowski, & van Driel, 2019). To begin addressing this ambiguity and advance understanding of the link between PCK and teaching experiences, this study seeks to analyse how empirical studies link PCK and practical experiences of (preservice) STEM teachers. The analysis is done via a systematic literature review that focuses on N=97 empirical studies. Results suggest that most studies favour Magnusson's (1999) PCK model as a conceptual framework and almost always include the components 'knowledge of student understanding' and 'knowledge of instructional strategies and representations' in their analyses. The implications of these findings for further empirical research regarding links between PCK and practical teaching experiences are discussed.

Keywords: Pedagogical Content Knowledge, Teacher Professional Development, Teaching Practices

INTRODUCTION

Teachers' professional knowledge for teaching in science, technology, engineering, and mathematics (STEM) subjects has been identified as an important attribute for improving teaching and students' learning outcomes (Abell, 2007; Hume, Cooper, & Borowski, 2019; Magnusson et al., 1999). As a category of STEM teachers' professional knowledge (Shulman, 1986), pedagogical content knowledge (PCK) has been considered a key knowledge form for improving teaching (Hume et al., 2019; Loughran, Berry, & Mulhall, 2012), since it facilitates a transformation of subject matter knowledge into a more comprehensible form that is accessible to students (Shulman, 1986). Authors like Grossman et al. (2009), Magnusson et al. (1999) and Park and Oliver (2008) added refinements to Shulman's PCK construct including, amongst others, components of PCK for effective STEM teaching, i.e., orientations to teaching science (OTS), knowledge of student understanding (KSU/KS), knowledge of instructional strategies and representations (KISR), knowledge of curriculum (KC/CuK), knowledge of instructional strategies (KI), and knowledge of assessment (KA). Other knowledge categories should also be given due consideration for effective STEM teaching, including content knowledge (CK), and pedagogical knowledge (PK) (Shulman, 1986), and more recently knowledge of teaching context (CxK) (Fernandez-Balboa & Stiehl, 1995; Grossman, 1990) as a knowledge of the specific classroom circumstances and the students (e.g., ethnic background and gender composition). It is argued developing applicable PCK in professional development is presupposed upon effectively applying PCK in authentic practical teaching situations (Grossman et al., 2009; Shulman, 1986). Accordingly, some research studies began investigating effective ways for implementing practical teaching experiences in (preservice) STEM teacher professional development that promote development of applicable PCK. For example, the use of Content Representations (CoRes) by Loughran, Mulhall and Berry, (2004) and reflective writing after practical teaching experiences by Hume (2009) were found to be successful ways to make PCK explicit and promote professional development. Unfortunately, to date studies have employed a varied plethora of methods, research designs, and PCK conceptualisations for analyzing links between PCK and practical teaching experiences, resulting in findings that are difficult to integrate and reach consensus.

This paper reports partial findings from a systematic literature review we undertook in an attempt to compare and integrate methods and findings from studies that examine links between PCK and practical teaching experiences in STEM teacher education. In this paper, we address one of the research questions (RQ) from this study: How do STEM studies that link teachers' PCK and their teaching practice conceptualise PCK?

METHOD

The systematic literature review began by explicating the research interest (i.e., what links exist between PCK and practical experiences in STEM teacher education) and browsing through relevant electronic literature databases (peDocs, ERIC, WoS and PsycINFO) using the key terms "(knowledge AND practice) AND (teacher OR teaching OR "teacher education") AND (physics OR chemistry OR biology OR mathematics OR science OR STEM) AND ("Pedagogical Content Knowledge" OR PCK)". Peer reviewed articles from 1986 to 2018 that used a PCK conceptual framework and investigated a link between teachers' PCK and their practical experiences were included. Overall, N=97 studies were retained for analysis. For the data related to the RQ reported in this paper, content analysis was used, such that established PCK models (e.g., Magnusson et al., 1999, Park & Oliver, 2008, and others) formed the initial coding units and formerly unidentified PCK models were added in the process. Interrater reliability, as measured through Cohen's κ, was substantial: $\kappa = 0.93$.

RESULTS

Each of the reviewed studies adhered to one of two broad categories of PCK models as described by Park and Oliver (2008) and Kind (2009): either to more integrative models (N=9; 9.3%) or to more transformative models (*N*=88; 90.7%). The integrative model holds that PCK is comprised of different knowledge categories (and is therefore not in itself a unique knowledge form), while the transformative model considers PCK to be an independent knowledge category (Kind, 2009). In the first group, all studies examined PCK in combination with CK and PK, while KS, CuK, and AK were interspersed at times in these analyses (see Table 1). In the larger second group, almost a third of the studies used the PCK model by Magnusson et al. (1999) (*N*=30, see Table 2). The majority of these studies included all five PCK components, however OTS was most often left out in the minority that used fewer components. Another *N*=36 studies were identified that did not specify a particular PCK model but rather eclectically used different components of PCK, most often KSU and KISR.

Table 1. More integrative PCK models.

Model	*(N=9)*	*CK*	*PK*	*CxK*	*KS*	*CuK*	*AK*
Cochran et al. (1993)	*(N=1)*	*1*	*1*	*1*	*1*		
Grossman (1990)	*(N=1)*	*1*	*1*	*1*		*1*	
Shulman (1986)	*(N=3)*	*3*	*3*			*1*	
Not specified	*(N=4)*	*3*	*3*	*3*	*1*	*1*	*1*
Sum of References		*8*	*8*	*5*	*2*	*3*	*1*

Table 2. More transformative PCK models.

Model	*(N=88)*	*KSU*	*KISR*	*KA*	*KC*	*OTS*
Abell (2007)	*(N=1)*	*1*	*1*	*1*	*1*	*1*
Gess-Newsome (2015)	*(N=4)*	*2*	*4*	*1*	*3*	*1*
Grossman (1990)	*(N=2)*	*2*	*2*		*1*	*1*
Hanuscin et. al (2011)	*(N=3)*	*3*	*3*	*3*	*3*	*3*
Hill et al. (2008)	*(N=1)*	*1*	*1*		*1*	
Magnusson et al. (1999)	*(N=30)*	*27*	*26*	*22*	*22*	*18*
Park & Oliver (2008a)	*(N=1)*	*3*	*3*	*3*	*3*	*3*
Park & Oliver (2008b)	*(N=3)*	*1*	*1*	*1*	*1*	*1*
Rollnick et al. (2008)	*(N=1)*		*1*	*1*	*1*	
Saxton et al. (2014)	*(N=1)*	*1*	*1*	*1*	*1*	*1*
Shulman (1986)	*(N=8)*	*7*	*6*			*1*
Turner-Bisset (1999, 2001)	*(N=1)*	*1*	*1*		*1*	*1*
Not specified	*(N=32)*	*26*	*26*	*7*	*12*	*8*
Sum of References		*75*	*76*	*40*	*50*	*39*

DISCUSSION

The review revealed that studies examining PCK and teaching practice together employ a variety of PCK conceptualisations. Differentiation of studies into those with either an integrative or a transformative perspective of PCK was considered reasonable, where the former applies to a group of studies that view PCK as an integration of different knowledge categories rather than a separate entity, and the latter applies to studies that conceptualise PCK as an independent knowledge category. The group with the integrative perspective of PCK proved to be quite small, while the majority of studies adopted transformative models of PCK, most notably the model by Magnusson et al. (1999). Of particular interest with respect to links between PCK and practical teaching experiences was the finding that KSU and KISR are almost always included in the analyses, which is not surprising given these two components resonate most closely with those aspects of teachers' knowledge that Shulman (1986) originally identified as PCK. In our estimation, these choices for analysis are reasonable when considering the complexity of student thinking and the benefits gained from teachers learning to diagnose students understanding for effective teaching (Sadler, Sonnert, Coyle, Cook-Smith, & Miller, 2013). In contrast, it was surprising that only a tiny minority of studies included CxK into their analyses. This was surprising because the context-dependency of PCK was emphasized from early on (Grossman, 1990; Magnusson et al., 1999).

Recently, a conceptual framework known as the Refined Consensus Model (RCM) has been proposed that integrates different PCK models (Carlson et al., 2019). We consider the RCM a useful advancement on existing PCK models, because not only does it comprise the most salient features identified in our reviewed studies that link PCK and practical teaching experience, it also recognises and is sensitive to the context-dependency of PCK. As such, the RCM differentiates three realms of PCK to acknowledge that PCK research shared amongst educational scholars is different to the PCK that a teacher holds, and in turn to the PCK that a teacher enacts in the moment of teaching. This differentiation also acknowledges that potentially teachers implicitly know much about teaching (Carpenter, Fennema, Peterson, & Carey, 1988), but may be unable to access this knowledge explicitly when reflecting on and enacting their teaching.

When studying links between PCK and practical teaching experiences, we suggest the following: 1) Since KSU and KISR are widely established focii in PCK analysis and teaching practice it might be opportune to hone in on particular mechanisms in the teaching context that trigger teachers' use of certain KSU- and KISR-related knowledge. Also, developmental trajectories (e.g., from more transmissive to more constructivist instructional beliefs) can be hypothesised and tested. Such investigations were not revealed in our literature review so a possible gap in the research exists, 2) Adopting the RCM in studies investigating links between PCK and practical teaching experiences seems fruitful, in order to determine what the field knows, what teachers in a certain developmental stage know, and how contextual factors might account for episodes where certain PCK is/is not utilised. Linking suitable research methodologies to the different realms of PCK would be beneficial as a next research task.

A more comprehensive summary of the present study is expected to appear in a peer reviewed publication. In that review, we will address further research questions regarding, employed methods, conceptualisations of PCK, the teaching cycle and other aspects. We will also discuss the limitations of such a literature review when investigating relationships between PCK and teaching practice.

References

Abell, S. K. (2007). Research on Science Teacher Knowledge. In S. K. Abell & N. Lederman (Eds.), *Handbook of research on science education.* Mawhah, New Jersey: Lawrence Erlbaum Associates Publishers.

Carlson, J., Daehler, K., Alonzo, A., Barendsen, E., Berry, A., Borowski, A., . . . Wilson, C. D. (2019). The Refined Consensus Model of Pedagogical Content Knowledge. In A. Hume, R. Cooper, & A. Borowski (Eds.), *Repositioning Pedagogical Content Knowledge in Teachers' Professional Knowledge.* Singapore: Springer.

Carpenter, T. P., Fennema, E., Peterson, P. L., & Carey, D. A. (1988). Teachers' Pedagogical Content Knowledge of Students' Problem Solving in Elementary Arithmetic. *Journal for Research in Mathematics Education*, *19*(5), 385–401.

Fernandez-Balboa, J.-M., & Stiehl, J. (1995). The generic nature of pedagogical content knowledge among college professors. *Teaching and Teacher Education*, *11*(3), 393-306.

Grossman, P. L. (1990). *The making of a teacher: Teacher knowledge and teacher education.: Professional development and practice series.* New York, NY: Teachers College Press.

Grossman, P. L., Compton, C., Igra, D., Ronfeldt, M., Shahan, E., & Williamson, P. W. (2009). Teaching practice: A cross-professional perspective. *Teachers College Record*, *111*(9), 2055–2100.

Hume, A. (2009). Promoting higher levels of reflective writing in student journals. *Higher Education Research & Development*, *28*(3), 247–260.

Hume, A., Cooper, R., & Borowski, A. (Eds.). (2019). *Repositioning Pedagogical Content Knowledge in Teachers' Professional Knowledge*. Singapore: Springer.

Kind, V. (2009). Pedagogical content knowledge in science education: Perspectives and potential for progress. *Studies in Science Education*, *45*(2), 169–204. https://doi.org/10.1080/03057260903142285

Loughran, J., Berry, A., & Mulhall, P. (2012). *Understanding and Developing Science Teachers' Pedagogical Content Knowledge* (2. Auflage). Rotterdam, Boston, Taipei: Sense Publishers.

Magnusson, S., Krajcik, J. S., & Borko, H. (1999). Nature, sources, and development of pedagogical content knowledge for science teaching. In J. Gess-Newsome & N. G. Lederman (Eds.), *Examining pedagogical content knowledge: The construct and its implication for science education* (pp. 95–132). Dordrecht: Kluwer Academic.

Park, S., & Oliver, J. S. (2008). Revisiting the Conceptualisation of Pedagogical Content Knowledge (PCK): PCK as a Conceptual Tool to Understand Teachers as Professionals. *Research in Science Education*, *38*(3), 261–284. https://doi.org/10.1007/s11165-007-9049-6

Sadler, P. M., Sonnert, G., Coyle, H. P., Cook-Smith, N., & Miller, J. L. (2013). The Influence of Teachers' Knowledge on Student Learning in Middle School Physical

Science Classrooms. *American Educational Research Journal*, *50*(5), 1020–1049. https://doi.org/10.3102/0002831213477680

Shulman, L. S. (1986). Those Who Understand: Knowledge Growth in Teaching. *Educational Researcher*, *15*(2), 4–14.

Van Driel, J. H., & Berry, A. (2012). Teacher Professional Development Focusing on Pedagogical Content Knowledge. *Educational Researcher*, *41*(1), 26–28. https://doi.org/10.3102/0013189X11431010

Wilson, C. D., Borowski, A., & van Driel, J. H. (2019). Perspectives on the Future of PCK Research in Science Education and Beyond. In A. Hume, R. Cooper, & A. Borowski (Eds.), *Repositioning Pedagogical Content Knowledge in Teachers' Professional Knowledge* (pp. 289–300). Singapore: Springer.

PROFESSIONALISING TEACHERS FOR INQUIRY-BASED SCIENCE EDUCATION - CHALLENGES AND LIMITS

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Even though inquiry-based science education (IBSE) has been considered as an indispensable element of contemporary science education, science teachers still refrain from implementing it in their own classes. One of the reasons teachers name for that is that they themselves would not feel confident enough to implement IBSE on their own – even after having participated in a respective professional development (PD) programme. An empirical review has shown that most of the offered PD programmes especially lack elements like authentic inquiry experiences or practicing lesson development. In this study, we present a PD programme, which focuses on lesson development linked with in-depth reflection and, in this way, strives for bridging the gap between theory and practice. Collaborating with three chemistry teachers, we examined what challenges we – as teacher educators – faced when planning and conducting this especially designed PD programme. Moreover, we investigated how far an "ideal" PD programme is realisable under the prevailing conditions and what boundaries teacher educators encounter in this context.

Keywords: Continuing professional development, Inquiry-based teaching, Instructional design

INTRODUCTION

For more than 10 years, elements of IBSE have been incorporated in the Austrian science education standards for grade 8 (BIFIE, 2011) as well as in the curricula for chemistry at lower (BMUK, 2000) and upper secondary schools (BMB, 2016; bm:bwk, 2004). Nevertheless – similarly to many other countries (Capps, Shemwell & Young, 2016; Crawford, 2014; DiBiase & McDonald, 2015; Engeln, Euler & Maass, 2013) – IBSE has found its way into Austrian science classrooms only rarely until now (Hofer, Lembens & Abels, 2016). Reasons teachers name for this are that schools would lack of sufficient resources (time, equipment, spatial resources etc.), the appropriate organisational framework (flexible schedules, project-based approaches etc.) and that IBSE would not be compatible with the requirements of final exams. Moreover, Austrian teachers argue to not be appropriately prepared to apply IBSE to their own science classes without further support (Hofer, Abels & Lembens, 2018; Hofer et al., 2016; cf. Anderson, 2002; DiBiase & McDonald, 2015; Wallace & Kang, 2004).

An analysis of the PISA 2015 results, however, revealed the consequences of this insufficient implementation practice. Austrian students are lacking inquiry skills, especially of those belonging to the procedural and the epistemic domain (Suchan & Breit, 2016). Furthermore, students' statements indicate that science education in Austria still focuses on transferring knowledge rather than on working on problems and developing inquiry skills.

To prepare teachers for implementing IBSE in their own science classes, Capps, Crawford and Constas (2012) suggest developing PD programmes according to the following nine 'critical features of effective PD': *Total Time*, *Extended Support*, *Authentic Experience*, *Coherency*, *Develop Lessons*, *Modeled Inquiry*[1], *Reflection*, *Transference* and *Content Knowledge* (see Table 1). Capps et al. (2012) gained these features from examining literature with regard to PD in both the fields of general education research (Darling-Hammond & McLaughlin, 1995; Desimone, 2009) and of science education research (Garet, Porter, Desimone, Birman & Yoon, 2001; Loucks-Horsley, Love, Stiles, Mundry & Hewson, 2003; Penuel, Fishman, Yamaguchi & Gallagher, 2007). Besides findings from empirical studies, they also included the suggestions given in the teaching standards, one part of the National Science Education standards (National Research Council, 1996, 2000), when creating their list of 'critical features'.

Table 1. Critical features of effective PD programmes for IBSE (Capps et al., 2012, p. 298).

Feature	Description of feature
Total Time	Amount of time allotted for the programme
Extended Support	Programmes providing sustained support for teachers over an extended period of time
Authentic Experience	Programmes in which teachers conduct their own inquiry study
Coherency	Programmes that align with standard documents
Develop Lessons	Programmes in which teachers design inquiry-based lessons for use in their own classrooms
Modeled Inquiry	Programmes offering teachers the opportunity to engage in classroom inquiry
Reflection	Programmes in which teachers are given the explicit opportunity to reflect on their experiences
Transference	Programmes in which teachers explicitly discuss about enacting the curriculum in the classroom
Content Knowledge	Programmes that focus on science subject matter and content learning for teachers

Referring to these nine features, Capps et al. (2012) analysed 17 empirical studies dealing with PD programmes for IBSE and found that none of them addressed all of the nine features. Especially the features *Authentic Experience* (5/17) and *Develop Lessons* (7/17) were considered only rarely. The authors therefore assume these two features being the "missing link in helping teachers enact inquiry-based instruction in their own classrooms" (p. 306). Based on this assumption, they recommend modifying or extending already existing PD programmes in such a way that they particularly emphasise these two features.

In the following, we present a PD programme, which emphasises the feature *Develop Lessons* (one of the two underrepresented features) and links it with in-depth reflection (*Reflection*). After having briefly outlined the design of the PD programme, we discuss the difficulties we encountered when developing and conducting this programme. Moreover, we examine how far it is possible to realise an "ideal" PD programme for IBSE – according to the nine features suggested by Capps et al. (2012) – under the conditions prevailing in Austria.

[1] original spelling

THE PROFESSIONAL DEVELOPMENT PROGRAMME

Based on the data and experience gained in the course of the EU FP7-project TEMI (Hofer et al., 2016), we developed a PD programme that aimed at supporting teachers in implementing IBSE in their own science classes. For this purpose, the programme focused on the feature *Develop Lessons*. This includes designing and planning IBSE units and developing and preparing the material required for implementing them. As illustrated in Figure 1, the PD programme encompassed three IBSE units lasting 100 minutes (equivalent of two chemistry lessons) each. In cooperation with three Viennese secondary chemistry teachers, we collaboratively designed and planned the three units. In the following, these units were implemented individually by each teacher in their own chemistry classes (classes in grade 11 for the Units 1 and 2 and classes in grade 12 for Unit 3). Subsequently, a joint meeting was arranged in which the participating teachers exchanged the experiences they made during the implementation in their own classes and reflected on the findings they gained from this unit. Finally, the teachers discussed the implications and started with the planning of the following unit.

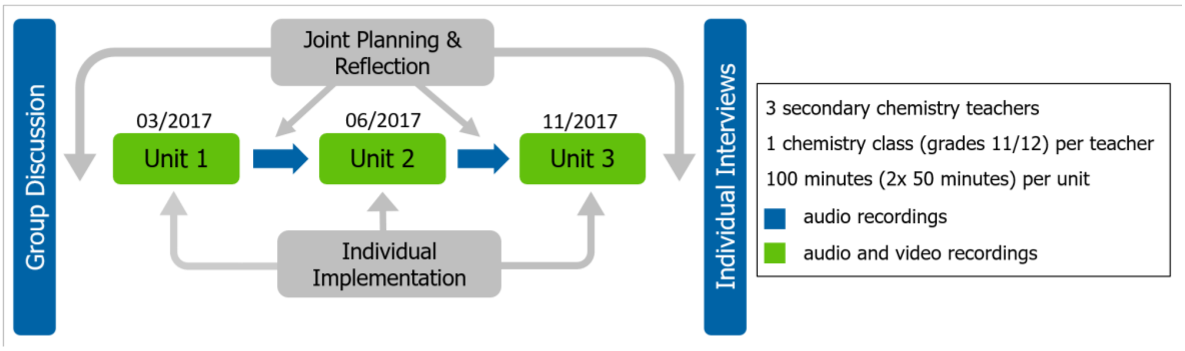

Figure 1. Design of the professional development programme.

In order to identify the emerging challenges and limits, the entire PD programme was accompanied by a continuous collection of data. The statements during the joint meetings (planning and reflection) were audio-recorded and during the individual implementation in the respective classrooms, both audio and video recordings were conducted (see Figure 1). Additionally, field notes were taken and observation protocols were filled in. For the purpose of data triangulation, audio recordings of both a preliminary group discussion and final interviews with the participating teachers were available.

INSIGHT INTO FIRST RESULTS

To discuss the challenges we were confronted with when developing and conducting the PD programme described above, we exemplarily refer to three of the nine 'critical features' proposed by Capps et al. (2012): (1) *Develop Lessons* and (2) *Reflection* (the features this PD programme focused on) as well as (3) *Authentic Experience* (that feature Capps et al. (2012) found to be underrepresented in most PD programmes for IBSE as well). Moreover, we examine how far it is possible to realise an "ideal" PD programme for IBSE – according to the nine features suggested by Capps et al., (2012) – under the conditions prevailing in Austria.

Feature 1: ***Develop Lessons***

In the course of the PD programme, it became apparent that the participating teachers required a systematic support. Especially at the beginning, teachers needed to be accompanied step by step when designing and planning units for IBSE. For us as teacher educators, it constituted one of the most challenging tasks to develop (further) teachers' knowledge and/or skills in several areas (subject matter, scientific inquiry, Nature of Science (NOS) / Nature of Scientific Inquiry (NOSI)) simultaneously. Additionally, knowledge about and skills in these areas had to be linked to the general steps of lesson planning (defining goals, planning lessons from "back to front", considering the process of gaining knowledge from investigations etc.). Due to the participating teachers' beliefs regarding IBSE, NOS/NOSI and science education in general (e.g. investigations are not preceded by a question to be answered; hypotheses can be proved by one experiment; after students have conducted an investigation, the teacher explains the results), it took a great amount of effort and persuasion to align the developed units with the 'Essential Features of Classroom Inquiry' (National Research Council, 2000) at some points.

Feature 2: ***Reflection***

To allow the teachers to reflect systematically on the experiences when implementing IBSE units in their own science classes, relevant knowledge and skill as well as sufficient time are required. In the course of the PD programme, it turned out that the participating teachers were lacking in both. On the one hand, lacking knowledge and skill regarding planning, conducting, observing and reflecting lessons led to subjective and superficial impressions instead of evidence-based observation and reflection. And on the other hand, teachers had such a tight schedule that reflecting on the implemented unit was only possible at the end of a day – six to eight hours after the respective lessons took place. As a result, teachers just wrote down their first impressions in note form instead of reflecting on their experiences in a profound and systematic way. These incomplete records, in turn, made it difficult for the teachers to introduce detailed information and differentiated descriptions of specific issues in the joint sessions. At this point, it was indispensable having available the field notes taken by the researcher. Referring to these records, teachers had the ability to reconstruct selected situations of the unit.

Feature 3: ***Authentic Experience***

Capps, Crawford and Constas (2012) identified – in addition to the feature *Develop Lessons* – especially the feature *Authentic Experience* to be underrepresented in most of the PD programmes they analysed. When attempting to enable teachers to engage in *Authentic Experience*, we primarily faced organisational obstacles. In addition to a lack of time on the part of the teachers, it was challenging to find institutions that were willing to cooperate in this setting. The reasons for this are multifarious. One the one hand, there are legal issues (insurance, disclaimer of liability, non-disclosure agreement etc.) that refrain many institutions from cooperating with teachers in these settings. On the other hand, institutions would need to spend resources in order to accompany and support the teachers; however, they receive no (financial) compensation in exchange for their participation. Beyond this, teachers would need support in order to be able to transfer the experiences they made to their own working environment. Only if they get the opportunity to apply aspects of their experiences to their own teaching strategies, there will be sustained impact to their classroom practice.

Obstacles to realise an "ideal" PD programme

It became apparent already during the design and planning of the PD programme that it is hard to create several of the prerequisites considered being especially beneficial for teacher PD at once. At this point, we are going to discuss two aspects, which result in a situation in which several of the 'critical features of effective PD' are realisable only with difficulty, great effort, or limited scope.

A considerable number of teachers in Austria are allowed to participate only in PD programmes, which are arranged as one-day workshops and/or take place outside teaching time. For this reason, PD programmes that are scheduled to extend over a longer period of time (*Total Time*) and include several full-day and/or multi-day modules are met with little response. Thus, the educational institutions responsible for teacher PD in Austria do not offer long lasting PD programmes already from the outset, reasoning that these programmes would not attract wide interest anyway. Consequently, it is considerably more challenging to conduct programmes that are more comprehensive regarding time (*Total Time*) and overall content (*Content, Knowledge, Authentic Experience*) and thus, support effective and sustainable PD.

Despite the limited duration of most PD programmes, many headmasters allow only one teacher to participate in the same PD offer. For this reason, teachers need to stay in contact with colleagues from other schools in order to make it possible to continue developing their own knowledge and skills in the framework of professional learning communities (cf. Darling-Hammond & McLaughlin, 1995; Garet et al., 2001; Loucks-Horsley et al., 2003). In such communities, teachers would have the opportunity to concentrate on transferring the contents of the PD programme to their own science lessons (*Transference*) and reflect on the experiences (*Reflection*) they gain in the course of application. Depending on professional learning communities outside of a teacher's own school implies a substantially higher effort in terms of both time and organisation.

CONCLUSION

To summarise, conducting the presented study revealed challenges in two main areas: firstly, teachers' prior knowledge, skills and beliefs regarding IBSE and secondly, the framework conditions for teacher PD in Austria. As many Austrian teachers have only little or no experience with IBSE, designing and planning units for IBSE (*Develop Lessons*) constitutes an enormous challenge not only for the teachers participating in the PD programme, but also for the teacher educators who need to support them according to their individual needs. Referring to Capps et al. (2012), the findings from this study would strengthen the hypothesis that the feature *Develop Lessons* could be one "missing link in helping teachers enact inquiry-based instruction in their own classrooms" (p. 306).

Finally, it can be stated that teacher PD in Austria must no longer be regarded as necessary evil, but as an essential element of teachers' professional responsibilities. Only then can we create appropriate framework conditions to realise long-term PD programmes, which build upon one another and, thus, ensure the effective, purposeful and sustainable professionalisation of teachers for IBSE.

ACKNOWLEDGEMENT

We are very thankful for the teachers cooperating in this research project.

This research project arose from TEMI (Teaching Enquiry with Mysteries Incorporated), a project under the Seventh Framework Programme (FP7, Science in Society) of the European Commission, Grant Agreement ID: 321403.

REFERENCES

Anderson, R. D. (2002). Reforming science teaching: What research says about inquiry. Journal of Science Teacher Education, 13(1), 1-12. DOI: 10.1023/a:1015171124982

BIFIE (Bundesinstitut für Bildungsforschung, Innovation und Entwicklung des österreichischen Schulwesens [Federal Institute for educational research, innovation and development of the Austrian school system]). (2011). *Kompetenzmodell Naturwissenschaften 8. Schulstufe [Competency model Science Grade 8]*. Wien: BIFIE

BMB (Bundesministerium für Bildung [Federal Ministry of Education]). (2016). *Bundesgesetzblatt II Nr. 219/2016 vom 9. August 2016 [Federal Law Gazette of the Republic of Austria No. 219/2016, Part II]*.

bm:bwk (Bundesministerium für Bildung, Wissenschaft und Kultur [Federal Ministry for Education, Science and Culture]). (2004). AHS-Lehrpläne Oberstufe neu: Chemie [New curricula for upper secondary schools: Chemistry].

BMUK (Bundesministerium für Unterricht und kulturelle Angelegenheiten [Federal Ministry for Education and Cultural Affairs]. (2000). Lehrpläne der AHS-Unterstufe: Chemie [Curricula for lower secondary schools: Chemistry].

Capps, D. K., Crawford, B. A. & Constas, M. A. (2012). A review of empirical literature on inquiry professional development: Alignment with best practices and a critique of the findings. Journal of Science Teacher Education, 23(3), 291-318.

Capps, D. K., Shemwell, J. T. & Young, A. M. (2016). Over reported and misunderstood? A study of teachers' reported enactment and knowledge of inquiry-based science teaching. International Journal of Science Education, 38(6), 934-959.

Crawford, B. A. (2014). From Inquiry to Scientific Practices in the Science Classroom. In Lederman, N. G. & Abell, S. K. (Eds.), Handbook of Research on Science Education (Vol. 2, pp. 515-541). New York: Routledge.

Darling-Hammond, L. & McLaughlin, M. W. (1995). Policies that support professional development in an era of reform. *Phi delta kappan, 76*(8), 597-604.

Desimone, L. M. (2009). Improving impact studies of teachers' professional development: Toward better conceptualizations and measures. *Educational Researcher, 38*(3), 181-199.

DiBiase, W. & McDonald, J. R. (2015). Science Teacher Attitudes Toward Inquiry-Based Teaching and Learning. The Clearing House: A Journal of Educational Strategies, Issues and Ideas, 88(2), 29-38. DOI: 10.1080/00098655.2014.987717

Engeln, K., Euler, M. & Maass, K. (2013). Inquiry-based learning in mathematics and science: a comparative baseline study of teachers' beliefs and practices across 12 European countries. ZDM, 45(6), 823-836. DOI: 10.1007/s11858-013-0507-5

Garet, M. S., Porter, A. C., Desimone, L., Birman, B. F. & Yoon, K. S. (2001). What makes professional development effective? Results from a national sample of teachers. *American educational research journal, 38*(4), 915-945.

Hofer, E., Lembens, A. & Abels, S. (2016). Enquiry-based science education in [Country] teacher professional development courses. In Eilks, I., Markic, S. & Ralle, B. (Eds.), 23rd Symposium on Chemistry and Science Education. TU Dortmund University, May 26-28, 2016 (pp. 271-278). Dortmund: Shaker Verlag.

Hofer, E., Abels, S. & Lembens, A. (2018). Inquiry-based learning and secondary chemistry education - a contradiction? RISTAL, 1, 51-65.

Loucks-Horsley, S., Love, N., Stiles, K. E., Mundry, S. & Hewson, P. W. (2003). *Designing professional development for teachers of science and mathematics* (2nd ed.). Thousand Oaks, CA: Corwin Press.

National Research Council (NRC). (1996). National science education standards: National Academy Press.

National Research Council (NRC). (2000). Inquiry and the National Science Education Standards: National Academy Press.

Penuel, W. R., Fishman, B. J., Yamaguchi, R. & Gallagher, L. P. (2007). What makes professional development effective? Strategies that foster curriculum implementation. *American educational research journal, 44*(4), 921-958.

Suchan, B. & Breit, S. (Eds.) (2016). PISA 2015. Grundkompetenzen am Ende der Pflichtschulzeit im internationalen Vergleich [PISA 2015. Basic competences at the end of compulsory schooling in international comparison]. Graz: Leykam.

Wallace, C. S. & Kang, N. H. (2004). An investigation of experienced secondary science teachers' beliefs about inquiry: An examination of competing belief sets. Journal of Research in Science Teaching, 41(9), 936-960.

SCIENCE TEACHERS CONTINUOUS EDUCATION THROUGH THE THREE PEDAGOGICAL MOMENTS

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This study aimed to evaluate the development of a continuous education course structured through the 3 Pedagogical Moments (PMs) with Science Teachers from Uruguaiana - RS, Brazil. The production of data occurred through numerous instruments. We noticed some limitations in relation to the teachers in following the proposal presented in the formative process, as well as in carrying out the implementation of the teaching plans in classroom.

Keywords: In-service Teacher Training, Teaching Practices, Science Education.

INTRODUCTION

It is increasingly essential for teachers to participate in spaces that foster their continuous education, because from these it is possible to promote reflections about their pedagogical practice, with an exchange of knowledge between professionals working in the same modality and educational levels, to reframe their teaching practice.

Researchers from different areas of education and teaching are investigating new ways of conceiving and organizing spaces for continuous education. In this sense, one of the studied proposals for this purpose are the 3 Pedagogical Moments (PM) that were proposed by the Brazilian researchers Delizoicov and Angotti (1994) as a transposition of Paulo Freire's dialogical-problematizing concept of education and that emerged from a dynamic planned to develop themes previously chosen in a science teaching project in Guinea-Bissau.

The 3 PM can be described the following way: the first PM is called "Initial Problematization" where real questions and / or situations that the students know and experience and that are linked to the content to be developed are presented. At this moment, the teacher will encourage discussions about the subject, allowing the exposition of alternative conceptions of students or instigating the understanding of other knowledge. The second PM is known as the "Knowledge Organization" where students will study the contents necessary to understand the theme and the first PM. The third PM is called "Application of knowledge", designed to perform the synthesis of the knowledge incorporated by the student, analysing and interpreting both the initial situations of the first PM and other situations that can be explained through the same scientific knowledge (Delizoicov & Angotti, 1994).

According to Fagundes (2013), the 3 PMs can be used to organize the lesson planning, contemplating current reality themes, allowing the contextualization of science teaching. On the other hand Muenchen (2010) and Giacomini and Muenchen (2015) mention that the 3 PM, beyond being used as didactic-pedagogical dynamics in the classroom, to build programs and curricula, can also be used to structure training processes, as long as changes are made to meet this proposal.

To work with the 3 PMs, it is necessary be present a theme in focus that is relevant to the social context in which it will be developed. In this sense, medicinal and toxic plants can be a possible topic to be used in science education, since according to data from the World Health Organization (WHO) 85% of people worldwide use these vegetables to treat diseases (Teixeira et al, 2014). Regarding Brazil, according data from the Ministry of Health, in the period from 2013 to 2015, the demand for treatments using medicinal plants and herbal medicines by the Sistema Único de Saúde (SUS) has more than doubled: a 161% growth was recorded (Portal Brasil, 2016). Besides that, the Sistema Nacional de Informações Tóxico-Farmacológicas (SINITOX, 2016) registered 363 cases of poisoning by plants in Brazil in 2016, and that 350 of them occurred in urban areas. It may seem like a small quantity of poisoning cases, taking in consideration the size of the Brazilian population, the problem is that many cases of plant poisoning are not even known.

If an analysis by Brazilian states is made, it will also be possible to check the presence of these vegetables in daily life, such as in the State of Rio Grande do Sul (RS), in which the population uses a variety of medicinal plants, for the most distinct therapeutic purposes (Dávila, 2011). One of the municipalities in which the use of numerous medicinal plants is verified is the city of Uruguaiana, in the border between Brazil and Argentina, according to the ethnobotanical study by Galvani and Barreneche (1994). In this same municipality, there were also several cases of intoxication by vegetables, as shown in the work of Dávila et al (2008) from their ethnobotanical study regarding toxic plants in the city of Uruguaiana - RS.

According to Silva and Santos (2017), the school represents an important space for the dialogue between popular knowledge and the concepts addressed in class, in addition to exercising the role of valuing students' personal experiences. Through the students popular knowledge, the teacher can (re) discover and (re) build knowledge necessary for scientific and technological literacy (Chassot, 2006).

However, has been seen throughout Brazilian academic productions in the Science Education area, that teachers encounter difficulties and / or feel insecure about the use of other teaching strategies. One way of solving this problem can be through the use of continuous education of teachers, since from these spaces you can promote reflections about pedagogical practice, with exchange of knowledge between professionals working in the same modality and educational level, reframing their teaching practice.

This study proposes to evaluate the development of a continuous education course structured though the 3 PMs, where the Toxic and Medicinal Plants theme in association with the 3 PMs was addressed, verifying the potentialities and challenges of a formative process in this format.

MATERIAL AND METHODS

The subjects involved in this investigation were 30 science teachers from the municipal education network of the city of Uruguaiana - RS, Brazil (Image 1). The choice of the study subjects was intentional, since it were the teachers at this location that asked the first author to develop a continuous education course with them. From this interest, an initial analysis of the conceptions of these teachers about science teaching was made in order to structure the course (Dávila, Folmer & Puntel, 2017).

Image 1 – Location of Uruguaiana - RS.

Source: G1 (2011).

The initial idea was to carry out a training process within the monthly meetings of pedagogical training offered by the Secretaria Municipal de Educação (SEMED), to be developed throughout the year, with periodic meetings. However, due to the annual planning of the pedagogical training of this institution, two meetings were authorized and granted. For this reason, the course consisted of two meetings, each lasting four hours, with an interval of two months between them so that the teachers had time to apply the teaching plans in a school context.

We developed a continuous education course, structured though Delizoicov and Angotti's (1994) 3 PMs, as described in the table below.

Table 01 - Continuous training course organized methodologically through the 3 PMs developing the contextualization theme "Medicinal and Toxic Plants" in association to the 3 PMs.

3 Pedagogical Moments	Description
First PM: Initial Problematization	Presentation of the course structure to situate the teachers. Application of initial questionnaire. Questionings regarding the subjects of the course to problematize it.
Second PM: Knowledge Organization	Expositive and dialogic Presentation of the current reality of science teaching; presentation of data from the dissertation in relation to the academic production in the area of science education; explanation of the results obtained with the participating students in the "Medicinal and Toxic Plants" workshop , showing the evolution of the students' answers and drawings regarding Botany and the theme. Explanation of the 3 PMs theoretical references (who they are and how they are organized), using as reference the books "Metodologia do ensino de Ciências" (Delizoicov & Angotti, 1994) and "Ensino de Ciências: Fundamentos e Métodos" (Delizoicov, Angotti & Pernambuco, 2011). Explanation and discussion about the use of themes in classroom, using for that purpose the official Brazilian documents that govern the Elementary School Final Grades (Parâmetros Curriculares Nacionais (PCN, 1998) and the Diretrizes Curriculares Nacionais (DCN, 2013)).
Third PM: Application of knowledge	Elaboration of structured teaching plans in the 3 PMs to develop the "Medicinal and Toxic Plants" theme in a class of their school (realized in the first meeting). In the second meeting, two months after the formative process, the results of the application of the teaching plan were presented in the form of a "Pedagogical Experiences Sharing Seminar".

Source: the author

The final activity (Pedagogical Experiences Sharing Seminar) was recorded and teachers were invited to participate in a semi-structured interview to present their testimony about this pedagogical experience faced in the course of continuous education.

As for the data analysis methodology, we adopted Content Analysis by (Bardin, 2011). For this analysis a triangulation of the data obtained by the different instruments (field diary, questionnaires, teaching plans and semi-structured interviews) was performed.

RESULTS AND DISCUSSION

From the 30 teachers invited, 14 female teachers took part. All with initial formation in their work area, three of them with specialization, with length of professional experience varying from 1 to 20 years.

We noticed that the first PM of the course provoked concerns, a lot of discussion of the topics selected for the continuous education, with reports of situations that occurred in the classroom during their teaching time. It was interesting, because it provided dialogue between the researcher and the teachers with different time amounts of experience in teaching. This dialogue between the subjects involved in the process was also verified by Giacomini and Muenchen (2015) when working with a group of teachers from different areas of knowledge in a formative process also organized through the 3 PMs, considering that the dialogue was mobilized by the teachers' reflection and action.

In the second PM when addressing the scientific knowledge needed to understand the use of the theme and the 3 PMs in the classroom, there was interest in the subject, questionings being conducted when some point of the theoric referential had not been well elucidated.

In the execution of the third PM, some challenges and limitations for the present study appeared. The first challenge was due to the concern of teachers in continuing the curriculum of the school year of the class where the teaching plan of this course that would be developed, because for them, to subordinate the content to the theme, would mean developing a work in parallel and they did not agree with that. A similar occurrence was seen in the reports of Muenchen (2010) interviews with the trainers of the continuous education courses in the municipality of Santa Maria - RS, Brazil, being one of the reasons that some course planning had a more conceptual than thematic focus. This demand was tried to be met, even knowing that this fact could increase the chances of use of the subject only as an example, illustration or a pretext to continue the programmatic contents of that school year, as pointed out by Wartha, Silva and Bejarno (2013).

The second challenge concerns the difficulty of the teachers to relate the theme of the course to any area other than Botany, showing again that they were trying to associate it to school content and not to explain the theme with the necessary scientific knowledge.

The third challenge of the third PM refers to the few teachers who finished the course, of the 14 participants; only seven teachers implemented their teaching plans.

The fourth challenge is linked to the previous one, because it was found that no teacher was able to develop the proposal of the continous education course, classifying the teaching plans (presented at the Experience Sharing Seminar), into three categories:

1st) Subtheme associated with the 3 MPs: within this category were included the works that approached the proposal of the continuous education.

2nd) Subtheme only: activities that used a sub-theme of the theme presented on the course.

3rd) Did not perform as instructed in the course: works that explored neither the theme nor the 3 PMs, but used the theme as an additional classroom task.

In the first category, two teaching plans were contemplated, from a teacher (called P1) who worked in a rural school and the other from a teacher (represented by P2) acting in a school located in a socially fragile area of the city.

Both plans have in common the approach of subthemes, chosen by the teachers, related to the theme presented in the formative process. The teachers understood that they could do it this way because they needed to adapt it to work with the content envisaged for that school year, in which hey had chosen to implement the activity of the training course. It is noticed that the use of themes was subordinated to the syllabus of that year and not the opposite, as is recommended by Delizoicov, Angotti and Pernambuco (2011).

The teachers addressed subthemes that were part of the students' reality, that besides contemplating the specific programatic contents of that year, had cultural issues, social problems and that had the potential to motivate further study by the students.

When comparing these data with the classification used by Silva and Mortimer (2010) when developing the conceptual, contextual, phenomenological and epistemological aspects of chemical content in the classroom, it is suggested that the teachers of this investigation, to chose subthemes from a contextual dimension, because they aimed to approach scientific content with a social, technological, environmental or historical context.

Next, the teaching plans of teachers P1 and P2 are described.

Teacher P1's teaching plan – Subtheme: Drugs derived from toxic plants and their effects on the nervous system

1st PM – Awareness: Videos about drugs, their effects on the nervous system, the risks to the body, and withdrawal crises were used and after that there was a talk to discuss.

Establish relationships between drugs and their effects on the nervous system: class discussion, and notes on the subject.

2nd PM – Explanation and notes on the nervous system, its anatomy and physiology; visualization in models and boards of the main organs and functions.

Group research on the main plant-derived drugs, their effects on the nervous system and the effects of withdrawal.

3rd PM – Organization of data and construction of information panels on the main plants that give origin to legal and illegal drugs and their main effects on the body.

Presentation of the work carried out to classmates in the form of seminars.

Resumptiom of the videos of the 1st PM.

Discussion of some questions.

Explaining though the use of scientific knowledge.

Teacher P2's teaching plan – Subtheme: Mate Herb

1st PM – Questions and discussion about where the Mate Herb they buy from the market comes from.

2nd PM – Historical, cultural and geographical approach to Mate Herb.

Before introducing scientific knowledge of sciences, students had to answer a questionnaire that contained the following questions: "Do you have the habit of drinking mate?; How many times a day do you take mate ? Do you know any benefits of mate? Do you know any harm of mate?".

Students had to apply this questionnaire to 15 people in their neighborhood and bring the data in the next class.

Creation of graphics with the data collected from the questionnaires.

Discussion of results.

Approach of the questions and answers of the questionnaire with the contents of the human body.

3rd PM – Application of recreational activities (crosswords, question-and-answer game related to the theme, memory game) to students as a way of evaluating the subject.

Regarding the second category "Subtheme only", was composed by only one teaching proposal. The teacher (represented by P3) launched the theme in the classroom to reflect on it, because according to her, already worked with themes in the classroom, but the students chose them. By developing in this way with the theme "Medicinal and Toxic Plants", students ended up leading the approach to "Energy", because they were interested in the process of photosynthesis.

In the last category, four teaching proposals were included, that used the theme "Medicinal and Toxic Plants" as a complementary task to the content that had been addressed by the teachers, in which students should conduct a group research on the subject and after that, present it to the class in a seminar format. All teachers in this category have claimed that the time was a limiting factor to implementing their planned activities.

The activities carried out by each teacher are identified below:

Teacher P4 – from the theme proposed in the training course, she extracted a subtheme of it to carry out a work complementary to the content of human physiology. The chosen subtopic "Substances extracted from vegetables: Caffeine and THC (extracted from marijuana)" was due to an association with the History teacher who wanted to deal with the subject of Coffee. The activity developed by the students corresponded to the elaboration of a folder and a parody, both about caffeine and THC. Four questions were given to guide the work: "what were the drugs Caffeine and THC?"; "where they were found?"; "what are the effects of these drugs on the human body, both beneficial and harmful?" and "a curiosity about these drugs". The history teacher asked for the history of coffee. Students had to present these activities in the classroom.

Teacher P5 - Had the understanding that she should approach the concept of a plant and its structures before the theme, therefore, the demonstration activity was developed before, but even so, she did not finish her planning, went no further than the proposal that will be described. She took a plant and asked the students to observe it and compare what was there of similarities and differences with the human body. Soon after, she placed a plant in water with dye and another plant in a container with water without dye and asked them to observe and write what would happen to the plant that was in the dye. The students made graphs of the hypotheses of what would happen to the plant that was in the dye. After a few days, they looked again at the plant that was in the dye and wrote down the reasons for the vegetable to be showing colored petals, which were initially white. The students made assumptions regarding photosynthesis, that the plants had a "small pipe". After this practical activity, she made a comment in in the classroom about what medicinal plants were and which could become toxic and from this moment on she was unable to carry on working with medicinal and toxic plants.

Teacher P6 – She covered with the students the content of plant morphology to later address the theme, as she believed that students needed prior knowledge to later study the theme. She developed a research activity related to medicinal and toxic plants, that she had found in the textbook, with the students. After researching it in pairs, they had to present it in the classroom.

Teacher P7 – Divided the class into groups and each had a topic about plants (terrarium assembly; plant experiment in the dark; conducting vessels; plant reproduction; root development; germination) and a group with medicinal and toxic plants. The teacher, as well as the others in this category, believed that the students should first have a theoretical background in botany, because she considered her students immature, in the sense that they had no idea what a plant is.

When interviewing teachers about the elaboration and execution of teaching plans, it was found that the teachers had difficulties during the time allotted for this activity. The first one was related to the time to execute the teaching strategy in the classroom. It was found that two months had been a short time to implement their teaching proposal with the students. This hindered the development of plans as discussed in the continuous education course, leading all teachers not to implement the theme “Medicinal and Toxic Plants”, but to unfold it in subthemes and depending on the teacher, to approach it from the 3 PMs or not. This difficulty of lack of time to organize, plan and implement the teaching plan may be linked to the current conditions of teaching work, as evidenced in the study by Donatelli and Oliveira (2010) with basic education teachers in RS.

Another factor present in the teachers' statements that may have limited the execution of the teaching strategy in a satisfactory way: the current curricular organization in schools, which developed a feeling of imprisonment to school content among teachers, becoming a challenge for the implementation of the theme from the perspective of the 3 PMs, limiting the investigation of the potentialities of the proposed theme.

It may be that in this study, the short duration of the training process has failed to change teaching practice. Sauerwein (2008) emphasizes that courses with this characteristic may not allow the increment of this in the permanent education of the teacher, perhaps using it for a short time in their pedagogical practices. However, Neto (2014, p. 13) points out that although this training format “does not seem to offer enough time for the processes of understanding and acceptance to materialize, they are important as they present alternatives, they motivate, they show ways of how, why, where and when to use a particular activity”.

It can also be seen through the interviews, that even teachers did not use the theme as initially proposed in the training process; positive results were obtained regarding the implementation of teaching plans. Although the theme was unfolded in different sub-themes or developed as a complementary activity to the sequence of contents that the teachers were addressing, if it succeeded in instigating the students' curiosity, giving subsidies to promote a dialogue between teacher - student, student - student and between popular knowledge and scientific knowledge. Moreover, through these plans, it can be ascertained that contents and developments can emerge from the theme “Medicinal and Toxic Plants” and serve as a subsidy for future planning, where the theme can be seen as the object of study that disciplinary contents are organized from, opening possibility for an articulation of the different areas of knowledge to work around a common objective.

FINAL CONSIDERATIONS

It was found that the formative process presented did not allow teachers in the 3rd PM to elaborate and execute teaching plans in which the school content was subordinated to the theme, requiring a continous education course like this, which is structured in 3 PM, to be developed with a longer duration and longer meetings, giving a greater support to teachers. However, it provided, as far as possible, the discussion of the pedagogical praxis of teachers as well as a greater interaction between university and school, offering a space for sharing knowledge and getting closer to the academic material.

Another aspect that may have interfered with the success of the 3rd PM was the teaching conception and curriculum of the teachers in this study, as they were shown to be “imprisoned” to the school contents of the current curricular organization of school..

Even with the challenges faced in this continuous education, teachers were active subjects in this training process, in which their concerns, teaching knowledge and doubts were heard and discussed, through the promoted dialogue, in addition to bringing the subjects involved to reflect on their pedagogical practices, studying a different teaching methodology and trying to develop a teaching plan different from their usual.

The theme "Medicinal and Toxic Plants" allowed immersion in different social contexts, as seen in the work implemented by the teachers, but it is believed to have a much greater potential if we have public policies giving subsidies to have greater curricular flexibility in school institutions.

REFERENCES

Bardin, L. (2011). *Análise de conteúdo [Content Analysis].* Lisboa: Edições 70.

Brasil. Secretaria de Educação Fundamental. (1998). *Parâmetros Curriculares Nacionais: terceiro e quarto ciclos do ensino fundamental (Ciências Naturais) [*National Curriculum Parameters: third and fourth cycles of elementary education (Natural Sciences)] Secretariat of Fundamental Education – Brasília: MEC/SEF. 138 p.

Brasil. Ministério da Educação. Secretaria de Educação Básica. (2013). *Diretrizes Curriculares Nacionais Gerais da Educação Básica [*General National Curriculum Guidelines for Basic Education]. Secretariat of Basic Education. Brasília: MEC, SEB, DICEI. 562 p.

Chassot, A. (2011). *Alfabetização científica: questões e desafios para a educação* [Scientific literacy: issues and challenges for education]. 5ª ed. Ijuí: Unijuí.

Authors. (2008). Published in VIII Salão de Iniciação Científica - Ed. Internacional; VIII Mostra Científica – Ed. Internacional e I Feira de Extensão – Ed. Internacional (PUCRS,UNIPAMPA, UCP – RA) Uruguaiana: Federal University of Pampa, Brazil.

Authors (2011). *Monograph, Federal University of Lavras* (UFLA), Brazil.

Authors. (2017). *Revista Exitus.*

Delizoicov, D. & Angotti, J. A. (1994). *Metodologia do Ensino de Ciências* [Science Teaching Methodology]. São Paulo: Cortez.

Delizoicov, D., Angotti, J. A. & Pernambuco, M. M. (2011). *Ensino de ciências: fundamentos e métodos* [Science teaching: fundamentals and methods]. 2ª Ed. São Paulo: Cortez.

Donatelli, S. & Oliveira, J. A. (2010). *O trabalho de professores da educação básica no Rio Grande do Sul* [The work of basic education teachers in Rio Grande do Sul]. São Paulo: Fundacentro.

Fagundes, E. M. (2013). *O uso de temas cotidianos para o ensino de ciências nos anos iniciais do ensino fundamental* [Use of topics of everyday for teaching science in the early years of elementary education]. (Published master's thesis) Federal Technological University of Paraná, Brazil). Retrieved from: http://repositorio.utfpr.edu.br/jspui/handle/1/1248?mode=full

Galvani, F. R. & Barreneche, M. L. (1994). Levantamento das espécies vegetais utilizadas em medicina popular no município de Uruguaiana (RS) [Survey about vegetables species used in the popular medicine in Uruguaiana county RS]. *Revista da FZVA,* 1 (1), p. 1 – 14. Retrieved from: http://revistaseletronicas.pucrs.br/ojs/index.php/fzva/article/view/1933

Giacomini, A. & Muenchen, C. (2015). Os Três Momentos Pedagógicos como organizadores de um processo formativo: algumas reflexões [The Three Pedagogical Moments as organizers of a training process: some reflections]. *Revista Brasileira de Pesquisa em Educação em Ciências,* 15 (2), 339 – 355. Retrieved from: https://periodicos.ufmg.br/index.php/rbpec/article/view/4317

G1. Mestre-sala de escola de samba no RS morre após descarga elétrica. Available in: http://g1.globo.com/brasil/noticia/2011/02/mestre-sala-de-escola-de-samba-no-rs-morre-apos-descarga-eletrica.html. Access in: April 2018.

Muenchen, C. (2010). *A disseminação dos Três Momentos Pedagógicos: um estudo sobre práticas docentes na região de Santa Maria/RS* [The dissemination of the Three Pedagogical Moments: a study on teaching practices in the region of Santa Maria - RS]. (Doctoral dissertation, Federal University of Santa Catarina (UFSC), Brazil). Retrieved from: https://repositorio.ufsc.br/xmlui/handle/123456789/93822

Neto, T. S. (2014). *Formação continuada de professores de química: uma análise sobre o entendimento e aceitação das atividades propostas em cursos de curta duração* [Continuing teacher education chemistry: a review of the understanding and acceptance of the proposed activities on short courses]. (Published Master's Dissertation). Federal University of Santa Maria, Santa Maria, Brazil. Retrieved from: https://teses.usp.br/teses/disponiveis/81/81132/tde-27042015-163717/en.php

Portal Brasil. (2016). *Uso de plantas medicinais e fitoterápicos sobe 161% [Use of medicinal plants and herbal medicines rises 161%].* Available in: http://www.brasil.gov.br/saude/2016/06/uso-de-plantas-medicinais-e-fitoterapicos-sobe-161. Access in: January 2018.

Sauerwein, I. P. S. (2008). *A Formação Continuada de Professores de Física – natureza, desafios e perspectivas [In-Service Physics Teacher Education (ISPTE) - nature, challenges and perspectives].* (Published Doctoral dissertation) Federal University of Santa Catarina (UFSC), Brazil). Retrieved from: https://repositorio.ufsc.br/handle/123456789/91222

Silva, P. S. & Mortimer, E. F. (2010). Desenvolvendo os aspectos conceituais, contextuais, fenomenológicos e epistemológicos do conteúdo químico em sala de aula [Developing the conceptual, contextual, phenomenological and epistemological aspects of chemical content in the classroom]. In: XV Encontro Nacional de Ensino de Química (XV ENEQ), 2010, Brasília, Brazil.

Silva, D. F. & Santos, M. G. (2017). Plantas medicinais, conhecimento local e ensino de botânica: uma experiência no ensino fundamental [Medicinal plants, local knowledge and botany teaching: an experience at elementary school]. *Revista Ciências & Ideias,* 8 (2), 139 – 164. doi: 10.22047/2176-1477/2017.v8i2.679.

Sistema Nacional de Informações Tóxico-Farmacológicas (SINITOX). (2016). *Casos Registrados de Intoxicação Humana por Agente Tóxico e Zona de Ocorrência do Brasil* [Registered Cases of Human Toxic Intoxication and Brazilian Occurrence Zone]. Retrieved from: https://sinitox.icict.fiocruz.br/dados-nacionais. Access in: January 2018.

Teixeira, A. H., Bezerra, M. M., Chaves, H. V., Val, D. R., Filho, S. M P, Silva, A. A. R. (2014). Conhecimento popular sobre o uso de plantas medicinais no município de Sobral – Ceará, Brasil [Popular knowledge on the use of medicinal plants in the municipality of Sobral, Ceará, Brazil]. *S A N A R E,* 13 (1), 23-28. Retrieved from: https://sanare.emnuvens.com.br/sanare/article/view/429/284

Wartha, E. J., Silva, E. L. & Bejarano, N. R. R. (2013). Cotidiano e Contextualização no Ensino de Química [Quotidian and contextualization in chemistry teaching.]. *Química Nova na Escola,* 35 (2), 84 - 91. Retrieved from: http://qnesc.sbq.org.br/online/qnesc35_2/04-CCD-151-12.pdf

THE TRANSITION FROM PRIMARY TO SECONDARY SCHOOL IN SCIENCE EDUCATION

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In science education, there are serious concerns about continuity and progression in students' learning at key points of transition especially during the transition from primary to secondary school. National and international studies show a lack of progress in students' learning as well as their loss of interest. One of the key issues seems to be a lack of teachers' competencies. Therefore, the aim of this study is to identify competencies required by teachers to ensure progression and continuity in students' learning. For this purpose, a Delphi survey is conducted which includes different experts related to the transition process in science education. In addition, guideline-based interviews with 5th grade students, who recently experienced the transition, will be used to capture the students' perspective. In a preparatory study, transition-related activities were derived deductively from the literature and summarised within a category system. The six main categories Knowledge of Curricula in Science Education*,* School Environment & Organisation*,* Assessment, Teaching Styles & Approaches*,* Cooperation *and* Empathy for Students' Transition Process *were used to structure and analyse the first round of the Delphi survey. First results show that experts demanded competencies in all these six categories.*

Keywords: Primary School, Secondary School, Teacher Professionalism

INTRODUCTION

In Germany, the education system is characterised by a number of transitions. The transition from primary to secondary school represents the first change that all students usually have to pass after the fourth grade at the age of 10. In particular, this transition is associated with changes within social, instructional as well as organisational aspects that might have an impact on students' learning (Ophuysen, 2009). With regard to science education, there are serious concerns about continuity and progression in students' learning related to the transition process.

Science Education in the Transition from Primary and Secondary School- Status Quo

In Germany, the transition from primary to secondary school is accompanied by differences in subjects' structure, teachers' education, as well as teaching styles. In primary school there is an integrative subject combining both natural and social sciences (called "Sachunterricht"; GDSU, 2003). That is why teachers at primary school need a broad (pedagogical) content knowledge in natural and social sciences. Therefore, they are known to be generalist teacher (Möller, 2014), often teaching subjects they did not formerly study themselves. In contrast, in secondary school, there are different science subjects (e.g. physics, biology, chemistry, geography and technology). Teachers of secondary schools are known to be specialist teacher (ibid.), due to their focus on one or two of those subjects. Furthermore, primary school's science education seems to be more student-centred including practical science, whereas secondary school's science education appears to be more teacher-centred (ibid.).

Difficulties associated with the transition process are investigated not only in Germany. International and national studies prove that there are key issues related to the transition from primary to secondary school, which affect students' learning (e.g. Galton, Gray, Rudduck, 1999, 2003; Ophuysen, 2009). In science education, studies across several countries indicated that students fail to manage the transition from primary to secondary school (Braund, 2008a; HMIe, 2005; Möller, 2014). In addition, there is also evidence that students' interest decline in the early years of secondary school. Especially in science education, various studies show the decline in subjects like physics (Walper, 2014). Moreover, the loss of interest when compared with students' interest at the end of primary school is worse in science than in math (Heine, Willeke, Best & Pospiech, 2013).

One of the key issues seems to be the lack of teachers' competencies. As a "co-constructive process" (Griebel & Hiebl, 2010, p. 18), primary and secondary school teachers must be capable of supporting a transition that ensures students' cumulative learning. Hempel and Maltzahn (2012) state, that primary and secondary school science teachers often are unfamiliar with each other's curricula. Moreover, secondary school science teachers are insecure of what to expect from their new students recently graduated from primary school. They even rate the primary school students' prior knowledge in the natural sciences to be quite low (ibid.) although there is no evidence. Instead, Dalehefte and Rieck (2014) indicate that primary school students learned scientific methods and possess a basic knowledge in sciences that are in line with the curriculum at secondary schools. Moreover, Hempel and Maltzahn (2012) point out that secondary school teacher often fail to refer to students' prior knowledge and learning experience. Racherbäumer and Kohnen (2014) declare that the diagnosis of prior knowledge at the beginning of the fifth grade is a rare exception, especially in natural science subjects. Galton, Gray and Ruddock (1999) as well as Braund and Driver (2002) state that teacher of secondary school distrust the students' levels of attainment that they have been assessed in the primary school. Moreover, it is their justification to "still cling to the principle of the 'fresh start'" (Galton, Gray, & Ruddock, 1999, p. 6). Therefore, basic skills and procedure as well as topics are often full repeated in secondary school (Braund, Crompton, Driver, & Parvin, 2003). Various models explaining the importance of teachers' competencies due to their influence on the quality of the transition process (Griebel and Hiebl, 2010; Ophuysen, 2005; Ophuysen & Harazd, 2014). However, the teachers' required competencies are still unkown.

Current Practice in Tackling Transition in Science Education– Review of Literature

The continuity and progression of students' learning at key points of transition have been considered at terms of curricula, administration and teacher training (Möller, 2016). Studies on the development and implementation of a spiral curriculum, so-called bridging units or materials show that a continuous curriculum is possible (e.g. Braund, 2008b; Burr & Simpson, 2006, 2007; McCormack, 2016). At the administrative level, the introduction of subjects which combining natural sciences at the beginning of secondary school was recommended, e.g. by Wodzinski (2006), but not implemented compulsory. Furthermore, joint activities or projects in primary and secondary schools are supported by regional projects (e.g. Demuth, Walther & Prenzel, 2011) and the development of regional school networks (e.g. Järvinen, Otto, Satory, & Sendzik, 2012). In addition, there are recommendations for pedagogic transitional-related activities, which are used in various ways already (Braund, Crompton, Driver, & Parvin, 2003; Galton, Gray, & Ruddock, 1999, 2013; Ophuysen, 2005). However, the transition in science education is rarely supported by teachers' transition-related activities (Hempel & Maltzahn, 2012; Rau-Patschke & Brüggerhoff, 2019).

RESEARCH QUESTIONS

The research aim of this study is to determine teachers' required competencies in order to ensure a continuous development of knowledge, interest and motivation during the transition in science education. Therefore, the central research questions of this study are:

Research Question 1: Which competencies do teachers require in order to ensure continuity in the student's learning process and in the development of knowledge, interest and motivation during the transition in science education?

Research Question 2: What recommendations can be derived from students' own experience during the transition in science education and which issues still need to be addressed to ensure the well-being of the students?

The following information relate to Research Question 1.

METHODS & DESIGN

To answer these questions, a three-stage Delphi survey was designed. The characteristics of the Delphi technique are the anonymous group interaction and responses, the iterative process and the feedback (Linstone & Turoff, 1975). Linstone and Turoff (1975) define the Delphi technique "[…] as a method for structuring a group communication process so that the process is effective in allowing a group of individuals, as a whole, to deal with a complex problem" (p. 3). The complex problem of the present study is the identification of previously unknown competencies required by teachers to ensure the continuity and progression in students' learning in science education. Since the variety of experts determines the quality of the results of the Delphi survey, members of the present Delphi expert panel were selected to represent a community who possess a wide range of expertise in the field of transition, science education as well as teacher training. Individuals from four areas within this community were involved in the study (hereafter called 'expert panel'):

- Science teacher of primary and secondary school
- Researchers in natural science education
- Teacher trainers of primary and secondary school in natural science education
- Headmasters of primary and secondary school

In a preparatory study, transition-related activities were deductively derived from the literature. These activities are used to formulate a first set of teacher's required competencies. They are summarised within a category system. The six main categories *Knowledge of Curricula in Science Education*, *School Environment & Organisation*, *Assessment*, *Teaching Styles & Approaches*, *Cooperation* and *Empathy for Students' Transition Process* are used to structure and analyse the first round of the Delphi survey (Rau-Patschke & Brüggerhoff, 2019).

In Round I, the experts were asked to answer open-ended questions related to these six categories. The main question was:

What are the characteristics of teachers who are capable of supporting a transition that ensures a continuous development of knowledge, interest and motivation during the transition in science education?

The responses are collected and analysed using qualitative content analysis (Mayring, 2015). The analysed skills, abilities and attitudes complete the category system.

In Round II, based upon these qualitative results, a questionnaire with closed questions will be developed and sent to a bigger expert panel (*N*=300). The experts are asked to rate the items on a 5-Point Likert Scale according to their relevance.

In Round III, the same expert panel is given the opportunity to reconsider and, if necessary, change their own opinion based on the group response. Finally, the results are analysed with regard to the consensus between the expert subgroups. Figure 1 illustrates the procedure of the present Delphi survey.

In the pilot phase *N*=16 experts took part of the open-ended questionnaire, equally divided in all four subgroups. For the first round of the Delphi survey a sample size of *N*= 140 experts is addressed. For the second and third round, a sample size of *N*=190 experts is aimed, in which the experts participate in both, the second and third, survey round.

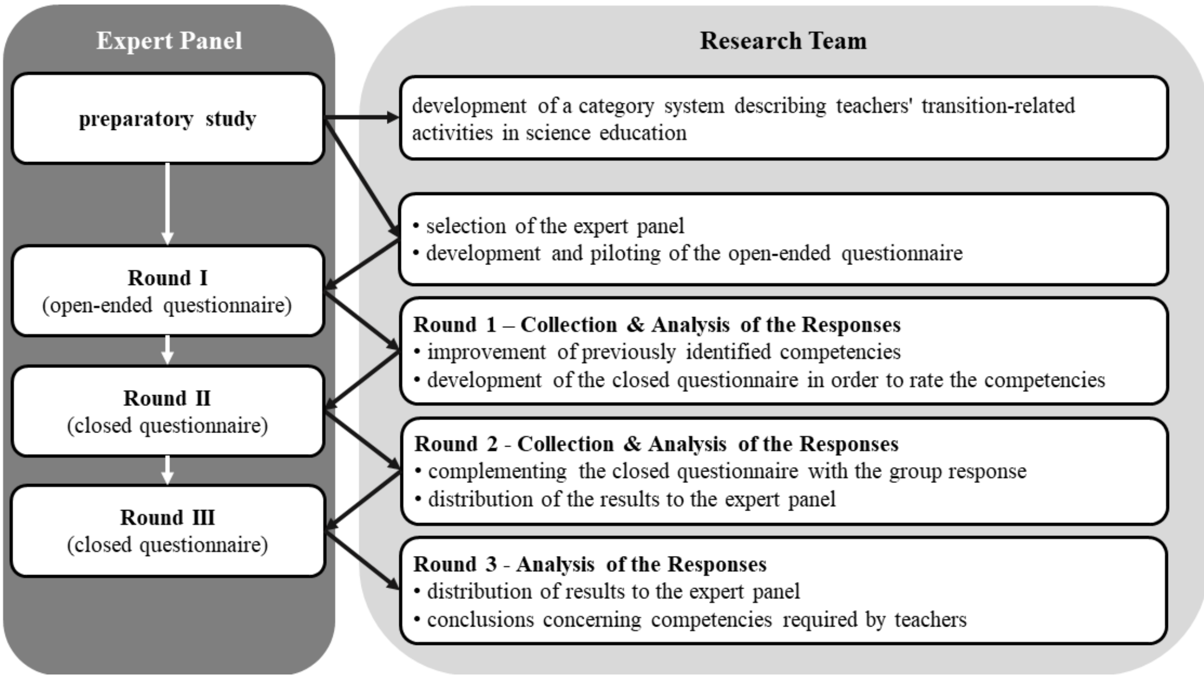

Figure 1. Flow chart of the Delphi study (based on Carabias et al., 2015)

RESULTS

The results show that experts demand skills, abilities and attitudes in all six categories (Figure 2). Especially in the categories *Knowledge of Curricula in Science Education*, *Assessment* and *Teaching Styles & Approaches* the experts require different skills and abilities that deal with knowledge about school policies, prior knowledge, core ideas, contents, methods and subject structures. So far, the demand skills and abilities in the categories *School Environment & Organisation* and *Cooperation* have remained nonspecific related to transition in science education so far. In particular, in the category of *Empathy for Students' Transition Process*, the experts demand specific attitudes and positions from teachers at primary and secondary school, which focus on the empathy of the teachers.

Knowledge of Curricula in Science Education	Primary and secondary school science teachers are familiar with each other's science subject structures.
School Environment & Organisation	Secondary school science teachers make the work in subject rooms a topic of discussion.
Assessment	Primary and secondary school science teachers advise students regarding their performance at key points of transition in science education.
Teaching Styles & Approaches	Secondary school science teachers use well-known methods of science education of primary schools.
Cooperation	Primary and secondary school science teachers are aware of the benefits of cooperation between primary and secondary schools in science education.
Empathy for Students' Transition Process	Primary and secondary school science teachers give attention to the differences between primary and secondary schools in science education.

Figure 2. Skills, abilities and attitudes demanded by the expert-panel

CONCLUSION

As the discussion about continuity and progression in students' learning at key points of transition the aim the study is to determine teachers' required competencies in order to ensure a continuous development of knowledge, interest and motivation during the transition in science education. Related to the categories *Knowledge of Curricula in Science Education*, *School Environment & Organisation*, *Assessment*, *Teaching Styles & Approaches*, *Cooperation* and *Empathy for Students' Transition Process*, the experts require abilities, skills and attitudes. However, they do not only seem to be of high relevance for the continuity and progression in students' learning at key points of transition, but also in everyday teaching. Therefore, the question arises if there are competencies already mentioned in models of teachers' profession which are important especially for transition. In order to answer this question, the main study will involve a larger sample size. In addition, by answering the second research question, the perspective of 5th grade students will also be captured. In guideline-based interviews, they will be asked about their requirements regarding transition-related activities.

REFERENCES

Braund, M. (2008a). Moving up – but Why Don't They Always Move On? In M. Braund (Ed.), *Starting Science ... Again? Making Progress in Science Learning* (pp. 22-34). London: SAGE Publications.

Braund, M. (2008b). Bridging the Divide: Part 2 – Science Bridging Units. In M. Braund (Ed.), *Starting Science ... Again? Making Progress in Science Learning* (pp. 97-98). London: SAGE Publications.

Braund, M., Crompton, Z., Driver, M., & Parvin, J. (2003). Bridging the key stage 2/3 gap in science. *SSR*, *85*(310), 117-123.

Burr, S., & Simpson, F. (2006). *Swing through with science: a project to support transition from primary to secondary school through science; the primary perspective*. Paper presented at the Scottish Educational Research Association (SERA) Conference, Perth. Retrieved from www.leeds.ac.uk/educol/documents/160934.doc [23.01.2020].

Burr, S., & Simpson, F. (2007). *Swing through with science: a project to support transition from primary to secondary school through science; the secondary perspective*. Paper presented at the Association for Science Education Research Association Science Interest Group, University of Birmingham. Retrieved from http://www.leeds.ac.uk/educol/documents/161006.htm [23.01.2020].

Dalehefte, I. M., & Rieck, K. (2014). How do German primary school teachers prepare students for science standards? Findings from a video study of the Professional Development Program SINUS for Primary Schools. *Form@re*, (2), 7-20. doi: 10.13128/formare-15123

Demuth, R., Walther, G., & Prenzel, M. (Eds.). (2011). *SINUS-Transfer: Grundschule. Unterricht entwickeln mit SINUS: 10 Module für den Mathematik- und Sachunterricht in der Grundschule* [SINUS-Transfer: Grundschule. School Development with SINUS: 10 Modules for Math and Science Education in Primary Schools]. Seelze: Klett; Kallmeyer.

Galton, M., Gray, J., & Rudduck, J. (2003). *Transfer and Transitions in the Middle Years of Schooling (7-14): Continuities and Discontinuities in Learning* (Research Report No 443). London: Department for Education and Skills.

Galton, M., Gray, J., & Rudduck, J. (1999). *The Impact of School Transitions and Transfers on Pupil Progress and Attainment* (Research Report No 131). London: Department for Education and Employment.

Gesellschaft für Didaktik des Sachunterrichts (GDSU) (2003). *Perspectives Framework for General Studies in Primary Education. A framework for teaching general knowledge.* Bad Heilbrunn: Julius Klinkhardt.

Griebel, W. & Hiebl, P. (2010). Transition als ko-konstruktiver Prozess: Übergang in die weiterführende Schule als Transition für Kind und Eltern - die Kompetenzen aller Beteiligten sind gefragt [Transition as a Co-Constructive Process: Transition to Secondary School as a Transition of Children and their Parents]. In *Akademie für Lehrerfortbildung und Personalführung* (Ed.): Übergänge gestalten! Grundschule-weiterführende Schulen [Managing Transitions. Primary School- Secondary School] (pp. 17–29). Dillingen a. d. Donau.

Heine, A., Willeke, M., Best, J., & Pospiech, G. (2013). Vom Sachunterricht zum Fachunterricht [The Transition from Primary to Secondary School in Science Education]. In S. Bernholt (Ed.), *Gesellschaft für Didaktik der Chemie und Physik (GDCP): Vol. 33. Inquiry-based Learning - Forschendes Lernen* (pp. 707–709). Kiel: IPN.

Hempel, M., & Maltzahn, K. von. (2012). *„Endlich haben wir richtige Physik!": Naturwissenschaftliche Interessen von Mädchen beim Übergang von der Grundschule in die weiterführenden Schulen* ["Finally, we have physics!" Scientific interests of girls during the transition from primary to secondary school]. Vechtaer fachdidaktische Forschungen und Berichte. Vechta.

HM Inspectorate of Education (HMIe) (2005). *Improving Achievement in Science. In Primary and Secondary School*. Livingston: Crown.

Järvinen, H., Otto, J., Sartory, K., & Sendzik, N. (2012). Schulnetzwerke im Übergang: Das Beispiel Schulen im Team [The Development of School Networks related to Transitions. The Example of Schulen im Team]. In N. Berkemeyer, S.-I. Beutel, H. Järvinen, & S. van Ophuysen (Eds.), *Lernen in der Grund- und weiterführenden Schule* [Students' Learning in Primary and Secondary School] (pp. 208–237). Köln: Carl Link.

Mayring, P. (2014). *Qualitative content analysis: theoretical foundation, basic procedures and software solution*. Klagenfurt: SSOAR.

McCormack, L. (2016). The use of CASE to bridge the transition between primary and secondary school science in Ireland. *SSR*, *98*(362), 47-54.

Möller, K. (2016). Anschlussfähigkeit im Sachunterricht nach unten und oben herstellen - Ziele, Bedingungen und Möglichkeiten [Progression and Continuity in Science Education in Primary School - Goals, Conditions and Possibilities]. In H. Giest, T. Goll, & A. Hartinger (Eds.), *Probleme und Perspektiven des Sachunterrichts: Vol. 26. Sachunterricht - zwischen Kompetenzorientierung, Persönlichkeitsentwicklung, Lebenswelt und Fachbezug* [Science Education in Primary School - Competencies, Personality Development, Living Environment and Subjects] (pp. 21–34). Bad Heilbrunn: Klinkhardt.

Möller, K. (2014). Vom naturwissenschaftlichen Sachunterricht zum Fachunterricht – Der Übergang von der Grundschule in die weiterführende Schule [The Transition from Primary to Secondary School in Science Education]. *ZfDN, 20*(1), 33–43. doi: 10.1007/s40573-014-0010-8

Linstone, H. A. & Turoff, M. (1975). Introduction. In H. A. Linstone & M. Turoff (Eds.), *The Delphi Method: Techniques and Applications*. Reading, Massachusetts: Addison-Wesley Publishing Company.

Ophuysen, S. van (2009). Moving to Secondary School: on the role of affective expectations in a tracking school system. *European Educational Research Journal, 8*(3), 434-446. doi: 10.2304/eej.2009.8.3.434

Ophuysen, S. van (2005). Gestaltungsmaßnahmen zum Übergang von der Grundschule zur weiterführenden Schule [Transition-Related Activities for Students' Transitions from Primary to Secondary School]. In H. G. Holtappels & K. Höhmann (Eds.), *Schulentwicklung und Schulwirksamkeit: Systemsteuerung, Bildungschancen und Entwicklung der Schule* [School Improvement and School Effectiveness: Control System, Opportunity for Education and School Development] (pp. 141-152). Weinheim: Juventa.

Ophuysen, S. van, & Harazd, B. (2014). Der Übergang von der Grundschule zur weiterführenden Schule aus der Perspektive der Schulqualität: ein Übergangsqualitätsmodell [The Transition from Primary to Secondary School: A Quality Model to Describe Transitons]. In M. Pfeifer (Ed.), *Schulqualität und Schulentwicklung. Theorien, Analysen und Potenziale* [School Quality and School Development. Theories, Analysis, Potentials] (pp. 73–92). Münster: Waxmann.

Racherbäumer, K., & Kohnen, M. (2014). Schulstufenübergreifende Kooperationen von Lehrkräften der Primar- und Sekundarstufe zur Gestaltung anschlussfähiger Bildungsprozesse am Beispiel der Naturwissenschaften und Mathematik [Cooperation of Primary and Secondary School Teachers. The Example of Science Education and Maths]. In A. B. Liegmann, I. Mammes, & K. Racherbäumer (Eds.), *Facetten von Übergängen im Bildungssystem* [Facets of Transitions in the Education System] (pp. 65-78). Münster: Waxmann.

Rau-Patschke, S. & Brüggerhoff, J. (2019). Fachspezifische und überfachliche Gestaltungsmaßnahmen für den Übergang vom Sachunterricht der Primarstufe zum Fachunterricht der Sekundarstufe [Transition-Related Activities for Students' Transition from Primary to Secondary School in Science Education]. In C. Donie, F. Foerster, M. Obermayr, A. Deckwerth, G. Kammermeyer, G. Lenske, M. Leuchter, & A. Wildemann (Eds.), *Grundschulpädagogik zwischen Wissenschaft und Transfer* [Primary School Education between the Areas of Science and Transfer] (pp. 408-414). Wiesbaden: Springer.

Walper, L. M., Lange, K., Kleickmann, T., & Möller, K. (2014). Students' Physics-Related Interests in the Transition from Primary to Secondary School – How do They Change and What Instructional Practices Influence Them? In C. P. Constantinou, N. Papadouris, & A. Hadjigeorgiou (Eds.), *ESERA 2013 Conference*: *Vol. 16. Science Education Research for Evidence-based Teaching and Coherence in Learning* (pp. 61–70). Nicosia: European Science Education Research Association.

Wodzinski, R. (2006). Zwischen Sachunterricht und Fachunterricht: Naturwissenschaftlicher Unterricht im 5. und 6. Schuljahr [Science Education in Primary and Secondary School. Science Education at the beginning of the 5th and 6th grade]. *Unterricht Physik*, *17*(93), 4–9.

THE STRUCTURAL CHALLENGE IN BRAZILIAN TEACHER EDUCATION: THE PHYSICS TEACHER SHORTAGE

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Studies have indicated the pivotal role that qualified and experienced teachers play in students outcomes as well as in curriculum reforms. Nevertheless, it is reasonable to say that the critical aspects of teacher education such as recruiting and retaining good teachers are commonly overlooked. The main goal of our broader study is to provide an accurate empirical picture about the Physics teacher education in Brazil, which might help to enrich a more international discussion on processes of teacher recruiting, retention and attrition in Science Education. Findings indicate that the distribution of qualified teachers across Brazilian states is uneven with a couple of them with less than 10% of the teachers with adequate qualification in Physics teaching. Moreover, roughly 5% of those who entered in the teacher education programs end up teaching Physics in high schools. It is a massive leak which has its major challenge in filling the gap between higher education institutions and the high school classrooms. To sum up, the study makes possible to empirically ground the debate over Physics teacher shortages and evaluate the extent to which there is, or is not, sufficient supply of teachers in this field. Besides the Physics teacher shortage is huge compared with developed countries, the numbers seem relatively stable throughout the years. It is, on the one hand, a relevant confirmation that the problem is not getting any worse, on the other hand, it is evident that all the effort to improve Physics teacher retention have been achieving little effective results. Today, there is a growing consensus coming from quantitative and qualitative studies that improvements in salary and working conditions are key to change the whole scenario. From an accurate picture of Physics teachers situation, it is possible to understand and work with the concrete educational scenario.

Keywords: Teacher education, teacher shortage, Physics teacher

INTRODUCTION

There is a growing consensus among researchers, policymakers, and practitioners that initial teacher education is a key factor in changing the current state of affairs in Science Education (Bauer & Prenzel, 2012). Even though curricular design, integration between teacher education programs and schools, teachers' knowledge are indisputably at the core of teacher education concerns, it is important to address the nature as well as the current state of Science teacher attrition and retention (Buchanan et al., 2013).

The lack of qualified teachers is especially critical in implementing any substantial change in Brazilian Science Education. Studies have indicated the pivotal role that qualified and experienced teachers play in students outcomes as well as in curriculum reforms (Borko et al., 2002; Delandshere & Arens, 2001). Although, the relevance of well trained teachers in the educational processes has become common sense in research and educational practice, it is reasonable to say that the critical aspects of teacher education as well as attrition, recruiting, and retaining teachers are commonly overlooked (Borko et al., 2002; Buchanan et al., 2013).

The scenario of shortage and to some extent inadequacy of initial teacher education, commonly referred as out-of-field teachers, is not restricted to Brazil. This issue has been the subject of several studies around the world, including in economically developed countries (du Plessis et al., 2014; Ingersoll, 2003). According to Du Plessis; Gillies and Carrol (2014), in Australia 16% of Science and 24% of Mathematics teachers are not qualified, whereas in England 31.4% of Physics teachers are framed in the same problem. As we will see in this study, the Brazilian scenario, with regard to the physics teacher, it is much more worrying and the numbers are not encouraging.

Moreover, since educational data started to be collected covering a variety of aspects, it is possible to identify struggles in Brazilian educational system to improve its general quality (Avalos, 2011), from general indicators like graduation rates to specific ones like the students' achievement in the Programme for International Student Assessment (PISA). We expect that by addressing the shortage of Physics teachers in Brazil might help to shield light in the general issue of teacher retention around the world. To better understand the concrete and structural challenges that developing countries are facing today regarding improving Science education indicators, it is important to build an accurate picture of what are the situation of Brazilian Physics teachers' formation and practical experience (Villani et al., 2009).

STUDY GOALS

The main goal of our broader study is to provide an accurate empirical picture about the Physics teacher education in Brazil. Although the data presented is mostly on national level, the study as might help to enrich a more international discussion on processes of teacher recruiting, retention and attrition in Science Education.

In this study we acknowledge that teachers' education and experience play a pivotal role in different aspects of Science education from pupils learning to curriculum reforms. Therefore, there is an underlying need to substantiate the Science Education research with data and evidence of the challenges that professional development faces today. We focused on two dimensions of teachers situation in Brazil: (i) teachers' undergraduate degree; and (ii) the number of incoming and concluding students in Physics teacher undergraduate programs, and in-service qualified teachers. We looked for relations between this two dimensions in order to understand how the professional choice is maintained or not when they initiate their professional life.

SOME REMARKS ON INITIAL TEACHER EDUCATION IN BRAZIL

Before addressing the Physics teacher situation, it is important to have an overview of how teacher education is structured in Brazil which might have some contrast with European programs, mainly after Bologna (Flores, 2011). Physics teaching is basically concentrated in the high school level and the qualification to teach is a higher education degree -- university level. There are little alternative paths to becoming a high school teacher and even though the design in the teacher education programs might vary, in the general outline al future teachers have to entry the university level of initial teacher education program.

The main implication is that future teachers must have a career decision early on in their academic lives, which might be too early for many. This characteristic of decision making has implications for the process of recruiting new students for teacher education programs and the ways students and institutions find to avoid dropouts. Most of the students take the decision to become a teacher while in the teacher education program and most of them do not go to work as teachers, even if they have completed the four years program (Gatti, 2013).

METHODS AND DATA GATHERING

The study is grounded on the governmental education data at national level in Brazil which stems from the datasets of basic schools and higher education census both publicly available by the Ministry of Education. The study is centered on the descriptive statistic adequate to build the empirical picture of teacher education (Agresti & Finlay, 2009). Most of the effort consists in assembly the data set from the last decade and inquiry about the concrete situation of Physics teachers in schools regarding their qualification.

This empirical picture created with a descriptive statistic might work as a starting point for investigating the concrete situation and public policies as well as provide the bases for models in broader studies.

FINDINGS

It is not uncommon that policymakers, curriculum designers and researchers set their actions and propositions based on an idealized teachers that may not find support in the concrete life of schools. One of the central issues is: who is actually conducting the Physics lessons?

In Brazil, since 2007 is known that Physics is the subject matter that lives the most critical scenario with 26% of its teachers with proper qualification -- i.e. higher education degrees in Physics teacher education (Pestana, 2009).

Table 1 - Percentage of the Physics teachers by each higher education degree | Source: 2018 Brazilian School Census

Teacher education in Math	Teacher education in any other field	Teacher education in Physics	Any other higher education degree	Higher education student	Teacher education in Sciences	Pedagogy
18,801	13070	12,597	5,358	3,238	2,829	3,048
31.9%	22.2%	21.4%	9.1%	5.5%	4.8%	5.2%

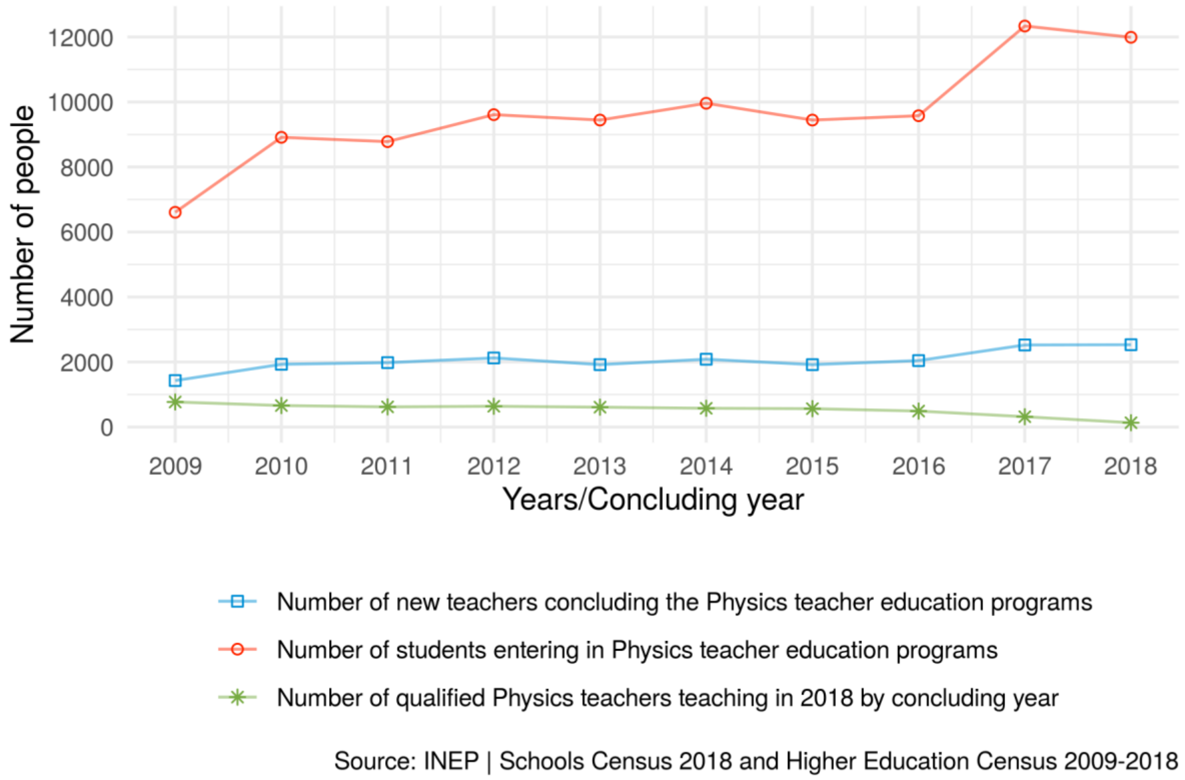

Figure1 - Graphic of the number of students entering in Physics teacher education programs by year, number of new teachers concluding the Physics teacher education programs by year, and number of qualified Physics teachers teaching in 2018 by concluding year.

Table 1 shows the percentage of the Physics teachers by each higher education degree. The largest group is formed by teachers has a background in Mathematics. In the national level, they correspond to 32% of the total number of Physics teachers. The qualified teachers correspond only to the third largest group and it is possible to estimate that 79.5% (more than 46,000) Physics teachers are non-qualified.

The distribution of qualified teachers across states is uneven with a couple of states with less than 10% of the teachers with adequate qualification. For instance the federal district has the best mark with 61% of qualified teachers while São Paulo, the most populous state, has 16.3 %.

The number of students entering into Physics teacher education programs roughly doubled from 2009 to 2017. What is mainly explained by the expansion of the higher education system and the growing number of teacher education programs in almost all subject matters. Although it is possible to observe a tendency of growing in the last year for students entering and new teachers leaving from teacher education programs, only one-quarter eventually concludes. Additionally, only one-fifth of new teacher go to classrooms in public and private schools. It means that roughly 5% of the those who entered in the teacher education programs end up teaching Physics in high schools. It is a massive leak which entails challenges in filling the gap between higher education institutions and the school classrooms as well as improving the ratio between the entering and the concluding in Physics teacher education programs.

Table 2 - Percentage of the Physics teachers by each higher education degree per region | Source: 2018 Brazilian School Census

Region	Teacher education in Math	Teacher education in any other field	Teacher education in Physics	Any other higher education degree	Higher education student	Teacher education in Sciences	Pedagogy
Center-West	1,179 26.3 %	741 16.5 %	803 17.9 %	737 16.4 %	272 6.1 %	492 11.0 %	260 5.8 %
Northest	4,956 31.2 %	4438 27.9 %	2,751 17.3 %	1,209 7.6 %	1388 8.7 %	474 3.0 %	685 4.3 %
North	1,913 33.1 %	1,399 24.2 %	1,093 18.9 %	257 4.4 %	301 5.2 %	325 5.6 %	497 8.6 %
Southeast	2,464 26.6 %	1,596 17.2 %	2,891 31.2 %	1,302 14.1 %	469 5.1 %	380 4.1 %	153 1.7 %
South	1,968 26.4 %	1,323 17.7 %	2,095 28.1 %	374 5.0 %	374 5.0 %	232 3.1 %	1,094 14.7 %

Some regional differences are shown in table 2. It may indicate that the demands and their solutions might be regional driven. regions like South which has historically better education indicators along with Southeast which is known for been a highly industrialized region has the higher rates of qualified teachers with 28.1 % and 31.2 % respectively.

FINAL CONSIDERATIONS

As data shows there is a shortage of Physics teachers in general and it is particularly aggravated for qualified teachers (Araujo & Vianna, 2011). Although such a shortage magnitude is known since 2006 with studies on the 2003 school census (INEP, 2006), there are few studies address the most particular characteristics and issues related to the physics teacher specially in recruiting and retaining in the initial teacher education program. Based on the 2009 school census, Gatti (2014) highlights that among all school subjects, Physics is the one with the lowest percentage of qualified teachers.

Besides the Physics teacher shortage is more acute compared with developed countries, the numbers seem relatively stable throughout the years. It is, on the one hand, a relevant confirmation that the problem is not getting any worse. On the other hand, it is evident that all the effort to improve Physics teacher retention have been achieving little effective results. There is a growing consensus coming from quantitative and qualitative studies that improvements in salary and working conditions are key to change the whole scenario (Richardson & Watt, 2005).

Furthermore, the dominant presence of teachers with Math background may help to explain the strong identification or reduction of Physics teaching to mathematical problems solving. This problem added by the uneven distribution of qualified Physics teachers across regions, allows to hypothesize that Physics teaching could have different characteristics in different regions. Another commonly neglected consequence of the critical Physics teacher shortage is that teachers can not create teachers study groups becoming isolate in his work at school, what may undermine professional development programs grounded on pair exchange and networking within the disciplinary field.

Finally, with a more accurate picture of Physics teachers situation, it is possible to understand and work with the concrete educational scenario and at the same time to propose ways to change it.

REFERENCES

Agresti, A., & Finlay, B. (2009). *Statistical Methods for the Social Sciences*. Pearson Prentice Hall.

Araujo, R. S., & Vianna, D. M. (2011). The shortage of science and mathematics teachers in Primary and Secondary Schools and the increase of teachers' training courses. *Ciência & Educação*, *17*(4), 807–822. https://doi.org/10.1590/S1516-73132011000400003

Avalos, B. (2011). Teacher professional development in Teaching and Teacher Education over ten years. *Teaching and Teacher Education*, *27*(1), 10–20. https://doi.org/10.1016/j.tate.2010.08.007

Bauer, J., & Prenzel, M. (2012). European Teacher Training Reforms. *Science*, *336*(6089), 1642–1643. https://doi.org/10.1126/science.1218387

Borko, H., Elliott, R., & Uchiyama, K. (2002). Professional development: a key to Kentucky's educational reform effort. *Teaching and Teacher Education*, *18*(8), 969–987. https://doi.org/10.1016/S0742-051X(02)00054-9

Buchanan, J., Prescott, A., Schuck, S., Aubusson, P., Burke, P., & Louviere, J. (2013). Teacher Retention and Attrition: Views of Early Career Teachers. *Australian Journal of Teacher Education*, *38*(3). https://eric.ed.gov/?id=EJ1012946

Delandshere, G., & Arens, S. A. (2001). Representations of teaching and standards-based reform: are we closing the debate about teacher education? *Teaching and Teacher Education*, *17*(5), 547–566. https://doi.org/10.1016/S0742-051X(01)00013-0

du Plessis, A. E., Gillies, R. M., & Carroll, A. (2014). Out-of-field teaching and professional development: A transnational investigation across Australia and South Africa. *International Journal of Educational Research*, *66*, 90–102. https://doi.org/10.1016/j.ijer.2014.03.002

Flores, M. A. (2011). Curriculum of initial teacher education in Portugal: new contexts, old problems. *Journal of Education for Teaching*, *37*(4), 461–470. https://doi.org/10.1080/02607476.2011.611015

Gatti, B. A. (2013). Educação, escola e formação de professores: políticas e impasses. [Education, school and teacher training: policies and impasses.] *Educar em Revista*, *0*(50), 51–67.

Gatti, B. A. (2014). A formação inicial de professores para a educação básica: as licenciaturas [Initial teacher education for basic education: undergraduate degrees]. *Revista USP*, *0*(100), 33–46. https://doi.org/10.11606/issn.2316-9036.v0i100p33-46

INEP. (2006). *Sinopse do Censo dos Profissionais do Magistério da Educação Básica : 2003 [Synopsis of the Census of Professionals of Basic Education Teachers: 2003]*. O Instituto.

Ingersoll, R. (2003). Is there a shortage among mathematics and science teachers. *Science Educator*, *12*(1), 1–9.

Pestana, M. I. (2009). *Estudo exploratório sobre o professor brasileiro com base nos resultados do Censo Escolar da Educação Básica 2007 [Exploratory study on the Brazilian teacher based on the results of the School Census of Basic Education 2007]*. Inep.

Richardson, P. W., & Watt, H. M. G. (2005). 'I've decided to become a teacher': Influences on career change. *Teaching and Teacher Education*, *21*(5), 475–489. https://doi.org/10.1016/j.tate.2005.03.007

Villani, A., Pacca, J. L. de A., & Freitas, D. de. (2009). Science teacher education in Brazil: 1950–2000. *Science & Education*, *18*(1), 125–148.

SUPPORTING PROFESSIONAL LEARNING COMMUNITIES TO DEVELOP CONTENT KNOWLEDGE FOR TEACHING AND LEARNING PHYSICS AT LOWER SECONDARY LEVEL

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Participation of physics at upper secondary level in Ireland, particularly among girls, is a matter of national concern. However, the situation in Ireland is not unique, with many countries seeking to address the low numbers of students continuing in physics at upper secondary level or at University level. In addition, many countries suffer from insufficient numbers of teachers qualified to teach physics at lower secondary level and this directly impacts on the retention rates at upper secondary level. This study reports on findings from a two-year collaboration, between physics education researchers and eleven science teachers, focused on enhancing the teaching and learning of physics at lower secondary level. Two professional learning community case studies are presented in this paper that examine the impact of a school-based professional development programme with all science teachers in two Irish second level schools. In the first year, a series of workshops with teachers were facilitated with three core objectives; namely, increasing teacher's confidence and specific content knowledge for teaching physics; raising their awareness of unconscious biases and career opportunities in Physics. In the second year, teachers and researchers collaborated to co-design a sequence of lessons in physics that embedded these three objectives. Using the Ambitious Science Teaching framework, we have measured the impact of this collaborative approach on teacher's planning of sequences of lessons to enhance the teaching and learning physics at lower secondary level.

Keywords: Teacher Professional Development, Inquiry-based teaching, Physics.

INTRODUCTION

The effect of fostering student and teacher identity in physics in increasing student engagement and participation in science, technology, engineering and mathematics (STEM) has been discussed in recent literature, e.g. Hazari reports that secondary level physics teachers can positively impact on physics identity development among their students (Hazari et al., 2010). Understanding the factors that influence students' interest in STEM, highlights processes that may selectively dissuade females from pursuing STEM career paths (Ito & McPherson, 2018). In particular, female experience of conceptual understanding and real-world/contextual relevance is reported lower than their male counterparts (Hazari et al., 2010). Therefore, increasing teacher awareness around the influence of stereotypes and biases on students' engagement is pivotal in enhancing the teaching and learning of physics at lower secondary level.

In Ireland, the 2019 statistics reported by the State Examinations Commissions show that 14% (7942) of the Irish Leaving Certificate student cohort choose to study and complete the physics examination at upper secondary level. Of the total student cohort (56,008) taking physics for the Leaving Certificate Examination only 4% (2116) of were girls (State Examinations Commission, 2019). The STEM Education Review group reported that 22% of the 723 Irish secondary level schools do not offer Physics as a separate subject at upper secondary level (STEM Education Review Group, 2016). This data highlights the need to encourage more students, particularly girls, to continue in physics at upper secondary level and the urgent need to promote physics teaching as a future career for young people nationwide.

Sustaining the pipeline of physics students in upper secondary school (ages 15-18 years) must begin with improving the student experience with physics at lower secondary level. Currently, in Ireland, teachers registered with the Teaching Council (Regulatory body for professional standards in teaching) with any one science subject in their final degree e.g. Physics, Chemistry, Biology to upper secondary level are also recognized to teach science at lower secondary level, to students aged 12-15 years. As there are only 1259 teachers who are recognised with qualifications to teach Physics, often the teaching of lower secondary level physics (as an integrated strand of science), is facilitated by teachers who have a Biology (3878 teachers) or Chemistry (2376 teachers) science specialism (STEM Education Review Group, 2016). Supporting these teachers so as to improve the quality of the teaching and learning of physics at lower secondary level and to respond to increasing diversities in classrooms is the core aim of this research.

In schools, hours dedicated for science department planning hours are commonly focussed on the upper secondary level science specialisms. However, a lack of collaboration among teachers who teach the same common lower secondary level curriculum and an absence of teacher professional learning communities (PLCs) in schools is widely reported. McLaughlin identifies strong professional communities as those teachers who share a sense of common mission and negotiate principles, policies and resources for their practice. She attributes, a community of teachers who work together and explore ways of improving practice in order to advance learning, to generating knowledge of practice (McLaughlin & Talbert, 2001). Dana & Yendol-Hoppey specify that PLC's unlike department meetings have a central focus on student learning and teacher professional learning. With the power to change school culture, teacher impact and student achievement, PLCs engage in deliberate and purposeful professional dialogue to learn from practice (Dana & Yendol-Hoppey, 2015). The aim of this study addresses this need to foster professional learning communities with teachers from the same science departments and enhance the teaching and learning of physics at lower secondary level.

THEORETICAL BASIS

Implementing teacher professional development programmes that are effective in increasing science teachers' confidence and content knowledge for teaching specific physics concepts at lower secondary level is challenging. The Ambitious Science Teacher (AST) framework outlines pedagogical approaches for engaging science through supporting intellectual engagement and promoting attention to equity (Windschitl et al., 2012). This framework supports teachers professional learning using four key practices: planning for engagement with important science ideas, eliciting students' ideas, supporting on-going changes in thinking and pressing for evidence-based explanations. The first practice, planning for engagement with important science ideas, outlines a design instruction for planning to engage students in big science ideas (Windschitl et al., 2012). Facilitating teachers to construct plans and deepen teachers' understanding of physics content is difficult to balance within teacher professional development programme (Banilower et al., 2006). The Ambitious Science Teaching framework supports teachers to design learning experiences focused on anchoring/big science ideas. Using conceptual tools for exploring big ideas through inquiry-based learning, teachers can frame activities for students in science classrooms (Thompson et al., 2013). Guidelines for teaching science, technology and society from the upper secondary Irish physics curriculum were adapted into the dimensions of planning framework to promote equity by highlighting the need to raise awareness of careers in STEM (National Council for Curriculum and Assessment, 2002).

In the context of the AST framework, this study will address the following research questions:

i) How can teachers be supported to develop their content knowledge for teaching physics at lower secondary level through planning sequences of lessons?
ii) How is teachers' awareness of unconscious bias, gender stereotypes and careers in STEM addressed in their planning of physics at lower secondary level?

METHODOLOGY

This study reports on a collaboration with two Irish second level schools, that are part of a wider research programme aimed at implementing a whole-school approach to addressing gender imbalance in upper second level physics and is further described in recent publications (O'Neill, McLoughlin & Gilheany, 2018). The three key objectives of this research programme are to;

i) Deepen science teacher's confidence and content knowledge for teaching physics,
ii) Increase awareness of STEM and careers in STEM;
iii) Adopt a whole school approach to addressing unconscious bias and gender stereotyping and build confidence and resilience for students, particularly girls, to continue with Physics.

The focus of this collaboration with science teachers was to facilitate workshops with science teachers that model inquiry-based teaching, learning and assessment practices that are appropriate for teachers to adopt in their own classroom practices. The participants in this study were eleven science teachers from two Irish secondary schools identified as PLC1 and PLC2. PLC1 consisted of three teachers qualified to teach Biology, one qualified to teach Chemistry and one qualified to teach physics. PLC2 consisted of three teachers qualified to teach Biology, two qualified to teach Chemistry and one qualified to teach Physics.

During the first year, science teachers participated in both guided and open inquiry-based workshops (Bevins & Price, 2016), that address specific concepts in Physics as identified by the collaborating teachers; Energy, Electricity, Light, Speed, Earth & Space, Forces, Density.

Teachers were facilitated to work in small groups (typically 3-4) to co-design these concept-based workshops alongside the researcher as part of a professional learning community. It is suggested that professional development models facilitate teachers becoming part of professional learning communities for fostering sustained collaborative practices among teachers in schools (Dana & Yendol-Hoppey, 2015).

During the second year, the teachers and researchers collaborated to co-design a sequence of lessons in physics that embedded all of the objectives of the programme; deepen teacher's confidence and content knowledge for teaching physics, increase awareness of careers in STEM and address unconscious bias and gender stereotyping. The co-designing of sequences of lessons consisted of one two-hour planning session with both PLC1 and PLC2 cohorts. The Ambitious Science Teaching (AST) protocols were adapted as a scaffolding tool to support collaborative planning through dimensions of planning (Windschitl et al., 2012). The dimensions of planning; causal explanation, essential question, scientific concepts, lesson activities, links to curriculum and how is the learning assessed were adapted from the Ambitious Science Teaching - Unit Planning Tool to fit the context and language used in the Irish education system (Table 1). Inclusive practices were also included in the approach adopted in this study and included a focus on fostering physics identity, raising awareness of unconscious biases and gender stereotyping (Hazari et al., 2010) and promoting STEM careers (National Council for Curriculum and Assessment, 2002), see Table 1. Teachers used a wind-up toy car, that moved non-linearly and gave off sparks, to anchor the planning of their sequence of lessons. Each sequence of lessons were evaluated using the AST framework to determine if the three key objectives of this research were achieved. The intellectual requirement for teachers in terms of planning questions and tasks in the classroom were classified as low-cognitive demand (focus on memorization, procedural tasks, recall understanding only) and high-cognitive demand (sense-making, no discrete answers, using evidence to support claims etc.) as defined by the cognitive demand in questions and tasks in Ambitious Science Teaching (A Discourse Primer for Science Teachers, 2015). Teachers' sequence of lessons were evaluated according to these criteria to establish patterns in teacher planning for engaging physics.

Table 1. Mapping Dimensions of Planning according to Ambitious Science Teaching and inclusive practices

	Dimensions of Planning	Description
Ambitious Science Teaching	Causal Explanation	• What's happening (description)? • Why is it happening (explanation)? • Detailed (researched) description of the phenomenon
	Essential Question(s)	• Record all questions relating to a phenomenon • Identify essential / investigable questions • Turn questions into investigative questions
	Scientific concepts	• Identify a range of physics/science concepts – related to causal explanation • Student conceptual difficulties
	Lesson activities	• Design experiments to support student learning • Sequence activities/experiments to construct • Consider effective instructional strategies
	Links to curriculum (cross strand)	• Identify learning outcomes on curriculum (in any of the strands) • Create links across the strands of curriculum
	How is learning assessed?	• Outline how the learning will be assessed

		• Develop/adapt rubrics/questions etc/
Inclusive Practices	Career/Societal Awareness	• Suggest similar phenomenon in everyday life that can be explained using this phenomenon • Identify careers in which this information could be helpful • Research/name someone you know who works in this area
	Unconscious Bias Awareness	• Creating awareness of stereotypes that surround different career types • Being aware of how one's own perceptions might influence the teaching process • Identifying any gendered language that may be connected to the topic (difficult, "maths-heavy" etc.)

FINDINGS

Table 2 and 3, present evidence on the dimensions of planning present in the sequences of lessons of two teacher professional learning communities, PLC1 and PLC2. For the specific examples included, the level of cognitive demand was determined and is expressed in each sequence of lessons within the dimensions of planning. Although both groups of professional learning communities received the same resources (access to ambitious science teaching resources, sample sequences of lessons, planning time with department) to work with, very different sequences of plans emerged from their work.

Different elements of the framework were absent on both sets of PLC plans. PLC1 had no evidence of a causal explanation or essential question and focused solely on scientific concepts to build their sequence of lessons. Lesson activities showed a high level of cognitive demand, in PLC1s plan, with activities focused on student inquiry learning and designing learning experiences around learning goals. Key experiments and investigations that were relevant to the development of ideas and practices were included. Assessment practices were clearly described within each activity along with specific questions outlined as appropriate. Curriculum links and reference to careers were specified within activities, however these links were not well described and their connection to success criteria or measurable outcomes were lacking.

Table 2: Evidence of Dimensions of Planning in PLC 1 Sequences of Lessons

Dimensions of Planning	Specific Examples in Plans	Cognitive Demands Questions and Tasks
Causal Explanation	Not Present in plan	
Essential Question(s)	Not present in plan	
Scientific concepts	Forces, Combustion, Light, Torques, Heat, Energy Transfer	
Lesson activities	• E.g. Students design their own lever and explain	Higher Cognitive Demand

	in their own words how it works. • E.g. Light: Design an instrument that will allow you to see objects on the other side of the desk from a variety of different materials.	• Processing Ideas: tasks required students to use ideas and information in ways that expanded understanding. • Connected activities with Ideas; Selected tasks that required some thought and the task solution was not self-evident from the solution.
Links to curriculum (cross strand)	• E.g. Investigate patterns of physical observables – but patterns are not outlined	• Specific cross strand curriculum links highlighted but not linked to success criteria of activities.
How is the learning assessed	• E.g. Questioning: How many mirrors will you use and why? What does this [experiment] tell you about the way light behaves?	Higher Cognitive Demand • Approach outlined with specific questions/connections to activity described
Career/Societal Awareness	• E.g.	• Specific careers linked with each individual activity. No links made with the content specifically.
Unconscious Bias Awareness	• E.g. Fireman/woman	• Bias in gender specific careers mentioned - misconceptions and differentiation included in bias (may be a misunderstanding)

In the sequence of lessons produced by PLC2, most of the dimensions of planning were evident. A causal explanation was described with a strong focus on what was happening rather than a scientific explanation of why it happened. There was some indication that teachers attempted to expand their description to include more in-depth explanation e.g. “When there is an odd number of gears, the last gear will always turn in the same direction as the first one”, but this led to new ideas which caused more confusion among PLC1 members and was the explanation remained without further commentary or clarification.

Table 3: Evidence of Dimensions of Planning in PLC 2 Sequences of Lessons

Dimensions of Planning	Specific Examples in Plans	Cognitive Demands Questions and Tasks
Causal Explanation	• E.g. Adjacent gears are connected to either a chain or belt that is connected to a spring which moves in opposite directions. • E.g. When there is an odd number of gears the last gear will always turn in the same direction as the first one…but why?	Lower Cognitive demand • Seeking only a "what" explanation. • Some consideration of "why" explanation for one specific aspect of the phenomenon but with little detail.
Essential Question(s)	• E.g. How long will the toy work? Does friction stop the toy from working?	Lower Cognitive demand • Does not lend to developing an explanatory model to answer the question.
Scientific concepts	Heat transfer, Graphs and Slopes, Friction, Potential Energy, Kinetic Energy, Speed, Metals/Non-metals	
Lesson activities	• E.g. Write a plan indicating how long it takes to walk 15 metres……Consider why some people walk faster than others.	Medium Cognitive Demand • Connected activity with ideas. Selecting tasks that require some thought, however, approach does not suggest that the task solutions are not self-evident to student.
Links to curriculum (cross strand)	• E.g. for Heat transfer activity link to conductivity in the curriculum is not specified in the activity.	• Specific cross strand curriculum links highlighted but not linked to success criteria of activities.
How is the learning assessed	• E.g. Grouping, Peer assessment and Self-assessment	Lower Cognitive Demand • Assessment methods listed but not connected to activities
Career/Societal Awareness	• Six broad careers listed with no link to context of phenomenon.	
Unconscious Bias Awareness	• Not present	

It was evident from the plans and collaborating with the PLCs on developing these plans, that the two PLCs had very different priorities when planning their sequences of lessons. PLC1 focused their planning on student learning and student outcomes, e.g. “Students design their own lever and explain in their own words how it works”. There was clear evidence to suggest that PLC1 had concerns around how students process ideas. This PLC also engaged fully with the need to raise career awareness in their classroom practice. PLC2 were more focused on the teachers’ content knowledge for teaching physics and approached the planning as if the teachers themselves were the learners e.g. When there is an odd number of gears the last gear will always turn in the same direction as the first one…but why?”. This resulted in a much more disjointed written plan, however, the discussions and sharing among PLC members provided an opportunity for teachers to identify the gaps in their own knowledge and learning.

DISCUSSION

From our analyses of teacher’s plans for sequences of physics lessons, it was evident that teacher written plans lacked detail. All eight aspects of the dimensions of planning, six from Ambitious Science Teaching and two from inclusive practices, were evident to some degree, however all aspects of the dimensions of planning were not evidenced in any single plan. These findings highlight the need for further PLC activities to co-design, implement and reflect on lessons and to consider what refinement is necessary to engage students in physics concepts at lower secondary level.

Our findings indicate that these teachers lack specific content knowledge for teaching physics, and this impacted on their ability to propose complete causal explanations and investigative essential questions. Probing specific content knowledge for the purpose of deepening non-physics science teachers content knowledge for teaching is required to promote teacher confidence and competence in teaching physics at lower secondary level (Etkina et al., 2018).

Finally, enhancing teachers’ reflective and collaborative skills in order to support groups of teachers in planning for engaging science needs to at the goal of a professional learning community. Adopting a research practice partnership model, as proposed by Penuel, that encourages mutualistic relationships between the researchers and teachers through shared learning goals could see an evolution in the support needed to facilitate groups of teachers in designing, planning, implementing, reflecting and refining sequences of lessons for lower secondary level physics (Penuel & Gallagher, 2017).

ACKNOWLEDGEMENTS

This programme has received funding from Science Foundation Ireland Discover Programme (2017-2019) in a strategic partnership with CASTeL at Dublin City University and Institute of Physics.

REFERENCES

A Discourse Primer for Science Teachers. (2015). Ambitious Science Teaching. http://ambitiousscienceteaching.org/wp-content/uploads/2014/09/Discourse-Primer.pdf

Banilower, E. R., Boyd, S. E., Pasley, J. D., & Weiss, I. R. (2006). Lessons from a Decade of Mathematics and Science Reform: A Capstone Report for the Local Systemic Change through Teacher Enhancement Initiative. *Horizon Research, Inc.(NJ1)*. https://files.eric.ed.gov/fulltext/ED518421.pdf

Bevins, S., & Price, G. (2016). Reconceptualising inquiry in science education. *International Journal of Science Education*, *38*(1), 17–29. https://doi.org/10.1080/09500693.2015.1124300

Dana, N. F., & Yendol-Hoppey, D. (2015). *The PLC Book*. Corwin Press. https://files.hbe.com.au/samplepages/CO4483.pdf

Etkina, E., Gitomer, D., Iaconangelo, C., Phelps, G., Seeley, L., & Vokos, S. (2018). Design of an assessment to probe teachers' content knowledge for teaching: An example from energy in high school physics. *Physical Review Physics Education Research*, *14*(1), 010127. https://doi.org/10.1103/PhysRevPhysEducRes.14.010127

Hazari, Z., Sonnert, G., Sadler, P. M., & Shanahan, M. (2010). Connecting high school physics experiences, outcome expectations, physics identity, and physics career choice: A gender study. *Journal of Research in Science Teaching*, *47*(8), 978–1003. https://doi.org/10.1002/tea.20363

Ito, T., & McPherson, E. (2018). Factors Influencing High School Students' Interest in pSTEM. *Frontiers in Psychology*, *9*, 1535. https://doi.org/10.3389/fpsyg.2018.01535

McLaughlin, M. W., & Talbert, J. E. (2001). *Professional Communities and the Work of High School Teaching*. University of Chicago Press.

National Council for Curriculum and Assessment. (2002). *Physics Leaving Certificate: Guideline for Teachers*. Department of Education and Science. https://www.curriculumonline.ie/getmedia/d0239968-7efb-4442-8632-4c8fd843c6f5/SCSEC27_Physics_guidelines_eng.pdf

O'Neill D, McLoughlin E and Gilheany S 2018 Creating research-practice collaborations to address gender imbalance in physics at second level, Connecting Research, Policy and Practice in STEM Education - Proceedings of the Eighth Science and Mathematics Education Conference 67-72

Penuel, W. R., & Gallagher, D. J. (2017). *Creating Research Practice Partnerships in Education.* ERIC.

State Examinations Commission (2019). State Examination Statistics, Retrieved from: https://www.examinations.ie/statistics/?l=en&mc=st&sc=r12

STEM Education Review Group. (2016). *A Report on Science, Technology, Engineering and Mathematics (STEM) Education Analysis and Recommendations*. https://www.education.ie/en/Publications/Education-Reports/STEM-Education-in-the-Irish-School-System.pdf

Thompson, J., Windschitl, M., & Braaten, M. (2013). Developing a Theory of Ambitious Early-Career Teacher Practice. *American Educational Research Journal*, *50*(3), 574–615. https://doi.org/10.3102/0002831213476334

Windschitl, M., Thompson, J., Braaten, M., & Stroupe, D. (2012). Proposing a core set of instructional practices and tools for teachers of science. *Science Education*, *96*(5), 878–903.

LEARNING ACTIVITIES TO FOSTER SCIENTIFIC COMPETENCES: A COLLABORATION BETWEEN HIGH SCHOOL TEACHERS AND PHYSICS RESEARCHERS

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Our group has carried out a collaboration project with a group of high school physics teachers engaged in a PLS (Progetto Lauree Scientifiche) professional development course promoted by the Department of Science and High Technology (DiSAT) of Insubria in Como, Italy. The aim of the course was to enable teachers to create balanced and effective learning activities to be used in class to reinforce the scientific competencies and skills required in the Final Exam of the Italian Secondary School (Esame di Stato). The aim of this paper is to present the result of this collaboration to understand how to better support the collaboration between physics researchers and high school teachers in order to design teaching and learning materials that could be effectively integrated in the daily classroom activities. We focused our attention to problem solving and data interpretation skills and the relationship between theoretical models and measurements process as requested in the last education reform for Italian secondary school final exam.

Keywords: Teachers, Experiments, Competences

INTRODUCTION

The last EU recommendations on key competences for lifelong learning encourage educational institutions to strengthen the collaboration between physics researchers and secondary school teachers in order to implement competence-oriented education, training and learning. The PLS project (Progetto Lauree Scientifiche) promotes teachers training programmes for the educational staff in Como and Varese school district: faculty members and physics researchers in different fields of theoretical and experimental physics have been actively involved in the professional development programme. One of the aims of the PLS project is to support teachers in improving the way physics is taught in Secondary School.

The last education reform in Italy is promoting new curriculum design practices that should help teachers change their role in student's learning process: from operating as mere reviewers of knowledge acquisition to becoming facilitators of scientific competencies development processes. This change of perspective have raised many concerns among teachers, mostly related to the gap between the way physics curriculum is developed in classroom and the framework of the Final Exam Paper (Seconda Prova dell'Esame di Stato per il Liceo Scientifico). Since the last twenty years the Final Exam Paper was mathematics only, structrued as a list of exercises and problems related to a precise syllabus that need to be covered by the school year. Physics was only part of the oral examination: students are supposed to answer a couple of questions about the last year topics (electromagentism, special relativity and quantum mechanics). However "exam simulation papers" published in the last three years focused the attention on scientific competencies and skills such as hypothesizing, interpretation of experimental data and making conclusions more than on content knowledge. In addition to that, in 2018 a new school legislation introduced the possibility of having an exam paper only about physics or with problems that integrates mathematics and physics topics.

To support teachers in this transition between "knowledge – oriented" and "competences - oriented" educational practices, at the beginning of 2018/19 school year the PLS project at DiSAT promoted a collaboration with a group of about 40 mathematics and physics teachers of the Como school district in order to support them in defining appropriate teaching activities to prepare students for the Final Exam Paper. In this way the analysis of learning needs and goals will be easily extended to all the entire physics curriculum and be used to design and plan learning activities since the first year of high school. This PLS project focused its attention to the scientific competencies related to the analysis and interpretation of experimental data and the relationship between physical models and experimental results. The purpose of this paper is to present the results of this collaborative project and to give suggestions on how to foster the process of scientific competencies acquisition and to orient teacher training programs.

Theoretical framework

Long terms experiences and recent researches in physics education in Italy show how high school teachers can be productively engaged in renewing instructional methods if they feel the need of enlarging their own view and understanding of the topic (Besson et al., 2010). Nevertheless the past collaborations between DiSAT and local schools have shown that the transfer process of learning and teaching material from physics researchers to teachers has not been effective in terms of implementing the use of new teaching strategies. A relevant element that has been pointed out by physics researchers at DiSAT, during internal evaluation meetings about their long experience in teachers training in the Como area, is that teachers are often simply delegating to researchers the role of explaining complex topics or running experimental activities in extra-curricular workshops. On the other hand teachers are often concerned about a feasible educational transposition at schools of what they learn in the training courses especially regarding the intrinsic difficulty of the topics, generally labeled as "to difficult for the students", or pointing out the lack of time and resources to perform the laboratory activities presented in the training courses.

In the theoretical framework of active learning (Fraser et al., 2014) the training courses promoted by physics researchers in this project aim to improve conceptual understanding and promote a meta-reflection about the role of scientific competences. In order to renew instructional methods, the training course also include "hands-on/minds-on" workshops using a guided inquiry methodology (Rönnebeck et al., 2016) so teachers can immediately have the perception of the didactic applicability of what they have experienced in the workshop.

Project actions

Between December 2018 and February 2019, our group organized a series of 5 meetings (2 hours each) for a group of 40 high school teachers. On average, 20 teachers attended each meeting. In the first three seminars physics researchers and teachers solved together the problems of the exam paper simulations that were published in December 2018. This activity allowed the participants to define which parts of the test were particularly challenging for the students, pointing out the main skills and competences (problem solving, data analysis and interpretation) needed to tackle the problems. Teachers also shared teaching experiences and materials they used to prepare last year students for the final exam paper.

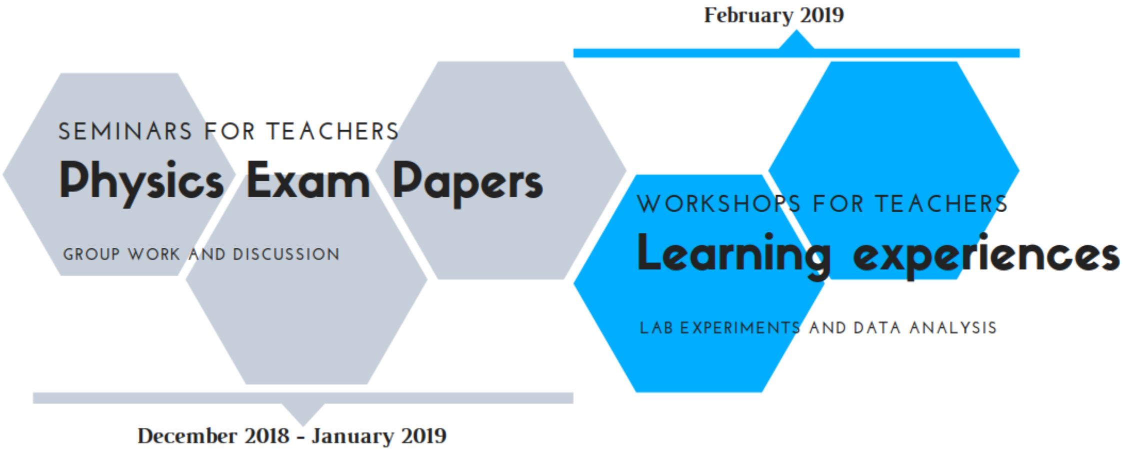

Figure 1. Project structure

In this first three meetings, teachers had the opportunity to discuss and share their view about the problems solving skills needed to solve the exam questions. In the last two sessions, teachers took part in two different physics workshops performing two experiments using simple materials and smartphone sensors. The first learning experience was about the measurement of the magnetic field of a little magnet. The second learning experience was about the measurement of the time collision of a ping pong ball with a table. Both those experiences were selected because the topics are part of the physics curriculum (mechanics and electromagnetism) and give the possibility to easily gather real data that can be analyzed and then discussed with students with different methodologies.

DATA ANALYSIS IN EXAM PAPER PROBLEMS

As mentioned before the first three meetings of the teachers training was dedicated to the analysis of the three exam paper published by the *Ministero dell'Istruzione dell'Università e della Ricerca* to help teachers understand the characteristics of the new exam format. What was relevant in the discussion with teachers was the reflection about the assessment criteria indicators attached to the Exam Paper (table 1) and their relation with specific scientific competences.

Criteria	Description
Analyze	Examine the problem identifying the significant aspects of the phenomenon and formulating the explanatory hypotheses through models, analogies or laws.

Resolution process application	Problem formalization and application of the concepts, mathematical methods and appropriate disciplinary problem solving strategies, performing the calculations needed.
Interpret, represent and elaborate data	Process the data, proposed or derived from experiments, checking the relevance to a chosen model. Representing and connect the data using the necessary graphic-symbolic codes.
Argue	Describe the resolution process adopted, the solution strategy e the fundamental steps. Communicate the achieved results evaluating the consistency with the problems and using disciplinary specific languages

Table 1. Assessment Criteria for the Physics Exam Paper

The criteria are not only related to the ability to solve the problem numerically, but also to the skills and competencies needed to analyze the problem, modelling and interpreting data.

Discussion about the quality of a fit

During one of the seminars the discussion between teachers and researchers was focused on how to fulfil the assessment criteria related to one problem that ask students to show that a give data set could be fit using a linear model. This kind of question allows students to explore the connection between experimental data and the theoretical model used to fit the data. This is worth to be done in a didactical context to foster a more general reflection about nature of science, in particular on how physics researchers' experimental results contribute to the development of interpretative models of physical phenomena.

Unfortunately, as reported by teachers, experimental activities that involve data analysis and interpretation are not part of usual curriculum activities. The lack of materials and resources in school to adequately incorporate performing experiments into curricular activities planning has also been taken into account. Statistic literacy is generally part of mathematics curriculum: as a result, the basic techniques of data analysis, such as the linear regression, are not fully covered during the instruction programme. In addition to that, most of the teachers admitted that they had never been properly trained to run experiments and do not feel competent enough to perform experiments with students.

What makes a measurement a "good one" was the first point of discussion. The conclusion was that a scientifically reliable estimation of a physical variable could be obtained only with a correct measurement procedure that estimates uncertainty from multiple measurements. Than what to do in when the experiment "is not working" and the data are not in accordance with the theoretical model? In that case students should be able to use their measurement device correctly in order to reduce the effect of systematic uncertainties. Following the result of this discussion, the group of teachers took part in two workshops about low cost physics experiments that could be used to recreate the condition presented in the exam paper question and to reflect on the scientific experimental inquiry process.

To promote a more active approach, teachers follow the same learning activity path designed for secondary school students, but they are guided to reflect not only on the content but also on the difficulties that can arise in performing the activity in the class with the students. The two learning experiences have been structured as a guided inquiry learning activity so the participants (divided in small groups of three) have to use a proper theoretical model to describe the physical phenomena to guide the measurement process during experimental activities.

LEARNING EXPERIENCE 1: DATA ANALYSIS

The first workshop was about the measurement of small magnet magnetic field using smartphone sensors (Arribas et al., 2015). The experimetal activity worksheet are also available at https://ls-osa.uniroma3.it/ This experience have been chosen because of its connection with the previous teachers work groups where the necessity of a reflection about the relationship between theoretical physical models and experimental data have been repeatedly pointed out. The inquiry question in this case was abouthow is it possible to fit a set of data using a specific theoretical model?

A specific attention have been payed to the data acquisition process using smartphone app and to the data analysis techniques. The aim of the learning activity is to support students' reflection on the relation between the theoretical model of a physical phenomenon and the experiments related to it.

Activity description

The purpose of the practice is to determine the dependence on the distance of the component x of the magnetic field produced by a small cylindrical magnet. The measurements are taken using the magnetic sensor of a smartphone and an app for the data acquisition: we used Phyphox and Physics Toolbox. The activity also requires a pencil, a sheet of paper and a ruler. The activity took two hours and involved about 15 teachers. The activity structure is intended to mimic the sequence of an experimental scientific inquiry: starting from the elaboration of a theoretical model, moving to the preparation and calibration of experimental set-up and data collection and finally to data analysis and interpretation. During the workshop we focused on the different aspectes of experimental activities.

Development of a physical model

Following teachers' request of being properly introduced to the physics of the small cylindrical magnets magnetic fields, the experimental activity have been preceded by a short lecture by a faculty member of DiSAT. This part of the activity made it possible to analyze in detail the theoretical model underneath the relation between the physics variables used to describe the phenomena. As reported by the teachers during the discussion, this introduction is consider a useful and essential tool to engage the student into the laboratory activity: in their experience, students seem to prefer to infer the interpretation of a single phenomenon from a general model instead of inductively built a scientific model from observations.

The modeling of the magnetic field gives also some elements about the type of magnets that could be used. The field generated by a permanent magnet of cylindrical shape is calculated on the axis of symmetry x-direction at distance much larger than its radius a (but not necessarily larger than its length l). The permanent magnet is schematized as a collection of circular loops crossed by a current of intensity I that can be identified with the superficial magnetization currents. Under this conditions the magnetic field in the x-direction is given by

$$B_x(x) = \frac{\mu_0}{2\pi} m \frac{x}{\left(x^2 - \frac{l^2}{4}\right)^2} \quad (3)$$

where m is the magnetic moment of the magnet and μ_0 is the magnetic permeability of free space. If then $l << x$ the x-component of the magnetic field becomes:

$$B_x(x) = \frac{\mu_0 m}{2\pi} \frac{1}{x^3} \quad (4)$$

Becoming familiar with experimental devices

An important part of the experience was about learning how to properly use the data acquisition device. Teachers spent time to learn how to use the smartphone app, focusing the attention on how the device collects data. The first problem is to determine the position of the sensor inside the device. Secondly, the smartphone sensors need to be properly calibrated, taking into count that the measurements are strongly dependent on the device orientation and distance between the smartphone and the magnet. The possibility to verify the consistency of a theoretical model is bounded by the possibilities given by the characteristics of the experimental devices: this is something students need to understand to properly evaluate the results of their experimental activities. Teachers reported that they could not collect data when the smartphone was too close (less than 5 cm) to the magnet, due to the sensor saturation (when $x < 5$ cm the value of B did not change): that implies that the model could be verified only in a specific interval of distances from the device.

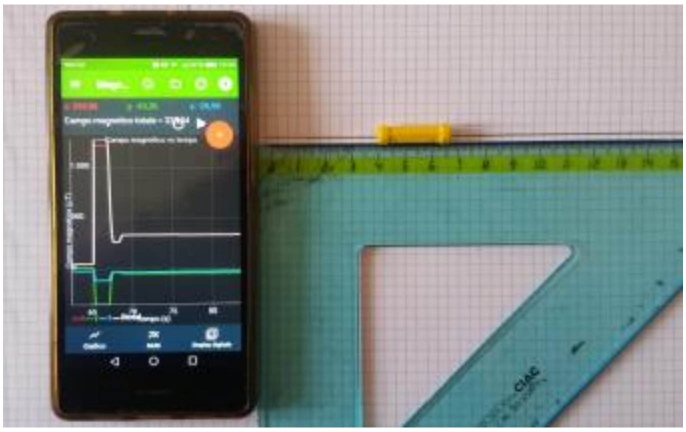

Figure 2. Experimental setup

For the same reason the evaluation of the experimental uncertainty is part of the data acquisition process: every device, even digital ones, collect data with a specific uncertainty. This aspect was reported by the teachers during the practice: the value of the magnetic field measured by the smartphone fluctuates rapidly and this required an adjustment of the acquisition procedure. The values of the field for each measurement could be only obtained by averaging the values recorded in a specific period of time. In this way, an error corresponding to the uncertainty of the mean was associated with each value of B_i.

Data elaboration process

The discussion generated around the problem of data elaboration was about how to fit the function that corresponds to the theoretical model (equation (4)). The spreadsheet used in schools (i.e. MS Excel, LibreOfficeCalc, GspreadSheet) give the opportunity to fit power functions, but some teachers noticed that it would be useful to have the possibility to fit the data using a function using multiple parameters like the following

$$\boldsymbol{B(x) = \frac{k}{x^b}} \quad \text{or} \quad \boldsymbol{B(x) = \frac{k}{x^b} + c} \tag{5}$$

where the parameter could be related to specific physics constant (k) or instrumental offset error (c). As suggested by some teachers during the group discussion, a possible way to tackle this problem is to use a "logarithmic version" of the function in equation (5): in this way the fit function becomes linear and data could be analyzed using familiar the least square method.

$$\boldsymbol{ln(B) = ln(a) - bln(x)} \tag{6}$$

In this case the gradient of the line represents the specific power dependence of the field intensity on distance. As suggested by physics researchers who participated in the meetings, a parametric function fit could be easily done using Matlab or Mathematica. Unfortunately the licences for those softwares are out of the public school budget. A more affordable alternative could be the use of Phyton and its data analysis libraries like NumPy and SciPy or the Python module Pandas. As suggested by teachers, the Python programming language could be also an opportunity to interact with computer science teachers and ICT experts in school. In figures 4 and 5 there are two examples of data elaboration made by the teachers with the data collected during the laboratory activities.

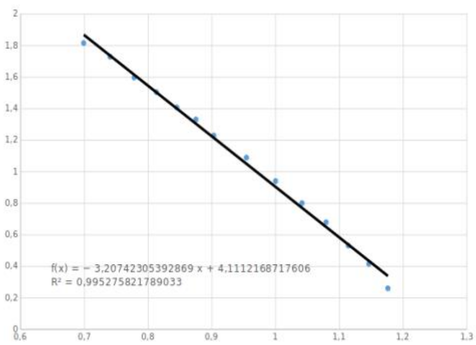

Figure 3. Graph from the data using *ln*(*B*) vs *ln*(*x*) with MSExcel

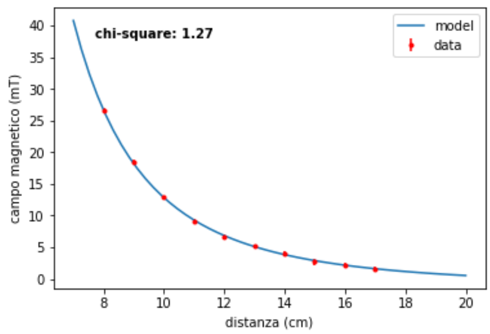

Figure 4. Graph of parametric function from data with Phyton

LEARNING EXPERIENCES 2: MODELS AND MEASURES

The second learning activity had been proposed by one of the teachers and was about the measurement of the time collision of a ping pong ball with a table (Oladyshkin & Oladyshkina, 2016). The same experiment as also been part of the project "Olimpiadi italiane della Fisica – Gara Nzionale, Prova Sperimentale 2018"(https://www.olifis.it/). This experience have been structured as a guided inquiry learning activity so the participants (divided in small groups of three) have to built a proper theoretical model to describe the physical phenomena in order to guide the measurement process during experimental activities. The inquiry question was about how to estimate the time of collision of a freely falling ping-pong ball and a table. During the activity a model of the collision process have been developed, identifying the physical variables that determine the system dynamics during the collision so the measurements have been taken in accordance with the theoretical model.

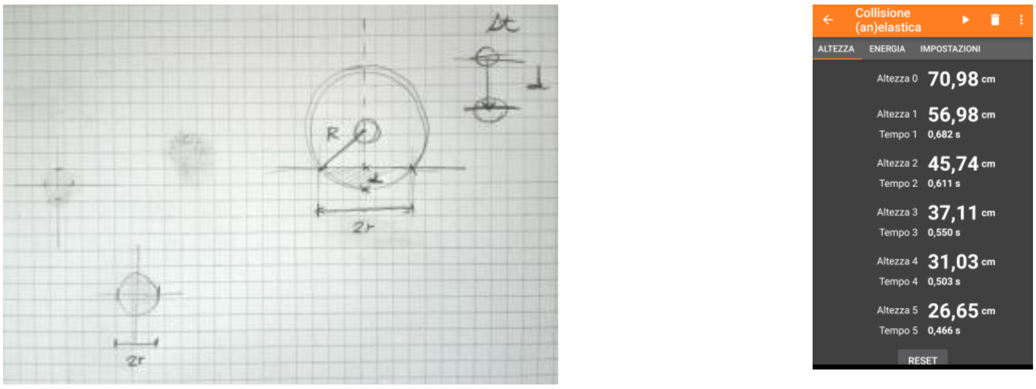

Figure 5. Teachers' notes during group activity and Phyphox App – (in)elastic collision

In the first part each group should explicit the hypotheses used to model the collision between the ball and the plane. The collision is not completely elastic so it is necessary to first determine the coefficient of restitution e_V . Due to the fact that the able is not moving, in this case e_V is the ratio of the velocity of the ball after and before the collision. Also assuming the mechanical energy conservation before and after the collision it possible to determine e using the following formula:

$$e_V = \sqrt{\frac{h\prime}{h}} \qquad (7)$$

where *h'* and *h* are the vertical position of the ball before and after the collision. Using Phyphox "(in)elastic collision" app it is possible to perform multiple measurements of *h'* and *h* and get an estimation of e_V and its uncertainty. In the second part each group painted the ball using a pencil and directly estimate the diameter *2a* of the round shape imprint of the ball on a blank paper.

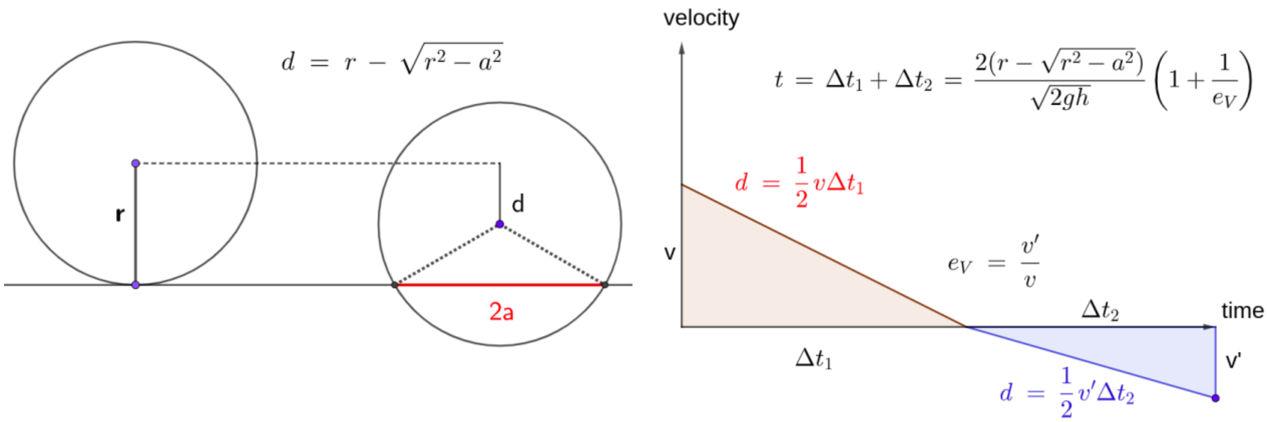

Figure 6: Collision process geometrical analysis and kinematics

In the last part the groups have discussed their conclusions comparing their results, in particular what kind of systematic uncertainty can affect the measurements.

In this activity the connection between the physical model and the measurement process is explicit in the way different theoretical hypothesis (i.e. uniform acceleration, neglecting energy dissipation, during the collision) have been used in order to have measurements sufficiently accurate to get a reasonable estimation of collision time. During the activity teachers have discussed on how to help students to understand the role of those hypotheses in determine systematic errors, generating an overestimation of the duration of the collision.

CONCLUSION

The collaboration between researchers and teachers is crucial to promote the development of science competencies. The activities presented in this paper have showed how school teachers are determined to improve the level of their teaching through collaboration. The meetings have been good opportunities to share teaching experiences and materials. The teachers agreed that high quality, scientifically-based learning activities need to be implemented into the curricular classroom activities and then become part of daily teachers' practices in order to be effective: in this sense teachers need to be more committed to the design of their curricular instructional laboratory activities and processes. On the other hand physics researchers need to foster that design process, promoting collaboration activities with teachers and supporting the creation of an active educational ecosystem.

REFERENCES

Arribas, E., Escobar, I., Suarez, C. P., Najera, A., & Beléndez, A. (2015). Measurement of the magnetic field of small magnets with a smartphone: A very economical laboratory practice for introductory physics courses. *European Journal of Physics*, *36*(6), 065002. https://doi.org/10.1088/0143-0807/36/6/065002

Besson, U., Borghi, L., Ambrosis, A. D., & Mascheretti, P. (2010). A Three-Dimensional Approach and Open Source Structure for the Design and Experimentation of Teaching-Learning Sequences: The case of friction. *International Journal of Science Education*, *32*(10), 1289–1313. https://doi.org/10.1080/09500690903023350

Fraser, J. M., Timan, A. L., Miller, K., Dowd, J. E., Tucker, L., & Mazur, E. (2014). Teaching and physics education research: Bridging the gap. *Reports on Progress in Physics*, *77*(3), 032401. https://doi.org/10.1088/0034-4885/77/3/032401

Oladyshkin, I. V., & Oladyshkina, A. A. (2016). Millisecond measurements without equipment: Time of collision of a ping-pong ball with a table. *Physics Education*, *52*(1), 013006. https://doi.org/10.1088/1361-6552/52/1/013006

Rönnebeck, S., Bernholt, S., & Ropohl, M. (2016). Searching for a common ground – A literature review of empirical research on scientific inquiry activities. *Studies in Science Education*, *52*(2), 161–197. https://doi.org/10.1080/03057267.2016.1206351

SCIENCE TEACHERS' PEDAGOGICAL DEVELOPMENT: FOCUSING ON LESSON STUDY

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This study examines how Japanese science teachers pursue pedagogical development. The research questions investigated were (1) what is 'traditional science teaching in Japan'?; and (2) how do Japanese science teachers acquire orthodox teaching values and intentions within their professional learning communities? We focused on 'lesson study', which is a comprehensive and well-articulated approach to examining teaching practices within professional learning communities. A literature review and three empirical research studies were conducted to answer these questions. Quantitative data from questionnaires comparing teachers in Japan and England were summarised in tabular form and statistical tests were applied. The results demonstrated that science teachers' pedagogical development reflects the culture in which they teach. Data sources included life story interviews with five experienced teachers and questionnaires completed by 177 science teachers, focusing on the topic of lesson study for professional development. Furthermore, the results demonstrated that science teachers acquired norms of the teaching profession and orthodox teaching values and intentions through lesson study. We suggest that, to challenge orthodox beliefs, it is important for teachers to recognise that lesson study is one of many effective vehicles for pedagogical development.

Keywords: Pedagogical development, teaching values, lesson study

BACKGROUND, THEORETICAL FRAMEWORK, AND RESEARCH QUESTIONS

Background

Dillon and Manning (2010) argue that science teachers' pedagogical development relates to their challenge of orthodox 'teaching values and intentions' (p. 14), which can be described as 'traditional science teaching' (p. 14). This means that teachers' pedagogical development is a sociocultural activity situated within a professional learning community, and is thus affected by professional norms.

What is traditional science teaching in Japan? As an example, let us consider the National Center for Education Statistics (NCES; 2006), which stated that Japanese science lessons at the eighth-grade level perform the following tasks: (1) focus on developing scientific ideas by making connections between ideas and evidence through an inquiry-oriented, inductive approach, in which data are collected and interpreted to formulate a main idea or conclusion; and (2) be conceptually coherent, with an emphasis on identifying patterns in data and making connections between ideas and evidence, and conducting practical work as a central role in developing main ideas. This is one typical way of teaching Japanese science lessons. Science teaching practices in laboratories and classrooms are partly based on the knowledge base and expertise of teachers. Japanese science teachers have engaged in 'Lesson Study or lesson study', a professional practice that has become deeply embedded in teachers' professional culture (Isozaki, 2015; Isozaki & Isozaki, 2011). Japanese teachers experience the system of lesson study since their pre-service teacher education (see Figure 1), recognising that their knowledge base and teaching competencies are enhanced through lesson study as a part of continuing professional development (CPD).

Theoretical Framework

This study focuses on two theoretical frameworks: first, the socio-cultural perspective of science teaching and science lessons, and second, lesson study (or Lesson Study) in the professional learning community. The NCES (2006) examined the science teaching of five countries through a video study and demonstrated that each country had a different approach to science teaching. This means that science teaching is a socio-cultural activity. Davis, Janssen and Van Driel (2016) reviewed the literature on science teachers and science curriculum materials and pointed out that much of the teacher-curriculum research adopts, either implicitly or explicitly, a sociocultural perspective.

Stigler and Hiebert's (1999) book introduced one reason why lesson study was an important key approach to obtaining a higher score in international comparisons, such as the Trends in International Mathematics and Science Study (TIMSS), which had a strong impact on Japanese educators. We focused on lesson study, which is a comprehensive and well-articulated approach to examining one's teaching practice that Japanese teachers engage in as an essential part of their CPD within their professional learning community. Of course, there are other vehicles for teachers' CPD, such as workshops, action research, and self-study. Isozaki (2015) highlighted the differences amng lesson study, workshops, and action research as follows. First, lesson study should be considered a process that begins with a research question driven by the participants, whereas workshops often begin with answers while being motivated by outside school experts. Second, lesson study emphasizes the process involving collaboration with colleagues (sometimes including outside advisors, such as professors and consultant teachers of local boards of education) and a common focus. In contrast, action research examines teachers' own teaching and students' learning by engaging in research projects in their classrooms, although working with colleagues is usually optional. They, therefore, can learn professional norms through lesson study as well as in schools. This is the reason why we focus on lesson study as the way in which Japanese science teachers challenge orthodox 'teaching values and intentions'.

Research Questions

This study investigated Japanese science teachers' pedagogical development from a sociocultural perspective. The following research questions were investigated: (1) what is 'traditional science teaching' in Japan; and (2) where and how do Japanese science teachers challenge orthodox 'teaching values and intentions' within their professional learning communities? Resolving these research questions will, therefore, contribute to the support of teachers' pedagogical development.

METHODS AND DATA

To address the research questions delineated above, we conducted a literature review on science teaching and lesson study from different sociocultural perspectives. First, we reviewed the literature on science lessons/teaching from international and sociocultural perspectives; for example, The Third International Mathematics and Science 1999 Study Video Study (NCES, 2016), Trends in International Mathematics and Science Survey (TIMSS) 2015 (Mullis, Martin, Foy, & Hooper, 2016), and Stigler and Hiebert (1999). Second, we reviewed the literature on lesson study from international and sociocultural perspectives; for example, Doig, Groves and Fujii (2011), Isozaki (2015), Isozaki and Isozaki (2011), and Lewis and Hurd (2011), Teaching and Learning International Survey (TALIS; OECD, 2014).

We then conducted the following three empirical research studies. First, we conducted comparative research on three dimensions of science teaching–science teachers' beliefs, approaches used in designing lessons, and methods used in teaching science–with 84 science teachers in lower secondary schools in Japan and 24 science teachers at comprehensive schools in England in 2013. The quantitative data from the questionnaires were summarized in tabular form, and statistical tests were applied (Nozoe & Isozaki, 2018). Next, we collected qualitative life-history data through semi-structured interviews with five experienced Japanese secondary school science teachers in 2015, whose teaching careers included more than 30 years of experience to investigate changes in their beliefs about the goals and purposes of science teaching over time. The life history interview data were analysed in terms of the Steps for Coding and Theorization (SCAT; Ueda & Isozaki, 2016). Third, we collected quantitative data in lesson study for Japanese secondary science teachers of all ages (N = 177) in Hiroshima by using a questionnaire survey with multiple choice and short essay questions conducted ion 2016 (Isozaki and Department of Science Education, and the Research Project Centre for the Next Generation Science Education, 2016; Ochi, Ueda, & Isozaki, 2018). We obtained permission from all teachers who contributed to any of these empirical studies.

RESULTS OF EMPIRICAL RESEARCH

Table 1 supports the findings by NCES (2006), Mullis, Martin, Foy and Hooper (2016), and Stigler and Hiebert (1999) that science teaching is a socio-cultural activity. By comparing the data from Japan with data from England, the results indicated that a science teacher's pedagogical perspective depends significantly on the country in which they teach. This demonstrates evidence that the educational culture of that country regulates science teachers' pedagogical development.

The results of the SCAT analysis of the interview data from the five experienced teachers demonstrated that 'the development of beliefs about the goals and purposes of science teaching throughout a teacher's professional career can be perceived as part of the science teacher's consecutive learning both inside and outside of school' (Ueda & Isozaki, 2016, p. 44). This means that experienced teaches initially participated enthusiastically in lesson study both formally and informally, aiming for self-improvement in their teaching, and to acquire the norms of the teaching profession.

Table 1: The most important learning objective in school science

Country	1. Skills of laboratory work and observation	2. Knowledge and understanding about science	3. 'Decision making' ability based on scientific evidence	4. Scientific thinking	5. Interest in science	6. Ability to explain scientifically	7. Investigation and inquiry	8. Relationship between science and daily life	9. Others
Japan (N=74)	3 (4.1)	9 (12.2)	11 (14.9)	10 (13.5)	16 (21.6)	1 (1.4)	4 (5.4)	19 (25.7)	1 (1.4)
England (N=17)	0 (0)	7 (41.2)	0 (0)	1 (5.9)	2 (11.8)	2 (11.8)	0 (0)	5 (29.4)	0 (0)
Total (N=91)	3 (3.3)	16 (17.6)	11 (12.1)	11 (12.1)	18 (19.8)	3 (3.3)	4 (4.4)	24 (26.4)	1 (1.1)

Note: Figures in parentheses are percentages of n or N values relating to each row.

(Source: Nozoe & Isozaki, 2018)

The questionnaire data demonstrated that 72.3% (N = 177) of the Japanese science teachers surveyed responded that they participated in lesson study for professional development in teaching and learning science. This trend was observed in the results of the TALIS, in which Japanese teachers reported higher-than-average participation rates (51%) for professional development in terms of observation visits to other schools (as compared to the TALIS average of 19%) (OECD, 2014). Through lesson study, teachers in their 20s to 40s indicated that they intended to learn how to conduct the 'research and development of new teaching materials' (*kyouzai-kenkyuu* in Japanese), and apply new teaching materials produced by others, while those in their 50s intended to learn new pedagogical methods in science. The data from the short essays on the preparation phase of lesson study demonstrated that teachers primarily concentrated on: (1) reflection on previous teaching materials, (2) development of new materials, and (3) development of a lesson plan according to students' understanding and skill levels.

DISCUSSION

What is traditional science teaching in Japan?

Generally, Japanese science lessons from elementary (the first to the sixth grade) to upper secondary school (the tenth to the twelfth grade) consist of three phases: introduction, development, and conclusion (Isozaki, 2015). As Stigler and Hiebert (1999) have observed, one of the main activities in the introduction phase is to review the previous lesson to grasp student understanding. The other important activity is to motivate students regarding today's lesson topic. The introduction phase generally takes up between five and ten minutes of the lesson time.

Japanese science teachers tend to consider the following questions during the preparation phase of lesson study and regular lessons: (1) Why is this unit's topic valuable to students?; (2) What do I want students to gain from this unit?; and (3) How can I provide a successful learning experience to students? To answer these questions, science teachers review their previous teaching and the resources gained through participating in the lesson study and other activities. They interpret the course of study, which is similar to the national curriculum and textbooks, as well as contemplate the scientific and educational values of the unit and teaching materials (Isozaki, et al., 2016).

At the beginning of the development phase, Japanese science teachers usually provide *one* question (*toi* or *hatsumon* in Japanese) extracted from today's topic; sometimes this question shares the same meaning as today's task, directly connecting students to the task before they engage in practical work. After providing this question, and before students embark on practical work, teachers often require students to work in a group or as individuals in forming a hypothesis or making a prediction. Indeed, the TIMSS 1999 video study (NCES, 2006) demonstrates that a higher percentage of Japanese students make a prediction as compared to students in Australia, the Czech Republic, the Netherlands, and the United States. According to the results of Isozaki et. al., (2016), and Ochi et. al. (2018), lower secondary school (the seventh to ninth grade) science teachers emphasize a set of objectives that should be achieved by learners in one lesson to formulate a question that is appropriate for the ability of learners. In designing a science lesson, they carefully consider the coherence between the objectives of the lesson, its *one* question, and the single conclusion to be drawn. Science teachers have to use various types of teacher knowledge, especially pedagogical content knowledge (PCK; Shulman, 1987) when formulating this question. It is noteworthy that Japanese science teachers recognise that formulating an adequate and appropriate question is one of the most important parts of designing a lesson.

After forming a hypothesis, students engage in practical work in conducting and resolving the task. Science teachers require students to collect and record data from practical work carefully. During practical work, science teachers must instruct each group, inspect their notebooks or worksheets to grasp their level of understanding and practical work data, as well as hear their 'thinking aloud' or 'muttering' (*tsubuyaki* in Japanese) as they walk around the classroom or between students' experimental desks. Doing this is considered as an important activity for teachers and called *kikan-shidou* or *kikan-jyunshi* in Japanese. If they discover that students (individuals or groups) are engaging in practical work incorrectly during walking around the classroom or between students' experimental desks, they must correct them accordingly. Of course, walking around the classroom or between students' experimental desks involves other important roles, including, for example, identifying students' degree of understanding, providing guidance to slower groups or students, and carefully observing that students are working safely. Science teachers can also grasp students' latent ideas by careful listening to their thinking aloud.

When engaging in practical work, students follow the worksheet created by the teacher. Some worksheets describe the practical work's objectives, procedures, and the point of discussion. After practical work, students are required to manipulate the data. According to the results of the TIMSS 1999 video study (NCES, 2006), Japanese and Australian students were guided by the teacher or textbook in manipulating data. Such practical work has been criticized as guided inquiry. Discussion after practical work leads to the development of a main conclusion or scientific idea as an answer to a question. Therefore, science teachers carefully consider the objectives of the lesson, leading question, and conclusion drawn, ensuring that they cohere appropriately. In other words, when 'making and revising a lesson plan' (*gakushuushidouan-sakusei* in Japanese), teachers create a narrative story or scenario for the lesson. The development phase generally takes up approximately thirty-five or forty minutes of the lesson.

In the conclusion phase, based on the results of practical activities, small group and whole-class discussions are conducted to pursue the development of one main conclusion; finally, the science teacher summarises the lesson. This conclusion phase takes up the final five to ten minutes of the lesson.

As a result of the analysis of the literature on science teaching in Japan, these processes can be identified as a typical Japanese science lesson from elementary to secondary school level.

Where and how do Japanese science teachers challenge orthodox 'teaching values and intentions'?

Where and how do Japanese science teachers learn this process of a typical science lesson? Prospective teachers experience the nuance of lesson study including the above-mentioned typical Japanese science lessons under their mentors during their short-term teaching practice in schools. After becoming a teacher, science teachers intended to participate in lesson study, which is deeply embedded in Japanese teachers' culture (see Figure 1).

Isozaki (2015) argued that lesson study should be divided into three phases, as illustrated in Figure 1: preparation, research lesson, and reflective meeting. The main activities at the preparation phase of lesson study include the research and development of teaching materials and making and revising a lesson plan. Research and development of teaching materials encapsulate these processes of internal didactic transposition, involving the important process of examining both teaching materials and the students' main activity task. Japanese lesson plans represent a teacher knowledge base, such as pedagogical knowledge, content knowledge, and pedagogical content knowledge, as proposed by Shulman (1987). Teachers believe that to design a good lesson, a teacher must create a question/task that will engage and motivate students (Isozaki et.al., 2016; Ochi et.al., 2018).

In the preparation phase of lesson study, science teachers consider scientific and educational values, reflect on their individual values as science teachers, and consider their students' learning perspectives, such as their needs and interests. If science teachers do not deeply engage in research and development of teaching materials that integrate both scientific and educational values and students' perspectives, there is no meaning for students in conducting the task, which would then be of no value to them (Isozaki, in press). As demonstrated by the results of our empirical research and the results of TALIS (OECD, 2014), Japanese teachers spend significant time on lesson preparation and learn from colleagues through lesson study. Lesson study helps to form a teacher/professional culture that provides opportunities to share the dominant values (Isozaki, 2015). The consideration of various educational values included in a lesson plan is key to a science teacher's role in designing lessons in Japan.

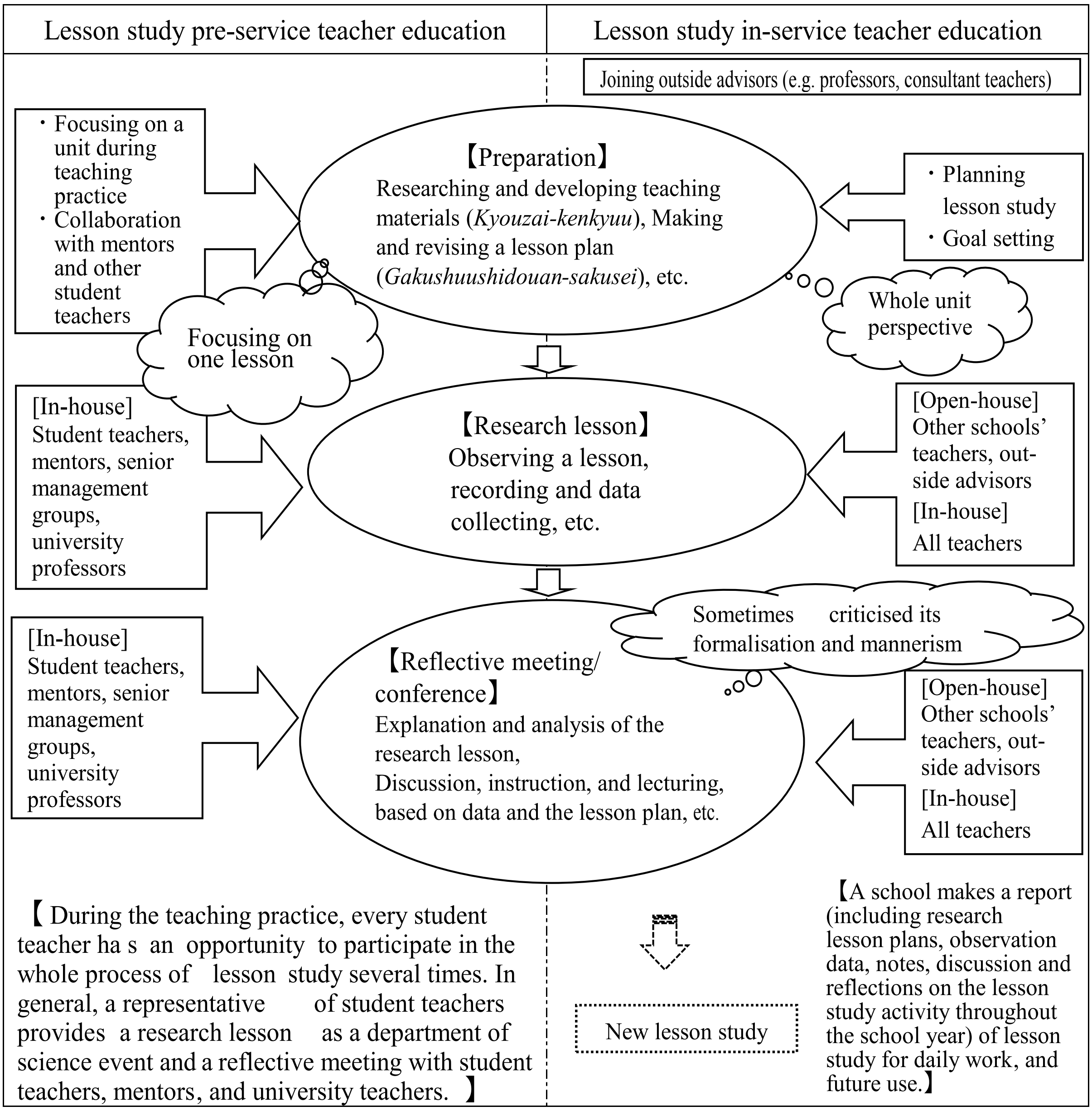

Figure 1: A typical process of lesson study in pre-and in-service teacher education

A research lesson in lesson study has similar processes to a regular lesson, with many science teachers employing an inquiry-based approach (Isozaki, 2015). However, while a science teacher will make and revise their lesson plans, as well as research and develop the teaching material for a regular lesson by themselves, collaboration with colleagues is a fundamental aspect of lesson study. Therefore, a science teacher conducting a research lesson will often consult with their colleagues–including senior school management and outside advisors, such as a professor–in the preparation phase of lesson study (Isozaki & Isozaki, 2011). Participants of lesson study carefully observe the research lesson with the revised lesson plan. While a reflective meeting is held with observers from within and outside the school after a research lesson, a reflective meeting is not held after every regular lesson. Therefore, science teachers need to reflect by themselves or through analysing students' achievements and performances, via notebooks, worksheets, and tests.

Consequently, Japanese science teachers can develop their teacher knowledge and skills within their professional learning community. By participating in lesson study, formally and informally, even experienced science teachers can learn from others and improve their teacher knowledge and teaching competencies.

Subsequently, traditionally, science teachers of Japanese secondary schools have the opportunities to share and learn professional norms and values within their professional learning communities, and to be able to challenge orthodox 'teaching values and intentions'.

CONCLUSION

Through lesson study within the professional learning community, Japanese science teachers can acquire the norms of the teaching profession and values in science teaching. As a result, they can challenge orthodox 'teaching values and intentions'. However, the standardisation of lesson study results in its stylisation (Isozaki, 2015). Therefore, to challenge such orthodoxy, it is essential that science teachers recognise that lesson study is one of the vehicles for science teachers' pedagogical development, and the values shared by science teachers sometimes are not up to date with the latest research trends. Using a comparative study, we need to consider other potential vehicles, such as self-study, to improve science teachers' pedagogical development from socio-cultural perspectives.

Isozaki, Isozaki, Kawakami, and Sawai (2015) demonstrated the qualitative and quantitative differences of PCK between novice and experienced science teachers and concluded that lesson study is potentially effective for developing teachers' professional knowledge base, and it must be an important vehicle for teachers' CPD. Despite its application history, neither teachers nor researchers seemed interested in investigating lesson study in Japan until Stigler and Hiebert's *The Teaching Gap: Best Ideas from the World's Teachers for Improving Education in the Classroom* was published in 1999. Clivaz and Takahashi (2017) argued that theorizing lesson study could help researchers and teachers outside of Japan understand its specific cultural norms. As lesson study is embedded in Japanese teachers' culture (Isozaki, 2015), there is space for non-Japanese science researchers to identify social and cultural norms in the Japanese school context. This means that Japanese researchers and teachers have to provide sufficient information to educators outside of Japan who wish to design similar lesson study projects for professional-pedagogical development to challenge Japan's success rate.

ACKNOWLEDGEMENT

This study was supported by JSPS KAKENHI under grant numbers JP17H01980 and JP17K04758.

REFERENCES

Clivaz, S., & Takahashi, A. (2017). Mathematics lesson study around the world: Conclusions and looking ahead. In M. Quaresma, C. Winsløw, S. Clivaz, J. P. da Ponte, A. Ní Shúilleabháin, & A. Takahashi (Eds.), *Mathematics lesson study around the world: Theoretical and methodological issues* (pp. 153–164). New York, NY: Springer.

Davis, E. A., Janssen, F. J. J. M., & Van Driel, J. H. (2016). Teachers and science curriculum materials: Where we are and where we need to go. *Studies in Science Education*, *52*(2), 127–160.

Dillon, J., & Manning, A. (2010). Science teachers, science teaching: Issues and challenges. In J. Osborne, and J. Dillon (Eds.), *Good practice in science teaching: What research has to say* (pp. 6–19). Buckingham, UK: Open University Press.

Doig, B., Groves, S., & Fujii, T. (2011). The critical role of task development in lesson study. In Lynn C. Hart, S. Alice, & A. Murata (Eds.), *Lesson study research and practice in mathematics education* (pp. 181‐199). Dordrecht, The Netherlands: Springer.

Isozaki, T. (2015). Lesson study research and practice in science classroom. In R. Gunstone (Ed.), *Encyclopedia of science education* (pp. 615–618). Dordrecht, The Netherlands: Springer Reference.

Isozaki, T. (in press). Teaching values in a professional community: Exploring Japan's lesson study. In D. Corrigan, C. Buntting, A. Jones, & A. Fitzgerald (Eds). *Values in science education: The shifting sands*. Dordrecht, The Netherlands: Springer.

Isozaki, T., the Department of Science Education, & the Research Project Centre for the Next Generation Science Education (2016). *A report on the survey of lesson study in Hiroshima* [in Japanese]. Unpublished.

Isozaki, T., & Isozaki, T. (2011). Why do teachers as a profession engage in lesson study as an essential part of their continuing professional development in Japan? *International Journal of Curriculum Development and Practice*, *13(1)*, 31–40.

Isozaki, T., Isozaki, T., Kawakami, S., & Sawai, K. (2015). How science teachers develop their professional knowledge through Lesson Study in Japan. A paper presented at the European Science Education Research Association 2015 conference in Finland.

Lewis, C., & Hurd, J. (2011). *Lesson study step by step: How teacher learning communities improve instruction*. Portsmouth, NH: Heinneman.

Mullis, I. V. S., Martin, M. O., Foy, P., & Hooper, M. (2016). *TIMSS 2015 International Results in science.* Retrieved from Boston College, TIMSS & PIRLS International Study Center website: http://timssandpirls.bc.edu/timss2015/international-results/

National Center for Education Statistics (2006). *Highlights from the TIMSS 1999 video study of eighth-grade science teaching* (NCES 2006–017). Washington, DC, USA: National Center for Education Statistics. Retrieved from https://nces.ed.gov/pubs2006/2006017.pdf.

Nozoe, S., & Isozaki, T. (2018). What affects Japanese science teachers' pedagogical perspectives in lower secondary schools? A paper presented at the East-Asian Association for Science Education 2018 conference in Taiwan.

Ochi, T, Ueda, Y, & Isozaki, T. (2018). How Japanese lower secondary science teachers improve their teaching competencies through lesson study: A qualitative study focusing on giving a research lesson, *Journal of Science Education in Japan*, 42(3), 231–241. [in Japanese with English abstract]

Organization for Economic Co-operation and Development (2014). *Results from TALIS 2013, Country note: Japan*. Paris: OECD. Retrieved from http://www.oecd.org/japan/TALIS-2013-country-note-Japan.pdf.

Shulman, L. (1987). Knowledge and teaching: Foundations of the new reform. *Harvard Educational Review*, *57*, 1–22.

Stigler, J. W., & Hiebert, J. (1999). *Teaching the gap: Best ideas from the world's teachers for improving education in the classroom*. New York, NY: Free Press.

Ueda, Y., & Isozaki, T. (2016). Reach into development of beliefs about the goals and purposes of science teaching: Analysis of life stories of five experienced science teachers. *Theory and Research for Developing Learning Systems*, *2*, 35–47.

TRANSFORMING THE PEDAGOGICAL PRACTICES OF ETHIOPIAN PHYSICS TEACHERS FROM DIDACTIC TO DIALOGIC TEACHING

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This paper reports on the Transforming the Pedagogical Practices of STEM Subjects project (TPSS) which trialled and implemented a national intervention to change the prevailing lecture-dominated teaching practices of physics teachers in Ethiopia. 60 teachers in fifty upper-cycle primary schools (Grades 5-8) received training on the principles of scientific reasoning, argumentation and dialogic teaching. 80 video-recorded physics lessons from a sub-sample of 40 teachers were analysed quantitatively and qualitatively to examine the impact on pedagogical practice and physics learning of students, including a control group. In-depth interviews with participants were also conducted to glean teachers' views on the training provided, the contextual constraints and the impact on student learning. Findings show that the teachers who received the project combined training (pre-service and in-service) implemented the most significant pedagogical changes. This includes the adoption of a wider repertoire of talk and affording students with opportunities to engage in classroom activities. The contextual challenges facing Ethiopian teachers continue to have an impact on their abilities to deliver the intended aims of the learner-centered curriculum. Implications arise for the introduction of pedagogical practice interventions in low income nations

Keywords: Dialogic Teacher education, physics

INTRODUCTION

Within science classrooms, effective teacher talk plays a central role in maximizing students' abilities to learn scientific concepts and reasoning processes. Verbal classroom discourse and its importance in student cognitive, communicative, social, and cultural development have received much attention from researchers (e.g. Alexander, 2018; Kind, 2017). Teacher talk in science classrooms gains particular significance in contexts that are under-resourced, over-populated, and linguistically-diverse, representative of the Ethiopian context. Several studies concluded that a typical traditional classroom in East Africa (and beyond) is marked by the pervasiveness of 'triadic dialogue' or recitation recipe (Frost & Little, 2014; Lemke, 1990). This creates a closed circuit of communication referred to as Initiation-Response-Feedback or IRF structure and the ensuing teaching practices are dubbed 'didactic teaching' which often comprises one-way lecturing and closed teacher questions as brief evaluations. This is regarded as problematic because active student contributions are discouraged, contradicting socio-cultural learning theory, which suggests knowledge and mental functions are internalized through language and social interaction (Wertsch, 1991).

Over-reliance on didactic teaching may apply to any nation or school subject, but is particularly dominant in STEM subjects (science, technology engineering and mathematics) as these typically teach "facts" given to students. In the UK, for example, Driver and Newton (1999) found that on average more than 75% of teaching time in science classrooms involved passive listening, copying and performing set exercises. Teacher-student dialogue comprised only 13% of teaching time, and mainly involved teacher-led questions. In developing nations, such as Ethiopia, didactic teaching is even more dominant because class sizes are larger, resources are scarce, and cultural traditions set expectations for this style. This restricts and constrains students' learning, and impacts negatively on recruitment and retention in STEM subjects beyond compulsory schooling (Osborne, Simon and Collins, 2003). Developing nations rely on STEM subjects as means to build economic success, and transforming the pedagogy to become 'dialogic' is therefore important to ensure a better future.

The current study draws on disciplinary dialogic teaching, which has additional elements to dialogical teaching, rooted in the socio-cultural theory of learning (Vygotsky, 1978). The additional elements in disciplinary dialogical teaching draw on reasoning and argumentation typical to the science community. Scientific knowledge is the outcome of debate in the 'science community of inquirers' (Peirce, 1934). Science educators have adopted this (philosophical) perspective and merged it with socio-cultural learning to form a strand of research and teaching known as scientific argumentation. In scientific argumentation, focus is on accountable talk, which follows norms and criteria established in the science community (e.g. Driver, Newton, & Osborne, 2000; Duschl & Grandy 2008; Michaels, O'Connor, & Resnick, 2008). Disciplinary dialogical teaching, accordingly, combines Alexander's theory of dialogic teaching and the concept of scientific argumentation: dialogical teaching in science should reflect the cultural ways of arguing/debating that is typical to science. Intervention studies gathering empirical evidence about the influence of dialogical teaching on students' learning of STEM subjects demonstrate significant gains (e.g. Mercer, Dawes, Wegerif, & Sams, 2004; Osborne, Simon, Chistodouluo, Howell-Richardson and Richardson, 2013; Venville & Dawson, 2010). A key aim for dialogical teaching is establishing exploratory talk, which makes students' ideas explicit as a stepping stone towards further conceptual change and development (Mercer, 2008).

The rationale for introducing argumentation-based dialogical teaching in science education rests on claims that informal reasoning is crucial to science inquiry (Latour, 1987). Barmby, Kind & Jones (2008) indicate that students' attitudes to science declines as they progress through secondary education, suggesting that positive experiences in the upper primary/ lower secondary (as used in this project) stage are critical for retaining interest. Dialogue and argumentation permit resolution of misunderstandings, tests students' reasoning, and ultimately prompts satisfaction from learning correct concepts, particularly when directed by a pedagogically skilled teacher. Another theoretical rationale underpinning the study explains conditions for professional development of teachers. It is well respected that many approaches to teacher development has had little sustained impact and that in-service training do not automatically transfer to classroom practice (Opfer & Pedder, 2011; Cazden, 2001). Success depends to a large extent on establishing a practice of collaborative reflection within a supportive community focused on professional learning (Horban, 2002).

CONTEXT

The study was carried out in Ethiopia, which is a low-income nation with many economic, cultural and pedagogical challenges. Traditional educational reforms in Ethiopia focused on enrolment and capacity building i.e. "mass" rather than "elite" education (Woldehanna & Gebremedhin, 2016). In response to that and since 1994, the Ethiopian Ministry of Education (MOE) has designed and implemented a series of Education Sector Development Programmes, in which classroom pedagogy has been the main focus. Compulsory education in Ethiopia is comprised of 8 years of primary education from grades 1 to 8 (7-14 in years) followed by 4 years of secondary school education from grades 9 to 12 (15-18 in years) with both numeracy and language literacy forming its focus (MoE, 2011). Based on the results of their obtained marks in the national Grade 10 Exam, students can either continue to higher education or join vocational training including teacher education. A significant number of primary school teachers come from students scoring lower marks in Grade 10 exams (Joshi & Verspoor, 2013). In addition, secondary school students who fail their 12 Grade National Exam enrol in one of the Colleges of Teacher Education where both groups (graduates of Grade 10 and Grade 12) study the same curriculum for 3 years (Alemu et al, 2019). Since 1994, the Ethiopian MoE introduced and implemented four major teacher education reform initiatives with the aim of expanding, standardizing and improving the quality of teacher education provision across the country. Mixed results were reported on the success of these initiatives in transforming traditional lecture-based teaching to student-centered and active teaching and learning.

Starting from this context, the research study looked towards a teacher education programme for the upper cycle of primary education (Grade 5-8) and sought to answer the following questions:

- To what extent and in what ways does a programme for transforming pedagogy introduced in CTE and as CPD in primary schools, or a combination of these in Ethiopia improve pupils' ability to reason scientifically?
- To what extent and in what ways does a programme for transforming the pedagogy introduced in Ethiopian CTEs and later in schools improve the teaching in primary schools towards disciplinary dialogical teaching? (Will pre-service teachers who have experienced and been trained in using dialogical teaching in ITE transfer this to their own teaching in schools?)

These research questions are related to the strategies of implementing disciplinary dialogical teaching into physics classroom, and if/how these works. We find it important to focus on changes in classroom practice and teachers' orientation/thinking and not just students' attainment. Improving attainment may have to go through many stages of development before we know more exactly which strategy is best, and to understand these intermediate stages we then have to learn from the changes that happens to practice and orientation. We also have to look at the wider perspective and take into consideration contextual factors.

RESEARCH METHODS AND DESIGN

Based on the study context, the study developed three models of training: the first was an initial training programme (pre-service) to implement argumentation-based dialogical teaching into physics courses in a three-year teacher education programme offered by Colleges of Teacher Education (CTEs) in Ethiopia. This was followed by the second training that introduced dialogic pedagogy through a programme of continuous professional development (in-service) to groups of teachers in schools. A third model arises from a combination of pre-service and in-service. This model provides pre-service and in-service to a cohort of teachers over two years, enabling impact on practice to be carried through from pre- to in-service.

The study used the same design repeated in two phases (CTE phase and school phase). It can be characterised as a quasi-intervention study, i.e. an intervention study, but without random allocation to the experimental and control groups. The present paper presents data from video-recordings of whole lessons in the school phase. These were captured simultaneously using two cameras, one recording the teacher with a fly-microphone, and the other recording the whole class. Each teacher in the treatment group was recorded twice, early and late in the academic year. Several sets of data are collected over two phases to investigate the extent to which the intervention enhanced teachers' pedagogic practice. Following candidates from Phase 1 to Phase 2, and dividing teachers in phase 2 into four groups (i.e. Pre-service, In-service, Combined and Control), allowed us to test the project strategies.

80 video-recorded physics lessons from a sub-sample of 40 teachers were collected and analysed quantitatively and qualitatively to examine the impact on pedagogical practice and physics learning of about 1200 students, including a control group. Data was analysed using NVivo 11 and SPSS. Another set of data came from interviews of each teacher after the lesson to ask about their rationales for and experiences of the teaching. Teachers in the experimental group also kept diaries of their lessons. Table 1 gives an overview of used methods, study samples and analysis.

Table 1. Overview of data collection and analysis in the school phase

Phase	Method	Sample	Analysis Procedure
Schools	Video-recording of whole lesson	N= 40 teachers 80 cross-sectional lessons	Recordings translated, transcribed and coded in NVivo with synchronised text and pictures. Quantitative data analysed using SPSS
	Teacher interviews	40 interviews	Narrative analysis used to identify and explore themes

Analysing the video recordings started with translating and transcribing dialogues into English using NVivo 11. Translation was needed because teaching was carried out in a mixture of English and Amharic. Next, transcripts were coded in the same software for time duration using a framework to identify different types of teaching (e.g. lecturing, working in groups, whole class discussions, teacher introducing lessons, teacher summarising lessons, etc.). The data was used to capture volume, i.e. percentage of lesson time spent within each category. We used NVivo for analysing the distribution and duration of teaching and learning activities based on self-developed framework e.g. how long time on lecturing (Rajab et al, 2018). The framework was designed to capture eight main categories based on a thematic analysis for a sample of 40 lessons. This was later statistically analysed using SPSS. During analysis, examples were extracted to illustrate answers to the research questions. Data was collected from a representative cross-sectional sample from many provinces across Ethiopia.

ANALYSIS AND DISCUSSION

Observational data from phase 2 of the study were analysed quantitatively and qualitatively. More often, treatment lessons show teachers demonstrating the intervention teaching, but teacher might exhibit more traditional teaching when not being observed i.e. the Observer's Paradox (Labov, 1994). Teachers, however, presented teaching material and their plans from all lessons and we did find the observed lessons representative of what most teachers did throughout the academic year. In the observed lessons, the average lesson time in the observed school lessons was 34 minutes. The longest lesson lasted around 50 minutes while the shortest recorded was 15 minutes (Figure 1).

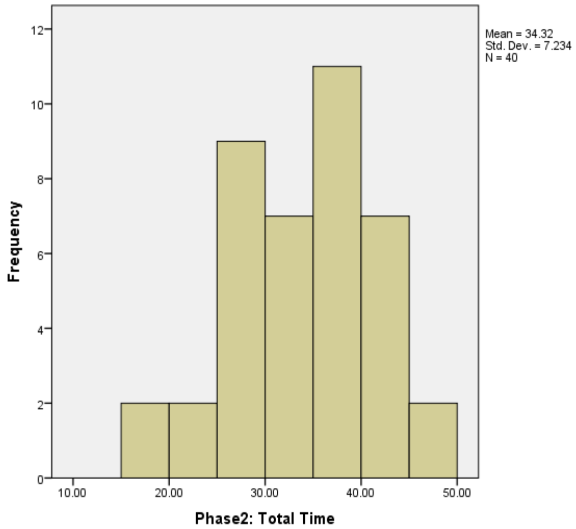

Figure 1. Phase 2: Average lesson time in observed schools

As shown in Table 2, treatment teachers significantly used more whole class dialogue than the control group. Intervention teachers spent more time in whole class discussion, demonstration and summarising student work. They demonstrated higher levels of engagement with the material, the available resources and students. In the control group, however, students spent on average 26% of class time carrying out individual seat-work such as copying the board silently or solving in-class homework. This was reduced to less than 10% in the intervention group. In the intervention group, student-led group work showed a significant increase up to 20% of the lesson time while this took less than 10% in the control group. Students in the intervention group were given more time to talk individually 13% while students' contribution in the control group did not exceed 5%. Lecturing at high levels, however, remains a persistent feature of the observed lessons across the two groups.

Table 2. % Lesson Time Spent on Different Teaching Activities at Schools (Ss: students; S: Student; T: Teacher, Intro: Introduce)

Group		Whole Class Dialogue	Group Work	Ss Seatwork	S Talk Individually	T Revise	T Summarize	T Lecture	T Intro
Control	N	10	10	10	10	10	10	10	10
	Mean	6.9	7.6	18.3	5.3	10.4	35.3	6.3	6.3
	Std. Deviation	6.6	15.6	20.9	8.8	5.5	21.3	3.1	3.1
Treatment	N	30	30	30	30	30	30	30	30
	Mean	13.6	18.7	8.7	5.2	9.3	35.6	5.4	5.4
	Std. Deviation	9.2	19.7	12.1	9.7	7.8	28.02	7.4	7.4
Total	N	40	40	40	40	40	40	40	40
	Mean	11.9	15.9	11.1	5.2	9.6	35.5	5.7	5.7
	Std. Deviation	9.04	19.2	15.1	9.4	7.2	26.2	6.6	6.6

Across the different teaching moves, the intervention group tended to engage students actively in whole class dialogue where scientific reasoning language was increasingly used e,g. how did you get to this answer? Intervention teachers allocated more time for both teacher-led and student-led group work. Students in the intervention group were noticeably afforded more time to express their views/responses while students in the control group spent more time either copying the board silently or solving problems alone. Within the intervention group, teachers showed improvements in balancing the different teaching moves where group work happened at a rate twice of the control teachers. In particular, the majority of intervention teachers managed to keep students engaged, thus avoiding the creation of 'silence pockets' during the course of the lessons. Silence pockets, where teachers chalk the board silently while students copy it, continued to be a major feature in the control group. Also, dialogic teaching, where teachers engage in a true whole class dialogue, was almost none-existing in the control group, but occurred in 11.45% of the time the treatment group as seen in Figure 2. Compared to control teachers, teachers in the treatment group spent more time on summarising tasks and lessons.

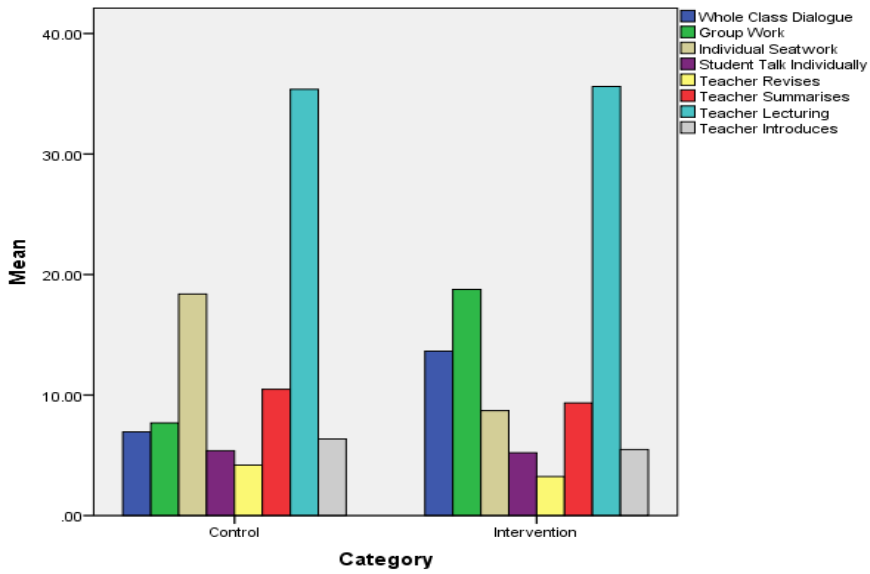

Figure 2. Percent of lesson time spent on different teaching activities at schools

For us, it became apparent that there are considerable changes in the pedagogical practices of intervention teachers as they noticeably reduced lecturing while giving students more space to talk and voice their opinions in the classroom. On the other hand, control teachers continued to use individual seatwork, marked by lengthy chunks of time where teachers were chalking the board silently or assigning tasks for individual problem solving in the classroom. Intervention teachers varied their teaching practices more and had a better balance across the class time.

While intervention teachers' practices changed to become more interactive, lecturing was still dominant across the whole sample as shown in Figures 2 and 3. With the exception of the combined group, lecturing continued to be the highest feature of pre-service and in-service groups. In the combined group, this was replaced with an even balance of teacher and student-led group-work. Even though lecturing (17%) was the third most recurring move in the combined group after group work (35%) and whole class discussion (21%), the control group was dominated by the lecturing at (35%) and individual seatwork (19%). Overall the three intervention groups managed to reduce individual seatwork in favour of diversifying the teaching activities to include granting students more time to express their views (student talk individually) or present their findings in front of the class, or summarising the main points.

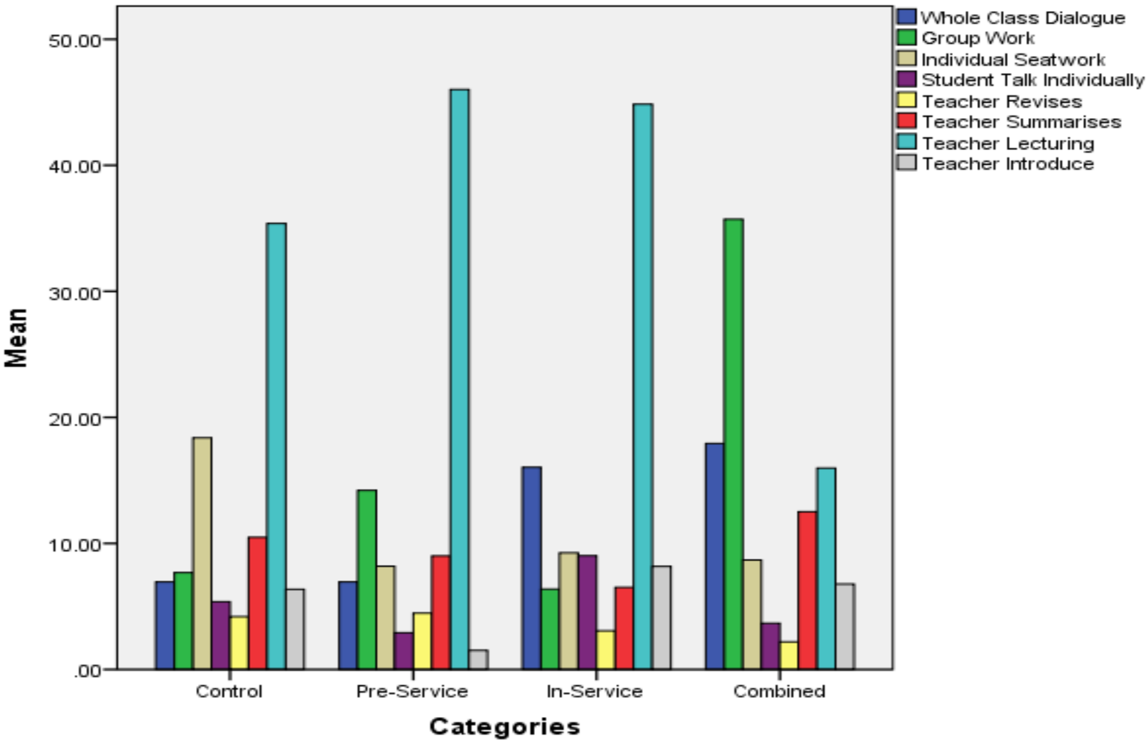

Figure 3. Teaching moves across categories in Phase 2

In discussing the results from Figure 3, it seems that the pedagogical practices of both the combined and in-service teachers were the most dialogic across the group while pre-service and control teachers were close in their use of whole class discussion practices. Individual seatwork was higher in the control group while in-service teachers exceeded other teachers across the whole round in giving individual students to talk more in the form of student presentation.

The video analysis showed a significant contrast between intervention and control teachers. While individual interventions teachers showed significant progress and pedagogical transformative features, the majority of teachers showed little signs of progress. Within the sample, teachers who received pre- and in-service (combined) and teachers who received in-service training were the most interactive and dialogic. In these two groups, teachers used high order reasoning and argumentation questions to probe the student learning process. Students were given the floor to voice out their opinions either individually or in small groups presenting in front of the class.

However, traditional pedagogical practices marked by unbalanced lengthy group work that in some cases occupied more than 65% of the class time prevailed in the control and intervention pre-service teachers. Within these two groups, teachers were not able to move away from the habit of silent chalking on board while students were passively copying the board.

Teachers from the combined group used open and reasoning-seeking questions (e.g. how, agree/disagree). They encouraged students to justify their responses by using why-questions or asking ‘what is your reason?’ In other cases, they asked students to think together by inviting other students to join the discussions. The majority of teacher questions from other groups (pre-service and in-service) continued to be mostly low-level re-call questions, aiming to check student basic understanding and test memorisation skills. The following example (Extract 1) illustrates a combined teacher’s use of good questioning techniques:

Extract 1. Excerpt from Teacher A's using some high-order questioning techniques

1	**T**	Discuss in your 1 to 5 groups. For example if a magnet is cut in two [Teacher is drawing on the board.] Now assume this magnet is cut into 2 parts. Then what will happen? Eve.
2	**T**	**What would you say happen if** a magnet is cut into 2?
3	**S**	[inaudible]
4	**T**	If it is cut north and south are cut, Yulia, do you agree with his assessment?
5	**T**	Do you agree? Badr, Rosa what do you think. Now this is a magnet. And if we cut it into 2 does it attract nails and other materials as it used to before. David what about you guys. Debate on this matter in your groups.

In the extract above, the teacher used a variety of high-order questions such as hypothesis-testing questions 'what would happen if'. He also uses agree/disagree questions encouraging other students to join the discussion. We also found that female teachers showed the most systematic progress with the deepest noticeable pedagogical transformation. The majority of teachers who were interviewed believed that more training would be good to enhance his understanding of dialogic teaching as they acknowledged the importance integrating such discourse in their practices. They believed that dialogic teaching enabled them come up with better questions and encouraged student critical thinking. In order to build on and internalise the pedagogical orientation introduced to intervention teachers, a top-up or refresher training between the two rounds of observation could have showed deeper and more consistent changes.

CONCLUSION

The analysis of the school data raised the main question about which educational strategy was most effective for changing the pedagogy and improving students' learning: training students in CTEs (Pre-Service), doing in-service training (In-Service) or doing both of these combined (Combined). The intervention comprised activities relating to physics concepts taught to 11 – 14-year olds. Data showed that teachers in the combined group presented the most significant changes to practice. Some teachers changed to use more scientific argumentation. Others changed a little and some not at all. There remains a gap between intended and attained curriculum in Ethiopian teacher education. This in turn leads to teachers' poor understanding of the subject matter. Education policy makers need to attend to bridging this gap in order to transform teaching within science subjects within Ethiopian schools.

ACKNOWLEDGEMENT

The TPSS project was kindly funded by an ESRC/ DfID grant from the UK Government.

Professor Per Kind, the original Principal Investigator, passed away on 1 October 2017. His inspiration for and work on the TPSS project is remembered through this publication and in Ethiopia.

REFERENCES

Alemu, M., Alemu, M., Kind, V., Tadesse, M., Michael, K. Kind, P. & Rajab, T. (2019). The knowledge gap between intended and attained curriculum in Ethiopian teacher education: identifying challenges for future development. *Compare: A Journal of Comparative and International Education*

Alexander, R.J. (2018). Developing dialogue: Genesis, process, trial. Research Papers in Education, 33(5), 1-38.
Barmby, P. and Kind, P. and Jones, K. (2008) ’Examining changing attitudes in secondary school science.’,International journal of science education., 30 (8). pp. 1075-1093
Cazden, C. (2001). Classroom discourse: The language of teaching and learning (2nd ed.).
Driver, R., Newton, P., & Osborne, J. (2000). Establishing the norms of scientific argumentation in classrooms. Science Education, 84(3), 287-312.
Duschl, R. A., & Grandy, R. E. (2008). Reconsidering the character and role of inquiry in school science: framing the debates. In R. A. Duschl & R. E. Grandy (Eds.), Teaching Scientific Inquiry: Recommendations for Research and Implementation. Rotterdam, NL: Sense Publisher.
Frost, M., & Little, A. W. (2014). Children’s learning practices in Ethiopia: observations from primary school classes. Oxford Review of Education, 40(1), 91-111.
Horban, G. (2002). Teacher Learning for Educational Change. Buckingham: Open University Press.
Joshi, R. D., and A. Verspoor. 2013. Secondary Education in Ethiopia. Supporting Growth and Transformation. World Bank.
Kind, V. (2017). Development of evidence-based, student-learning-oriented rubrics for pre-service science teachers' pedagogical content knowledge. International Journal of Science Education 41(7): 911-943.
Labov, W. (1972) Sociolinguistic Patterns Oxford: Blackwell
Latour, B. (1987). Science in action. Milton Keynes, England: Open University Press.
Lemke, J. L. (1990). Talking science: Language, learning and values. Norwoord, NJ: Ablex.
Mercer, N., & Hodgkinson, S. (Eds.). (2008). Exploring Talk in School: Sage.
Mercer, N., Dawes, L., Wegerif, R., & Sams, C. (2004). Reasoning as a scientist: Ways of helping children to use language to learn science. British Education Research Journal, 30(3), 359-377.
Michaels, S., O’Connor, C., & Resnick, L. B. (2008). Deliberative discourse idealized and realized: Accountable talk in the classroom and in civic life. Studies in the Philosophy of Education, 27, 283-297.
MOE. (2011). *Educational Statistics, Annual Abstract 2010/11*.
Opfer, V. D., & Pedder, D. (2011). Conceptualizing teacher professional learning. Review of Educational Research, 81(3), 376–407.
Osborne, J., Simon, S., Christodoulou, A., Howell-Richardson, C., & Richardson, K. (2013). Learning to Argue: A Study of Four Schools and Their Attempt to Develop the Use of Argumentation as a Common Instructional Practice and its Impact on Students. Journal of Research in Science Teaching, 50(3), 315-347.
Peirce, C.S. (1934) Collected Papers. Vol. 5 of 8, Pragmatism and Pragmati- cism. Cambridge: Harvard University Press.
Portsmouth, NH: Heinemann.
Venville, G. J., & Dawson, V. M. (2010). The impact of a classroom intervention on grade 10 students’ argumentation skills, informal reasoning, and conceptual understanding of science. Journal of Research in Science Teaching, 47(8), 952-977.
Vygotsky, L. S. (1978). Mind in society: The development of higher psychological processes. Cambridge, MA: Harvard University Press.
Wertsch, J. V. (1991). A sociocultural approach to socially shared cognition. In L. B. Resnick, J. M. Levine, & S. D. Teasley (Eds.), Perspectives on socially shared cognition (p. 85–100). American Psychological Association.

Woldehanna, T., & Gebremedhin, A. (2016). Learning Outcomes of Children Aged 12 in Ethiopia: A Comparison of Two Cohorts. Retrieved from Oxford: www.younglives.org.uk.

ADOPTING KNOWLDEGE BUILDING PEDAGOGY TO SUPPORT EPISTEMIC AGENCY AND COLLABORATVE CONTRIBUTION IN SCIENCE CLASSES: A CASE STUDY IN NEW ZEALAND SCHOOLS

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This paper draws on how secondary science teachers from three schools have helped to develop a Knowledge Building community with their junior classes. The following themes will be discussed:

Theoretical frameworks of Knowledge Building; adopting Knowledge Building as a pedagogy to support epistemic agency and collaborative contribution in science learning; initial findings of the research.

The aim of a Knowledge Building community (KBC) is to produce new ideas and knowledge, which is useful to, and useable by the community (Scardamalia, 2002). There is an emerging prospect for science teachers where teaching programmes could be developed for students to improve knowledge, even to create knowledge not just reproduce it. Knowledge Building has been described as a community process where students are empowered in knowledge creation as legitimate contributors (Lai, 2014). This phase of idea creation and improvement is at the heart of the Knowledge Building pedagogy.

Rather than teaching programmes demonstrating science content and verification, there was opportunity to participate in an inter-school collaborative project, gain critical insight into theoretical understanding about knowledge synthesis, and contribute to the approaches and innovations which have been the key in realising the objectives of the pilot study. A design-based research methodology was employed in the multi-site case of Year 9 (13-14-year-old students) studying science in their first year at secondary school. Qualitative data was collected from teacher interviews and professional learning meetings. Audio taped student recordings in class interactions were integrated into the analysis.

Integrating a Knowledge Building community into a science programme was both challenging and complex, however through the exploration on classroom pedagogy using the 12 KBC principles (Scardamalia & Bereiter, 2010), notable shifts were revealed in the quality of student discourse, informed sense making across curricular links and greater epistemic agency.

Keywords: Collaboration, knowledge building, epistemic agency

Introduction

Knowledge Building is a model developed by Scardamalia and Berieter (2003) to support students to be knowledge creators. Knowledge Building may be defined simply as the creating, testing and improvement of conceptual artefact, it is not confined to education but applies to creative knowledge work of all kinds (Scardamalia, 2002). Educators have long been advocating that young people will not be prepared to face the social, political, economic, health and environmental challenges in today's society and indeed the future (Collins & Halverson, 2010; Facer, 2011; Gilbert, 2005). It is argued that there should be opportunities for students to be able to not only share knowledge but invent new knowledge (Lai, 2014). Moje (2008) contends that students' understanding of how knowledge is created is perhaps as important as knowledge itself. Pellegrino and Hilton (2012) view 21st century skills as knowledge that can be transferred or applied in new situations. This transferable knowledge includes both conceptual knowledge within the explanatory domain of a discipline and also epistemic knowledge of how to apply knowledge in order to construct new knowledge. Where emphasis is placed on creating new solutions, new methods to solve problems rather than applying previously learned actions to solve new problems. Conventional teaching and learning centring on transmissive, routine, and reception of existing knowledge, will no longer be adequate in preparing our students to tackle multifarious and interconnected problems. Future-focussed pedagogies in science education should focus on supporting students to be innovative, explorative, and capable of building knowledge collaboratively as a class community or even further, as a community of classes. Consequently, future science education is charged with the responsibility to devise and develop pedagogies to increase young people's innovative capacity in order to meet the challenges of current times.

The Knowledge Building model

The Knowledge Building model stands out from inquiry learning and problem-based learning practices sometimes seen in science or modern learning environment programmes. On the surface, some of the features are similar to inquiry learning, and teachers can have difficulty in distinguishing between these two approaches. The Knowledge Building model goes further, to support students to go beyond sharing and reproducing knowledge. Lai (2014) maintains that the goal of Knowledge Building is to create new ideas and public knowledge communally. It builds a suite of student perspectives, gathering ideas and questions from all. There is an intentional phase of idea improvement, where students have opportunity to develop and create ideas. In this specific pedagogy, the students are supported to contribute their ideas as a community. A digital space is implemented into the learning and teaching programme to support the developing inquiry, where students post their ideas. Knowledge Forum, Moodle or Padlet web-based software have been designed and modified to support Knowledge Building using a set of scaffolding tools. Students can show their classmates their science inquiry over the entire course of lessons and to disclose new ideas created as they proceed in the topic. There is also opportunity for Knowledge Building classes from different schools to work on the same science inquiry, and potentially, whole school involvement to be developed across curriculum areas.

Young people as knowledge creators

Knowledge Building is a pedagogical model described by 12 principles (see appendix) developed by Scardamalia and Bereiter (2010). One of those clearly illustrates that ideas are improvable, able to be improved, and the setting is for young people to have the opportunity to perform this improvement practise as a community, rather than as individuals. Students take control of the inquiry, they are given autonomy to set, plan, have goals, engage in creating further questions and responses. It allows students to take over a significant portion of the responsibility for their own learning including planning, execution and evaluation. Another hallmark of the Knowledge Building model is that it makes an important distinction between learning and knowledge creation. For Bereiter and Scardamalia (2010), Knowledge Building is a means for students to create and develop communal ideas, however, it will also deepen individual understanding of content knowledge and help students become self-directed learners. Learning is seen as a personal, internal, cognitive process of knowledge representation for individuals, whereas Knowledge Building is an external progression of producing ideas, and where students collectively create and improve ideas, ideas are being treated as external, public artefacts (Lai, 2014). Gilbert (2017) reinforces the case that young people can be knowledge creators. She signals Knowledge Building does not focus on how disciplinary knowledge is constructed by experts, nor is it personal construction of content knowledge. Conversely, it provides a sense of autonomy for students to operate in a space between those concepts of personal construction and disciplinary knowledge.

Future-oriented capacities

An intention of future-oriented science education is developing knowledge with learners which considers implications for a human and potentially non-human society (Kurzweil, 2005). Scientific and future technologies come packaged with a variety of moral, political, ethical and indeed practical decisions. Future oriented examples could include: artificial intelligence, natural disaster relief, space travel, human genetic modification, synthetic life, nuclear fusion and renewable energies. Hodson (2010) urges the value of explicitly featuring socio-political contexts in science teaching programmes. Consecutively if current social and environmental problems are to be solved, there is necessity of future generations of scientifically and ethically literate citizens. As science teachers we can place prominence on using topics of personal and societal issues. This takes a much more future-oriented direction to help foster learner capabilities of personal construction using these topics of interest. My viewpoint, is that personal knowledge of socio-political contexts is an active, participatory practice, where learners construct ideas together, where they can make sense of different viewpoints, grapple with conflicting arguments and justify them. The Knowledge Building model develops these specific learner capacities of manipulating knowledge, and working collectively to create and improve ideas. The other important aspect of a future oriented capacity is for students to be encouraged to be responsible for other student's science learning. The Knowledge Building model does this specifically in terms of all student viewpoints are considered through community. Students can take roles in the inquiries, working in teams in the class with specific duties such as technician, researcher and director. They can support each other in the way they learn, using these roles.

Knowledge Building supports epistemic agency

A purpose of studying science defended in the New Zealand Curriculum (Ministry of Education, 2007), is for students "to use their current scientific knowledge and skills for problem solving and developing further knowledge" (MOE, 2007, p.28). Students determining what information is valid and reliable is a necessary part of becoming informed. Authentic scientific inquiry depends on making decisions about whether information is justifiable and posing questions to establish its validity (Barker, 2011). Students could use questions such as: How could we critique this evidence? How could we redesign this investigation to ensure we have not overlooked any issues that may compromise our findings? Scardamalia and Bereiter (2014) argue that Knowledge Building actively supports learners to have agency or the capacity to act and make decisions about knowledge. The concept of epistemic agency is where students have responsibility for the knowledge that they are investigating. This learner capacity to have awareness of and to have insight into the development of knowledge appears to be critical in both Nature of Science (Lederman & Lederman, 2004) and Building Knowledge ideologies.

What did Knowledge Building look like in the science classes?

Knowledge Building involves students using an inquiry progression of scaffolding and building ideas together as a class community (Scardamalia & Bereiter, 2010). This particular Knowledge Building community model developed by Lai (2014) required specific pedagogy that supported movement between analogue and digital experiences. In the early phase of the project students were encouraged to take on the role of knowledge creators, this was carefully discussed and integrated into the lessons by the teachers. Following this, students had experiences of real face to face practical inquiries, integrated with a set of digital affordances or possibilities offered by digital tools such as software programmes: Padlet, Moodle and Knowledge Forum. Prominence was placed on sharing questions and ideas collectively, using digital software. They drew on their experiences and were given opportunity through the digital mechanism to be able to communicate these. Initially the preliminary investigation inquiry involved a start-up question and associated background information, posed by the teacher or student, to evoke interest in a topic. The virtual discussion space was called a "view", and "notes" were posted by the students in the class, to develop a collective noticeboard which displayed the posted notes to all classmates. With support from the teacher students arranged the posted notes into themes, they refuted claims and acknowledged ideas from their peers. The view page simultaneously captured the questions and these were displayed from all members of the class. There was opportunity for small teams of students to collaborate together and consider specific sub-topics, developing side investigations to enable to respond to questions which they have been identified as significant. Other stages of the Knowledge Forum/Padlet/Moodle process were where students posed their own theories, they made notes, identified what they needed to understand, and had the opportunity using the digital medium to improve on the knowledge. Stages were communicated and viewed on specific pages of the software used. At these stages, students read literature; constructed real models with cardboard and paper; searched the internet for information; consulted their teacher/s; discussed their ideas with community experts; and conducted practical tasks. Students used the thinking prompts available or developed their own to support theory building or progressive problem solving.

Initial findings

The participating teachers in this pilot study identified six enablers that supported integration of a Knowledge Building community in their science class. These were signalled through a series of teacher interviews after the Knowledge Building programme was implemented, and from a final discourse where an agreed summary took place. First, teachers must have a good understanding of the Knowledge Building principles and know how to communicate these principles to their students. Without a good ***understanding*** of the Knowledge Building principles, teachers may use this approach just as a form of inquiry learning. Following discussions with the teachers-all commented that it was challenging process and it cannot be accomplished in a short time. The second was to encourage regular focussed episodes of ***evaluation*** where the students (working in small teams) would present to the class in a more formal manner what their current findings were. This was duration of a 30-45-minute progress meeting, usually each week, depending on class and teacher. Teachers noted that the students used this regular event to convey current ideas and questions; to discuss their digital view page; to develop their confidence in speaking to the class using the digital view page; to reflect on how they worked as a group; to use scientific language in the forum; and to hear alternative views on a topic. The students justified their opinions and discussed new questions that had arisen in their study. Students also noted the evaluation meetings as an important opportunity to talk about group dynamics, to call for any changes to the makeup of the teams. Third was ensuring that students had a clear understanding of topic purpose, that there was ***clarity*** around the learning context. Topic examples are as follows: How good is New Zealand's recycling program? Future space travel; and Keeping ourselves safe in a tsunami. Students had viewed for example, the introductory You-Tube clips and read the associated resources such as an introductory information pack that described the context and/or scenario. Teachers said it was important that students were acutely aware of the quality of posting onto the digital platform, and this meant time in class to develop the posts. Occasionally some students could be absent for a lesson or two, hence on return to class, they required an update from their working group. Fourth, that even though the classes had been divided up into small teams of two-three students, each team contributed to the class (see Appendix points 1 and 2) and there was responsibility to ensure all ideas were aired. Hence there was teacher expectation of a ***community of learners*** working together. Examples of this emphasis include: posters up in the room which stated expectations; PowerPoint slides discussing group roles; information packs which had guidelines about working as a team and as a class. Fourthly, each team had the responsibility of generating new questions, taking photos of their investigations, collecting ideas from each team member and writing up new ideas to show evidence that Knowledge Building progress was being made. This was logged into a ***knowledge portfolio***, one class used clear files for this purpose and the other two used digital software: Google classroom and Padlet. The knowledge portfolio showed evidence of ideas being shared. This resource had notes, reflections and the "digital views" from each group. Responsibility of regular updates was shared amongst the group members and this was a resource that the teacher took into consideration in terms of overall group progress. Finally, the teachers spoke fervently about the need to design a topic that had an ***open-ended*** context to it, this took time to prepare and plan for but the effort was rewarded by overall positive student engagement. It meant that some knowledge and investigations were highlighted as essential but teachers stressed the importance of encouraging diverging inquiries from the main context of the topic, where autonomy was apparent and that there was opportunity for students to pursue their own personal questions.

Conclusion

This pilot project confirmed that Knowledge Building communities could be developed in junior science classes through improved teacher understanding of the 12 principles. Integrating a Knowledge Building community into a science programme was a challenging shift in practice, however through the teacher's own exploration on classroom pedagogy using the 12 principles, this could develop and be a very practicable model to support future science learning at Year 9. Six enablers were identified by the teachers, and valid points have been made about the differences between inquiry learning and Knowledge Building; epistemic agency and collaborative contribution. The realisation this research has seen, means placing more faith and confidence in learners to help create knowledge within their class communities using carefully constructed classroom strategies and the use of a digital forum. This research also signals how classes integrating Knowledge Building can influence pedagogical teacher change. It is an area of science education that has opportunity for further investigation.

ACKNOWLEDGEMENT

The study acknowledges the support of the teachers and students who have made this project possible. It has been a partnership between the University of Waikato and three secondary schools in the Bay of Plenty region in New Zealand. Dr Simon Taylor is a lecturer and secondary graduate programme co-ordinator, Te Hononga School of Curriculum and Pedagogy, Faculty of Education, University of Waikato. E-mail: simont@waikato.ac.nz

Appendix

Scardamalia (2002) identifies twelve principles of Knowledge Building as follows:

1. Real ideas and authentic problems. In the classroom as a Knowledge Building community, learners are concerned with understanding, based on their real problems and observations in the real world.
2. Community knowledge, collective responsibility. Students' contribution to improving their collective knowledge in the classroom is the primary purpose of the Knowledge Building classroom.
3. Improvable ideas. Students' ideas are regarded as improvable objects.
4. Idea diversity. In the classroom, the diversity of ideas raised by students is necessary.
5. Rise above. Through a sustained improvement of ideas and understanding, students create higher level concepts.
6. Epistemic agency. Students themselves find their way in order to advance.
7. Democratizing knowledge. All individuals are invited to contribute to the knowledge advancement in the classroom.
8. Symmetric knowledge advancement. A goal for Knowledge building communities is to have individuals and organizations actively working to provide a reciprocal advance of their knowledge.
9. Pervasive Knowledge Building. Students contribute to collective Knowledge Building.
10. Constructive uses of authoritative sources. All members, including the teacher, sustain inquiry as a natural approach to support their understanding.
11. Knowledge Building discourse. Students are engaged in discourse to share with each other, and to improve the knowledge advancement in the classroom.
12. Concurrent, embedded, and transformative assessment. Students take a global view of their understanding, then decide how to approach their assessments. They create and engage in assessments in a variety of ways.

REFERENCES

Barker, M. (2011). Nature of Science and the New Zealand Curriculum: Fourteen underpinning ideas. *New Zealand Science Teacher* 126:33-37.

Collins, A. & Halverson, R. (2010). The second educational revolution: rethinking education in the age of technology. *Journal of Computer Assisted Learning. 26* (1),18-27.

Facer, K. (2011). *Learning futures: Education, technology and social change*. Oxford, UK: Routledge.

Gilbert, J. (2005). *Catching the Knowledge Wave? The Knowledge Society and the future of education.* Wellington: NZCER Press.

Gilbert, J. (2017). Untangling constructivism, knowledge, and knowledge-building for "future-oriented" teaching. Set: 2,1-7. *Research Information for Teachers.* http://doi.org/10.18296/set.0095.

Hodson, D. (2010). Time for action: Science education for an alternative future. *International Journal of Science Education, 25* (6), 645-670.

Kurzweil, R. (2005). *The singularity is near*. New York: Viking.

Lai, K. W. (2013). Knowledge building with senior secondary students: A New Zealand study. In N. Reynolds & M. Webb (Eds.), *Learning while we are connected* (pp.1-10). Torun, Poland: IFIP.

Lai, K.W. (2014). Transforming New Zealand schools as knowledge-building communities. From theory to practice. Set:1, 33-41. *Research Information for Teachers.*

Lederman, G., & Lederman, J. (2004). Revising instruction to teach about the nature of science. *The Science Teacher, 71*(9), 36-39.

Ministry of Education. (2007). *The New Zealand curriculum.* Wellington: Learning Media.

Moje, E. B. (2008). Foregrounding the disciplines in secondary literacy teaching and learning: A call for change. *Journal of Adolescent and Adult Literacy, 52* (2), 96-107.

Pellegrino, J., & Hilton, M. L. (2012). (Eds.). *Education for Life and Work: Developing Transferable Knowledge and Skills in the 21st Century*. Washington, DC: The National Academies Press.

Scardamalia, M. (2002). Collective cognitive responsibility for the advancement of knowledge. In B. Smith (Ed.), *Liberal education in a knowledge society* (pp.67-98). Chicago: Open Court.

Scardamalia, M., & Bereiter, C. (2003). Knowledge building. In J.W. Guthrie (Ed.) Encyclopaedia of education (pp.1370-1373). New York: Macmillan Reference.

Scardamalia, M., & Bereiter, C. (2010). A brief history of knowledge building. *Canadian Journal of Learning and Technology, 37(1).* Retrieved from https://www.cjlt.ca/index.php/cjlt/article/view/26367

GREEK SCIENCE TEACHERS' TPACK EXPRESSION FOLLOWING PROFESSIONAL DEVELOPMENT

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In the present study it was attempted to inquire science teachers' practices after being trained by Greek B' level professional development program concerning ICT integration. Class observations and respective interviews were used as research tools and were set in correspondence with TPACK model. Our goal is to present the outcomes of B' level and inquire the implementation of virtual labs and applets by trained science teachers and the context where this implementation occurs. The data analysis showed that science teachers have understood the use of these tools and actually implement them while recognizing their advantages. Moreover, they prefer that this implementation takes place in inquiry based teaching, following a teaching scenario.

Keywords: Professional development, TPACK

INTRODUCTION

Contemporary professional development programs (PDP) in ICT integration focus in the pedagogical exploitation and integration of ICT in classroom teaching since several studies have shown that effective teacher preparation is an important factor for successful ICT integration in education. (e.g. Giovannini et al 2010).

In Greece, since 2006, science teachers (among other teachers) are being trained by a multi-year and nation-wide professional development program (PDP) called B' level, concerning ICT integration in class provided by face to face or hybrid forms (B' level, 2010, Psillos & Paraskevas, 2017). Similarly to other PD programs (Voogt, Tilva & van den Akker, 2009, Shin et al, 2009, Hong & Stonier, 2014), the content and structure of B' level for science teachers is based on the well known TPACK model which provides for an integrated framework of professional knowledge which teachers have or should develop for effective ICT classroom integration. According to this model the interaction of Technology, Pedagogy and Content factors is a complex process related to synthetic forms of professional knowledge. TPACK is a powerful model used not only as a heuristic for course development but also for research aiming at investigating teachers' practices and implications of PD programs (Chai, Koh & Tsai, 2010).

Voogt, Tilya and Van den Accer (2009) in their research, intended to determine –with class observations- the extent to which trained science teachers were able to practice what they learned during their PDP about the integration of Microcomputer Based Laboratories (MBL) in inquiry based teaching. They, actually, concluded that trained teachers were able to create a classroom environment based on guided inquiry integrating MBL (ICT) which was appreciated by their students as more investigative. In another research, Shin et al (2009) aimed at examining –with class observations too- how teachers (trained by a PDP where they had to work on a range of assignments that required them to learn and use ICT in multiple pedagogical contexts) understood and showed in practice the interaction between technology, content and pedagogy. They find out that teachers gained a deeper understanding of how technology related to other aspects of teaching and they observed changes in teachers' knowledge, noting that this knowledge can have an effect on their practices. Similarly, Hong and Stonier (2014) in their study on whether TPACK understanding helps teachers –trained by a PDP which had as a goal to educate teachers on how to effectively integrate GIS technologies in their teaching by providing technological, pedagogical and content knowledge- integrate ICT, came to the conclusion that teachers integrated GIS in their teaching and this TPACK- based PDP was largely successful at helping them proceed.

In Greece, the content and structure of B' level program for science teachers which is based on TPACK, include: knowledge and applications of pedagogic approaches (mainly inquiry), familiarization and use of contemporary software (such as simulations, virtual labs and web based tools) and their added value (Psillos & Paraskevas, 2014), knowledge and skills about designing activities, worksheets and teaching scenarios integrating ICT.

This research is part of a multi level research program aiming at studying secondary science teachers' perceptions and expression in practice of their TPACK following their attention of B' Level PDP. The present study focuses on the "face to face" form which includes 96 hours of courses (for the General Pedagogical part and for the Specialization in Teaching Science ICT part), 24 hours of preparation and reflection practice and 24 hours of actual teaching (Samanta & Psillos 2015).

In our previous studies detailed elsewhere we used large scale questionnaires and in-depth interviews (Samanta & Psillos, 2015). In the present study, we report results of classroom observations and of the respective interviews, aiming at revealing the expression of teachers' TPACK in science teaching after attending the B level PDP.

METHOD

18 science teachers who had participated in B' level PDP agreed to have their teaching using ICT observed. Class observations were held in different schools during one didactic hour. Class observations were carried out using a special record tool- rubric that was designed according to TPACK model and after analyzing other similar rubrics. We decided to proceed to the linking of parameters observed to TPACK model according to Joyce, Weil & Calhoun (2011). The rubric was piloted and the feedback was taken into account. It was sent to a panel of TPACK experts (3 phd teachers and 2 school consultants) who evaluated the linking between the parameters and TPACK model. A special rubric was developed as well in order to be used during the respective semi-structured interviews. The interview questions were linked to TPACK, similarly to Jimoyiannis (2010) linking. For example, when asking if a science teacher was familiarized to virtual lab interface, the research aimed at revealing science teachers' TK but when asking why this virtual lab was used in this context in class, the research aimed at revealing the interaction between all TPACK's components. It is important to note that, following B' level's policy, the term TPACK wasn't mentioned to the participants so as not to

cause any agitation. After the completion of the observations and the interviews, the two rubrics filled for each participant were merged into one so as to gain an overall image of every teacher's practices. The 2 researchers discussed about the data, analyzed them and the linking between what teachers did (observation data) and what they think they did (interview data) and TPACK model emerged.

In order to better understand the research data and results, we must note that B' level focuses on promoting ICT integration to teachers who were taught and keep teaching in traditional way, who have limited access to equipment (usually 1 pc and projector per class and occasionally laboratories) and who have to follow a very stipulated curriculum. It is important to check and discuss the outcomes of B; level professional development program in such context and under specific limitations.

RESULTS

The observation and interview results were categorized according to TPACK's components which were merged for the sake of brevity (PK with PCK and TK with TCK).

Participants' technological and technological content knowledge (TK & TCK)

It was observed that the majority of science teachers employed virtual labs, simulations and applets which were taught to them during B' level and exist in national data bases. Few of them, in their interviews, mentioned that had searched the web for different applets and simulations suitable for their teaching and this was confirmed in our observation. They were familiar with virtual lab's and simulations' interface and certain affordances showing evidence of Technological Knowledge (TK). However, they did not fully exploit the affordances of these tools and this was confirmed in their interviews. They also admitted not being fully informed about all virtual labs potentialities and that every time they were occupied with them, they were finding new potentialities. So, they expressed the need to dedicate a lot of time, in order to get more familiarized showing evidence of evolving Technological Content Knowledge (TCK) based on B' level instruction. A trainee noted: *"I often use the virtual lab in class but for this, I spend a lot of my spare time searching for its features. I think I'm in the middle of the road and need to keep working and working…"*.

Participants' pedagogical and pedagogical content knowledge (PK & PCK)

Regarding the teaching approaches (pedagogical component- PK), almost all science teachers promoted group work to their students. We must note that teaching took place in science labs where there was only one pc and one projector. It is worth mentioning that the students participated in interactive presentations and manipulated software alternately due to equipment limitation. In their interviews, teachers expressed their preference to less traditional teaching, although they admitted keeping traditional elements. A trainee characteristically mentioned: *"It needs a lot of effort to change something so deep. I was taught traditionally and keep teaching this way but I try to reduce it. I think someday I will manage to do so."*

Most teachers, while interviewed, considered that their teaching is characterised by a high degree of freedom. Observations showed that they mainly applied guided inquiry teaching. Moreover, they stood up for inquiry based teaching, claiming that they believe it's suitable so as to reach the expected cognitive goals, expressing this way their pedagogical content knowledge (PCK) and mentioned having as a goal to find the way to apply inquiry to their teaching more often. They also expressed the need to be more trained about inquiry by PDP.

Participants' technological pedagogical content knowledge (TPACK)

The inquiry based teaching was linked by the interviewees to ICT integration. We must note that they mentioned using ICT in class in an inquiry based context in few occasions in a month due to equipment or time limitations. Except one teacher who kept his traditional habits, all the rest promoted inquiry and the majority gave their students a worksheet that was part of a teaching scenario with inquiry elements. All worksheets let their students observe, wonder, estimate and conclude. Thus, teachers found the way to express the interactions between all TPACK's components. Notably, they didn't find it necessary to depict this interaction in a written scenario as only some teachers had one, while the rest mentioned not having one by choice, even though they created a scenario data base during B' level. They noted that it makes them feel restricted and less free to change their teaching based on their students' needs.

CONCLUSIONS – SUGGESTIONS

One limitation of this study is that participants were observed only one time given the restrictions of schools' time table and comprised a convenient sample among the trained teachers due to difficulties in reaching classrooms employing ICT. Within such limitations, it seems that teachers are in a transitional phase, where B' level PDP helps them not only to increase their ICT integration but to evolve their teaching of science. Greek science teachers often use traditional teaching but prefer a well-designed "activity" idea –in an inquiry based teaching context- that encourages learning as a process linked to the curriculum context, which they employ occasionally, similarly to Voogt et al (2009). These results were relevant to the results of our previous research that showed that teachers' preference towards traditional methods has decreased and the preference towards the inquiry based has also increased (Samanta & Psillos 2015). Such a conclusion is an indication of considerable teachers' evolution since previous studies in Greece (Demetriadis et al, 2003) and in Russia (Nikolaev & Chugunov, 2012) showed that trained teachers had the tendency to adjust ICT to support traditional teaching but, in our present research, teachers made serious attempts in changing their traditional teaching. It is worth mentioning that the teachers admitted having hard time overcoming traditional methods. Besides, it is noticeable that, within external limitations, due to limited resources, the teachers of the sample employed interactive presentations in order to promote students' engagement showing flexible adaptation of pedagogical knowledge (PK).

Observation showed that the level of ICT integration via activities, worksheets and scenarios was impressively raised by the trained teachers who had planned integration of ICT in their teaching and they used activity worksheets. Yet, they preferred not to have a written scenario, although they were trained to develop them. One explanation is that written scenarios are time consuming and restrictive as mentioned in Samanta and Psillos (2018). This is something to be further searched. Such evidence show expression of aspects of TPACK but also limitations. Similarly, Drossel, Eickelmann and Gerick (2016) mentioned that more than half teachers interviewed (from Germany, Poland, Netherlands, Denmark and Australia) find that there is no time for preparing ICT infused lessons and Hong & Stonier (2014) suggested providing premade lessons due to lack of time.

Listening to the science teachers and their needs, we suggest that the upcoming B' level programs promote more clearly inquiry based teaching and give science teachers the fundamentals to apply inquiry. Moreover, teachers who have been trained need to have continuous support by the PDP because tools and pedagogical ideas are evolving and teachers' knowledge should be up to date. More class observations are in progress in order to compare the everyday practices of teachers trained in previews B' level programs and the practices of newly trained by B' level teachers.

ACKNOWLEDGEMENT

Supported by "Study of the development aspects of scientific literacy learners in formal and informal education conditions using online virtual labs and use of geographical data", funded by the sectoral operational programme Competitiveness, Entrepreneurship and Innovation 2014-2020 under the Partnership and Cooperation Agreement (NSRF) for the period 2014-2020.

REFERENCES

B level. (2010). *The project "In Service Training for the utilization and application of ICT in the teaching practice" of the Operational Program "Lifelong Learning",* NSRF (2007-2013), co-financed by Greece and the European Union (European Social Fund). (in Greek).

Chai, C. S., Koh, J. H. L., & Tsai, C. (2010). Facilitating Pre-service Teachers' Development of Technological, Pedagogical, and Content Knowledge (TPACK). *Educational Technology & Society*, *13*(4), 63–73.

Demetriadis, S., Barbas, A., Molohides, A., Palaigeorgiou, G., Psillos, D., Vlahavas, I., Tsoukalas, I. & Pombortsis, A. (2003) Cultures in Negotiation: Teachers' Acceptance/Resistance Attitudes Considering the Infusion of Technology into Schools, *Computers & Education*, vol 41, pp 19-37

Drossel, K., Eickelmann, B. & Gerick, J. (2016) Predictors of teachers' use of ICT in school- the relevance of school characteristics, teachers' attitudes and teacher collaboration. *Educ Inf Technol* vol 22. pp 551-573

Giovannini, M., Hunya, M., Lakkala, M., Moebius, S., Raymond, C., Simonnot, B. & Traina, I. (2010). Fostering the Use of ICT in Pedagogical Practices in Science Education. *elearning Papers*, 20, ISSN 1887-1542.

Hong, G. & Stonier, F. (2014). GIS In- Service Teacher Training Based on TPACK, *Journal of Geography* vol 114:3, pp 108-117

Jimoyiannis, A. (2010). Designing and implementing an integrated technological pedagogical science knowledge framework for science teachers professional development. *Computers & Education* vol 55, pp1259-1269

Joyce, B., Weil, M., Calhoun, E., (2011). Models of Teaching, 8th edition, Pearson, Prentice Hall.

Nikolaev, D. & Chugunov, D. (2012). *The education system in the Russian Federation: Education Bried.* World Bank Study, Washington DC

Psillos, D. & Paraskevas, A. (2014) Teachers' beliefs about TPACK. Case study of science teachers. *Proceedings of 9th Pan- Hellenic Congress with international participation*, Rethimnon, Greece

Psillos, D. & Paraskevas, A. (2017) Teachers' Views about of Technological Pedagogical Content Knowledge (TPACK): The Case of Compulsory Education Science in-service Teachers. *Research on e-Learning and ICT in Education,* pp231-240

Samanta, A. & Psillos D. (2015). Perspectives of science teachers' beliefs and practices after B' level in- service training program, *Proceedings of 9th Pan- Hellenic Conference for Science Education and ICT integration in education*, Thessaloniki, Greece (in Greek)

Samanta, A. & Psillos D. (2018). Science teachers' practices following professional development. *TechEdu International Conference on Technology and Innovation in Learning, Teaching and Education*, Thessaloniki, Greece, Springer

Shin, T., Koehler, M., Mishra, P., Schmidt, D., Baram, E. & Thompson, A. (2009) Changing Technological Pedagogical Content Knowledge (TPACK) through Course Experiences. Available from Pynya Mishra. Retrieved on: 6 March 2016

Voogt, J., Tilya, F., & van den Akker, J. (2009). Science teacher learning of MBL-supported student-centered science education in the context of secondary education in Tanzania. *Journal of Science Education and Technology*, 18, 429–438.

USING PRACTICAL WORK EFFECTIVELY IN THE SCHOOL SCIENCE LABORATORY: A TEACHER TRAINING PROGRAMME BASED ON THE LEARNING COMMUNITY APPROACH

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This study describes the design and implementation of an in-service teacher training programme for high school teachers aimed at improving their competence in the use of the laboratory for physics education. A framework for designing the programme was constructed based on PER literature, containing the following features: linking content, practice and research; action research; focus on teachers' beliefs; sufficient duration; and the learning community approach. The intervention aligns with recent international recommendations, and in particular with the need of providing teachers with meaningful, research-based professional development on inquiry teaching and opportunities to work collaboratively. Data for the evaluation of the programme were obtained using multiple instruments. The results suggest that all the identified features were effective, with action research and the learning community approach being decisive for promoting real change.

Keywords: Communities of Practice, In-service Teacher Training, Practical Work in Science

INTRODUCTION

In recent years, a renewed attention to the role of the laboratory in science education has been acknowledged not only by research (Hofstein & Lunetta, 2004; Rundgren, 2018) but also by several international reports and standards. A milestone was the document known as 'Rocard report' (Rocard et al., 2007), that called for "A reversal of school science-teaching pedagogy from mainly deductive to inquiry-based methods" (p. 2). The National Research Council clarified the meaning of inquiry teaching by identifying eight 'scientific practices' that should be developed in the classroom together with disciplinary core ideas and crosscutting concepts (National Research Council [NRC], 2012), and, more recently, the National Academies of Science, Engineering, and Medicine recommended that 'investigation should be the central approach for teaching and learning science' (National Academies of Science, Engineering, and Medicine, 2019, p. 5).

Despite the emphasis placed on inquiry education, the term 'inquiry' is often misunderstood and confused with simply proposing 'hands-on' activities (Crawford, 2014; Osborne, 2014). In contrast, effectiveness in the use of laboratory activities is only achieved if they are well-designed, their purpose is clear, and they are embedded in a carefully planned teaching-learning sequence (Abrahams & Millar, 2008; Millar, 2010; NRC, 2006). The situation is complicated by issues such as the inadequacy of laboratory facilities, classroom organisation, and the need to comply with national standards (Nivalainen, Asikainen, Sormunen, & Hirvonen, 2010).

This situation calls for a reflection about teacher training. Many teachers have had little personal experience in the lab in their education and pre-service training (Yalcin-Celik, Kadayifci, Uner, & Turan-Oluk, 2017) and, on the other hand, few in-service teacher training programmes address the problem specifically using the results of research in physics education (NRC, 2006). For these reasons, actions should be taken in order to provide teachers 'with appropriate instructional resources, opportunities to engage in sustained professional learning experiences and work collaboratively to design learning sequences, choose phenomena with contexts relevant to their students, and time to engage in and learn about inclusive pedagogies to promote equitable participation in science investigation' (National Academies of Science, Engineering, and Medicine, 2019, p.6).

In the light of these considerations, this study aims to provide insights into the following research question: *What features should an in-service teacher training programme have in order to promote an effective use of the school science laboratory, and which of these features are most effective?*

THEORETICAL BACKGROUND

A meaningful model for successful teacher training was proposed by Adey, Hewitt, Hewitt, and Landau (2004), who identified the following characteristics: theoretical justification (research-based); high quality (sufficient duration, coherent methodology, intense/engaging activities, tutoring for implementation); support by the school management; and sharing with colleagues. However, according to many accounts, teacher training courses are often short and factual in nature, which is unlikely to promote real and long-lasting change (Gilbert, 2010; NRC, 2006).

Desimone (2009) identified five 'core features' for effective teacher training, based on the results reported in previous literature: content focus; opportunities for teachers to engage in active learning; coherence between teacher learning and their knowledge and beliefs; sufficient duration; collective participation. In a comparative study, Capps, Crawford, and Constas (2012) investigated the effectiveness of the above-mentioned features in the context of professional development (PD) on inquiry, considering 17 PD programmes. Their results show a general alignment with these features, but also suggested a need of additional research into PD programmes on inquiry, in order to identify which features are more effective in this context.

In recent times, the topic of collective participation has been emphasized and expanded by focussing on teachers' collaboration. Some benefits of teacher collaboration are improved instructional practices, improved student learning, and a better breeding ground for innovation (Vangrieken, Dochy, Raes, & Kyndt, 2015). A structured, bottom-up approach to teacher collaboration are *learning communities*, or communities of practice (Wenger, 1998; Vangrieken, Meredith, Packer, & Kindt, 2017). Even in the context of science education, research suggests that learning communities can promote authentic innovation (Couso, 2008), and a number of teacher training programmes have been developed according to a learning community paradigm (Singer, Lotter, Feller, & Gates, 2011; Lotter, Yow, & Peters, 2014).

Another aspect that has received attention recently is action research (Gilbert, 2010; Laudonia, Mamlok-Naaman, Abels, & Eilks, 2017). Teachers engaging in action research identify a problem relevant to their context, formulate a research question, select the data they need to answer it, design and implement some actions, evaluate their results and draw conclusions in order to identify new research questions. Action research is particularly effective when practitioners are supported by experts who put them in contact with research results, provide coaching and feedback, and offer emotional support (Gilbert, 2010). A positive intercorrelation between action research and the learning community approach has been suggested (LINPILCARE project; Mamlok-Naaman, 2018).

RESEARCH DESIGN AND METHODOLOGY

Based on the background described above, we outlined a revised framework for our teacher training programme. Specifically, we identified five core features, the effectiveness of which was the core of our research question and was investigated using multiple methods and perspectives as described below. Based on the revised framework, we designed a programme, named 'CoLLABORA – a Community of Learners on LABORAtory work', which was implemented between May 2018 and June 2019.

Revised framework

Developing on Desimone's 'core features' we identified a revised set of five 'core features'.

Linking content, practice and research. Laboratory activities was contextualised into the topic 'waves and their applications', one of the core ideas of physics education (NRC, 2012). We proposed and discussed research-based activities and participants had the opportunity to design their own activities. We also discussed the purpose of laboratory activities into a teaching-learning sequence, the construction of effective laboratory worksheets, some issues related to assessment, and specific disciplinary and didactical issues about the topic.

Action research. Each participant designed his/her own action research project to be applied in their classroom. Two sessions at the beginning of the course were devoted to formulating an investigable research question and writing an action research plan. Opportunities from feedback and coaching were given throughout the course.

Focus on teachers' beliefs. We focussed on *self-efficacy beliefs*, i.e. context-dependent judgments about being able to perform a particular task and obtaining the desired outcomes (Bandura, 1986). Teachers who have a high sense of efficacy are more likely to teach effectively (Tschannen-Moran, Hoy & Hoy, 1998; Crawford, 2007; Lotter et al., 2018; Chicherkian, 2016). During the programme we monitored these beliefs using specific instruments.

Sufficient duration. The programme featured 45 hours of contact time over one year.

Learning community. We set up the group as a learning community, sharing expectations, goals, rules, and style. Participation of teachers from the same school was encouraged.

Methods

In order to gain information from multiple perspectives, we used a variety of instruments:

Individual questionnaires. An individual questionnaire was delivered at the beginning and at the end of the programme. The initial questionnaire investigated the participants' background, their use of the laboratory, the presence and characteristics of their school laboratory, their expectations about the programme and their knowledge of the learning community approach. The final questionnaire investigated if and how the participants' use of the laboratory had changed during the course, in which dimensions (physics content, use of practical work, etc.) they thought they had improved the most, what activities they had found more useful, the extent to which the learning community was helpful, and how much the course met their expectations.

Focussed group interview. At the end of the programme, a semi-structured focussed group interview was led, containing five questions: (1) What were the advantages of discussing laboratory practices within a specific disciplinary content? How did research results contribute to enhance the discussion about the use of the laboratory? (2) To what extent, and how, engaging in action-research was useful in order to enhance the use of the laboratory at school? (3) To what extent are self-efficacy beliefs relevant in enhancing the use of the laboratory? (4) To what extent was the course structure (duration, meeting schedule, etc.) relevant to promote enduring change in your practice? (5) What was the added value of setting up our group as a learning community and in what ways did this approach influence your practice?

Teaching Science as Inquiry test. We used the Teaching Science as Inquiry (TSI) test (Smolleck, Zembal-Saul, & Yoder, 2006) for assessing changes in the participants' self-efficacy beliefs about inquiry teaching. Consistently with Bandura's (1986) construct of self-efficacy, the TSI explores both personal self-efficacy (the belief of being capable of doing something) and outcome expectancy (the belief that teaching will have a positive outcome). Moreover, it allows assessing different dimensions and levels of inquiry (NRC, 2000).

Individual action research reports. At the beginning of the programme, each participant formulated his/her own research question and developed an action research plan. During the last meeting, each participant presented a report about their action-research project.

Participants

The programme involved 15 teachers from 11 secondary schools (grades 9-13). Most of them (9) had a degree in Mathematics, while the others had a degree in Physics (3), Engineering (3) or Astronomy (1). The participants' teaching experience ranged from 5 to >20 years.

Programme schedule

The programme, named 'CoLLABORA - A Community of Learners on LABORAtory work', was delivered between May 2018 and June 2019. Table 1 summarises the schedule and content of the meetings. In-between the meetings, collaborative online activities were proposed via the Moodle platform, which also contained all the course resources and a 'course journal'.

Table 1. Programme schedule and content.

Date	Topic/activities
May 11th, 2018	Learning community setup. Pre-course administration of the TSI test. Analysis of a research-based laboratory activity.
May 18th, 2018	Laboratory activity on ray optics + discussion.
September 7th, 2018	Laboratory activity on mechanical waves. Formulation of personal research questions + feedback from peers and researchers.
September 14th, 2018	Didactical issues about 'waves and their applications'. Design of personal action research plan + feedback from peers and researchers.
October 12th, 2018	Disciplinary and didactical issues about 'mechanical waves'. Reflection on scientific practices. Laboratory activity on standing waves + discussion.
November 9th, 2018	Disciplinary and didactical issues about 'sound waves'. Laboratory activity on sound waves + discussion; focus on the use of technology.
December 14th, 2018	Visit to the Museum of the History of Physics and discussion/reflection on learning in out-of-school contexts. Group work on the different purposes of laboratory activities into a teaching-learning sequence.
January 11th, 2019	Reflection+discussion on the assessment of practical work. Co-design of a laboratory activity on ray optics.
February 15th, 2019	Laboratory activities on wave optics according to the three types of experiments + discussion.
March 8th, 2019	Laboratory activity on light sources and their spectra + discussion.
April 12th, 2019	Laboratory activity on atomic spectra + reflection/discussion on the didactical issues of modern physics.
May 10th, 2019	Final workshop: each participant presented the outcomes of his/her own action research project.
June 7th, 2019	Final focussed group interview.

RESULTS

General outputs of the programme

According to the individual questionnaires, 70% of the teachers changed their use of practical work at school since they had started the course. Self-reported changes include using different kinds of activities, adopting a more open inquiry, and developing improved didactic and assessment tools. Besides gaining a better understanding of the role of practical work in physics education, participants also think they became more capable of designing a laboratory activity. The most appreciated activities during the programme were experimenting and constructing research-based experiences. Participants also valued the active engagement, the connection between physics content and scientific practices, and the collaborative approach.

Effectiveness of the five features

Below we report our results with respect to the five features of our framework.

Linking content, practice, and research. The participants considered useful to include the reflection on the laboratory into a content strand that is central throughout the curriculum. The use of research-based materials was relevant 'in order to qualify [their] didactic choices' (Lucia). In particular, discussing the purpose of the different laboratory activities in a teaching-learning sequence provided 'new ways of thinking about practical work […]' and it 'left room to the participants' creativity about how to use them in the classroom' (Sara).

Action research. According to the participants, engaging in action research was effective in fostering a more scientific attitude towards teaching: 'Even when I don't do planned action research, now I look at my everyday practice with a research attitude' (Alberto); 'I have learnt that there are many aspects of my practice I can experiment on' (Giorgio). Action research also fostered the development of positive self-efficacy beliefs, as it is discussed below. The time spent in formulating an investigable research question and developing an action research plan was considered particularly relevant: 'The best part of it was stopping to think about my practice in order to pose the right question' (Maria Rosa).

Focus on teachers' beliefs. The TSI scores at the beginning and at the end of the programme suggest that there was a slight overall improvement for self-efficacy (+0.14 on average for self-efficacy, +0.08 for outcome expectancy), but a large variability among participants was observed. A deeper analysis into the personal path of each teacher would be required in order to identify the factors that contributed to the evolution of their beliefs. However, a connection was suggested between high TSI gains and the completion of action research projects: 'Beliefs change if you try for yourself and you see that you like what you are doing' (Giorgio). The case study described below also supports this hypothesis. Concerning the five dimensions and levels of inquiry (NRC, 2000), the largest average improvement was observed for 'learner gives priority to evidence in responding to questions' (+0.28) and 'learner formulates explanations from evidence' (+0.20), and an overall increase towards a higher students' autonomy was observed (+0.28).

Sufficient duration. Consistently with the literature, the duration of the course was judged 'necessary for letting things settle' (Maria Rosa) and even 'not enough' (Alberto). Participants agreed that real change is a long-term process and that even more opportunities for meeting and working together would be needed.

Learning community. Working collaboratively with colleagues and establishing a relationship environment where ideas and difficulties could be shared 'without the fear of judgement' (Lucia) was decisive: 'I see the foundations for building a community of teachers who share materials and ideas' (Francesco). Participants particularly appreciated the possibility of interacting with colleagues from different backgrounds and contexts, which gave them the possibility to 'experience a wider network of relationships beyond the one in our schools' (Alberto). When two teachers from the same school were present, this was recognised as 'a seed to start a learning community in each school' (Francesco). The learning community was also identified as ‘a powerful strategy for reinforcing the relationship between schools and university’ (Giorgio). Collaborating online was however a critical aspect: according to the participants, part of the problem lay in the specific platform (Moodle, judged ‘not very user-friendly’, but they also acknowledged that working collaboratively is not automatic and requires training.

A case study: Lucia

We describe the experience of one of the participants, Lucia, more in detail, in order to describe how the course influenced a teacher’s practice in her specific case.

Background. Lucia got her degree in Mathematics in 2008; during her degree she followed no laboratory courses. At the beginning of the programme, Lucia had been teaching physics for 8 years and she was teaching in grades 9-10 in a technical high school. According to her initial interview, before the course she ‘occasionally’ proposed laboratory experiences. Lucia’s initial score in the TSI was 2.80 for self-efficacy and 2.90 for outcome expectancy.

Action research plan. Lucia’s action research plan was implemented in her 10th grade classrooms in January 2019. Her research employed a quasi-experimental design involving an experimental and a control classroom. Specifically, she wanted to test the effectiveness of a research-based observational experiment in the context of a teaching-learning sequence on mechanical waves, compared with a traditional laboratory. She evaluated her research using two different rubrics (an observation rubric filled in by herself and by an external observer, and the students’ self-evaluation), the analysis of students’ lab reports, and a test administered three months after the lab. Her results supported the effectiveness of the research-based laboratory and, as the start of a new action research cycle, she refined her research question as how to re-design the lab in order to engage all of the students, including the weakest ones.

Impact of the programme and effectiveness of the five features. In her final questionnaire, Lucia listed some of the new habits she implemented in her classroom: ‘Now I provide the students with the rubrics I use for assessment; I use a larger variety of laboratory activities; I have modified the structure of my lab worksheets in order to give the students more room for inquiry; and I encourage my students formulate their own questions’. Lucia particularly appreciated the research-based proposals, which she ‘thirsted for’: ‘It was like a pat on the back. It is good to know that someone is thinking about it’. She judged the experience of action research a crucial point of the programme: ‘During our pre-service teacher training, we were asked to design imaginary plans for imaginary classrooms; on the contrary, in everyday practice we just do the same things year after year. Engaging in action research gave me the opportunity to design and carry on a real project on a real classroom’. Lucia reported large gains in the TSI test (+0.93 for self-efficacy and +0.58 for outcome expectancy). She connected this improvement to her action research experience: ‘I felt a need for change, but, in my school, there is a traditional approach to lab activities… I used to think, “maybe I am a mathematician and I cannot do practical work, probably I am the wrong one”. This year I have worked on myself and now I believe that I can be comfortable in the lab and that I can promote change in my school’. For Lucia, improving her beliefs meant not only promoting personal change, but also making her think of herself as a change agent in her school. Lucia also appreciated the course organization and the learning community approach: ‘The monthly schedule allowed us to set our goals on a timeline pattern, then meet to build the community and step forward. The yearly duration allowed us to make small changes, with the opportunity discuss them soon after’. According to Lucia, ‘The strength of the programme was to offer stimuli while at the same time bringing out the very best from each participant. In most programmes, we listen to an expert and then we do some group work… here I found room for personal reflection and adequate input based on research, that motivated me to change; I found helpful colleagues and researchers who gave me precious feedback. This year I did not feel alone.’

DISCUSSION AND CONCLUSIONS

From the data collected with multiple instruments, we can conclude that all the features considered in our programme were effective, with action research and the learning community approach being decisive. In fact, engaging in action research impacted the teachers’ attitude towards their teaching (fostering a more evidence-based approach). Moreover, a successful action research project boosted the improvement of self-efficacy beliefs and promoted a sense of agency. Concerning the learning community approach, the participants highlighted the need of a ‘non-threatening, inspiring, trustful and collaborative’ context in which to grow as teachers and persons. These comments reinforce our choice of adopting this approach as out working model and supports us in envisaging actions to further improve it.

The focus on teachers’ beliefs seems relevant as a means to effectively impact teachers’ practice, though personal stories and paths should be taken into account to interpret the results. Qualitative, in depth instruments are needed in order to gain further insights on development of the participants’ beliefs. In the light of the results about action research and programme duration, we argue that even more time and opportunities for action research would be needed as sources of self-efficacy. This will be a priority for the continuation of the programme.

Based on the results of this study, we plan to continue the programme for another year, focussing on action research and experimentation in the classroom. We also plan to introduce more collaborative practices such as co-planning, engaging in micro-teaching sessions, observing and being observed by peers, giving and receiving feedback, with the aim of reinforcing the community and foster collaborative approaches to the teaching of physics. Secondly, we plan to design a revised version of the programme to be implemented with a new group, with the aim of enlarging the community and promote the establishment of local teachers’ networks. We hope that, in the long term, this effort will contribute to the formation of productive links between research and practice, the schools and the university, and foster change and innovation as well as personal and professional development.

ACKNOWLEDGMENT

The study was supported by the “Piano nazionale Lauree Scientifiche” of the Italian Ministry of Education, University and Research.

REFERENCES

Abrahams, I. & Millar, R. (2008) Does practical work really work? A study of the effectiveness of practical work as a teaching and learning method in school science. *International Journal of Science Education, 30*, 1945-1969.

Adey, P., Hewitt, G., Hewitt, J. & Landau, N. (2004). *The professional development of teachers: Practice and theory*. Dordrecht: Kluwer Academic.

Bandura, A. (1986). *Social foundations of thought and action: A social cognitive theory*. Englewood Cliffs, NJ: Prentice-Hall.

Capps, D.K., Crawford, B.A., & Constas, M.A. (2012). A review of empirical literature on inquiry professional development: Alignment with best practices and a critique of the findings. *Journal of Science Teacher Education, 23*, 291-318.

Chicherkian, T. & Shore, B.M. (2016). Preservice and practicing teachers' self-efficacy for inquiry-based instruction. *Cogent Education, 3*, 1236872.

Couso, D. (2008). Authentic collaboration: A promising paradigm for physics education reform. *International Newsletter on Physics Education (ICPE, IUPAP), 56*, 7-9.

Crawford, B.A. (2007). Learning to teach science in the rough and tumble of practice. *Journal of Research in Science Teaching, 44*, 613-642.

Crawford, B.A. (2014). From inquiry to scientific practices in the science classroom. In N.G. Lederman & S.K. Abell (Eds.), *Handbook of research on science education* (pp. 515-541). Abingdon: Routledge.

Desimone, L.M. (2009). Improving impact studies of teachers' professional development: Toward better conceptualizations and measures. *Educational Researcher, 38,* 181-199.

Etkina, E., Van Heuvelen, A., White-Brahmia, S., Brookes, D.T., Gentile, M., Murthy, S., Rosengrant, D., & Warren, A. (2006). Scientific abilities and their assessment. *Physical Review Special Topics - Physics Education Research, 2*, 020103.

Etkina, E. & Van Heuvelen, A. (2007). Investigative Science Learning Environment: A science process approach to learning physics. In E.F. Redish & P. Cooney (Eds.), *Research-based reform of university physics* (pp. 2-48). College Park, MD: American Association of Physics Teachers.

Gilbert, J.K. (2010) Supporting the development of effective science teachers. In J. Osborne & J. Dillon (Eds.), *Good practice in science teaching: What research has to say* (2nd ed., pp. 274-300). Maidenhead: Open University Press.

Hofstein, A. & Lunetta, V. N. (2004). The laboratory in science education: Foundations for the twenty-first century. *Science Education*, *88*, 28-54.

Laudonia, I., Mamlok-Naaman, R., Abels, S., & Eilks, I. (2017). Action research in science education: An analytical review of the literature. *Educational Action Research, 26*, 480-495.

LINPILCARE (LINk Practitioner Inquiry via effective Professional Learning Communities with the results of Academic Research) project. *Erasmus + KA2 strategic partnership for innovation in education* 2014-BE02-KA201-000432. Retrieved from: www.linpilcare.eu.

Lotter, C., Yow, J.A., & Peters, T.T. (2014). Building a community of practice around inquiry instruction through a professional development program. *International Journal of Science and Mathematics Education, 12*, 1Y23.

Lotter, C., Thompson, S., Dickenson, T.D., Smiley, W.F., Blue, G., & Rea, M. (2018). The impact of a practice: Teaching professional development model on teachers' inquiry instruction and inquiry efficacy beliefs. *International Journal of Science and Mathematics Education, 16*, 255-273.

Mamlok-Naaman, R. (2018). Using the Action Research rationale to enhance the creation of teachers' Professional Learning Communities (PLCs). *Action Research and Innovation in Science Education, 1*, 27-32.

Millar, R. (2010). Practical work. In J. Osborne & J. Dillon (Eds.), *Good practice in science teaching: What research has to say* (2nd ed., pp. 108-134). Maidenhead: Open University Press.

National Academies of Sciences, Engineering, and Medicine. (2019) *Science and engineering for grades 6-12: Investigation and design at the center*. Washington, DC: The National Academies Press.

National Research Council. (2000). *Inquiry and the national science education standards: A guide for teaching and learning*. Washington, DC: The National Academies Press.
National Research Council. (2006) *America's lab report: Investigations in high school science*. Washington, DC: The National Academies Press.
National Research Council. (2012). *A framework for K-12 science education: Practices, crosscutting concepts, and core ideas*. Washington, DC: The National Academies Press.
Nivalainen, V., Asikainen, M.A., Sormunen, K., & Hirvonen, P.E. (2010). Preservice and inservice teachers' challenges in the planning of practical work in physics. *Journal of Science Teacher Education, 21*, 393–409.
Osborne, J. (2014). Teaching scientific practices: Meeting the challenge of change. *Journal of Science Teacher Education, 25*, 177-196.
Rocard, M., Csermely, P., Jorde, D., Lenzen, D., Walberg-Henriksson, H. & Hemmo, V. (2007). *Science education now. A renewed pedagogy for the future of Europe*. Luxembourg: Office for Official Publications of the European Communities.
Rundgren, C.-J. (2018). Implementation of inquiry-based science education in different countries: Some reflections. *Cultural Studies in Science Education, 13*, 607-615.
Singer, J., Lotter, C., Feller, R., & Gates, H. (2011). Exploring a model of situated professional development: Impact on classroom practice. *Journal of Science Teacher Education, 22*, 203-227.
Smolleck, L.D., Zembal-Saul, C., & Yoder, E.P. (2006). The development and validation of an instrument to measure preservice teachers' self-efficacy in regard to the teaching of science as inquiry. *Journal of Science Teacher Education, 17*, 137-163.
Tschannen-Moran, M., Hoy, A.W., & Hoy, W.K. (1998). Teacher efficacy: Its meaning and measure. *Review of Educational Research, 68*, 202-248.
Vangrieken, K, Dochy, F., Raes, E., & Kyndt, E. (2015). Teacher collaboration: A systematic review. *Educational Research Review, 15*, 17-40.
Vangrieken, K., Meredith, C., Packer, T., & Kindt, E. (2017). Teacher communities as a context for professional development: A systematic review. *Teaching and Teacher Education, 61*, 47-59.
Wenger, E. (1998). *Communities of practice: Learning, meaning, and identity*. New York, NY: Cambridge University Press.
Yalcin-Celik, A., Kadayifci, H., Uner, S., & Turan-Oluk, N. (2017). Challenges faced by pre-service chemistry teachers teaching in a laboratory and their solution proposals. *European Journal of Teacher Education, 40*, 210-230.

DEVELOPMENT AND EVALUATION OF A TEACHER TRAINING ADDRESSING THE USE OF EXPERIMENTS IN CHEMISTRY EDUCATION

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Research on the quality of instruction in chemistry education provides quality characteristics which correlate positively with students' measured cognitive and affective variables. A content-specific individual teacher training using video analysis and focusing on these characteristics has shown efficacy down to student level. In the project at hand we develop and evaluate a comparable teacher training which is independent from the content. The one-day teacher training uses video data from the participating teachers' chemistry lessons. For an extensive evaluation on different levels (e.g. teachers' cognition and practical performance) several instruments have to be developed or adapted. Therefore, the project consists of two studies. In the first study, the instruments are developed and evaluated. The intervention itself is evaluated in a second study using a pre-post-follow up design.

Keywords: In-service Teacher Training, Training and Development, Video Analysis

THEORETICAL BACKGROUND

Research on the quality of instruction provides general or more precisely non subject-specific criteria which correlate positively with students' performance, interest and attitudes (Schulz, 2011; Seidel et al., 2006). From studies in science education, especially chemistry and physics, one can conclude a distinct relation between

a) criteria concerning structuring (e. g. clear separation of the experimentation process into planning, execution and evaluation)

b) target-orientation (e.g. transparency of learning goals and procedure; summary of results) and

c) students' learning outcomes (Schulz, 2011; Seidel et al., 2006).

Tesch & Duit (2004) showed a positive correlation between total duration of the experimentation process and students' learning gains, but no correlation between these gains and the duration of the execution of the experiment. This suggests that a structured embedding with appropriate planning and evaluation of the experiment is necessary for an increase in learning. From the aforementioned video studies (Schulz, 2011; Seidel et al., 2006; Tesch & Duit, 2004), which were conducted in regular lessons at German schools, it can be deduced that structuring plays a central role. This structuring, related to a learning objective according to factual content and functional learning-process-oriented aspects, can also be called sequencing.

Unfortunately, studies assessing science lessons reveal shortcomings in Germany (Schulz, 2011; Seidel et al., 2006) in comparison with other European countries (e.g. Finland and

Switzerland (Börlin & Labudde, 2014) regarding structuring as well as sequencing and target-orientation.

The development of teaching with regard to quality characteristics does not take place on its own. Therefore, learning opportunities for this topic must be created within the framework of pre-service teacher education and also in-service teacher training. According to Radtke (1996), in order to achieve a continuous professionalisation of teachers at this point, teachers' action must be linked and further developed with pedagogical content knowledge. A one-day teacher training to foster hands-on inquiry learning (Schmitt, 2016) was able to show short and medium-term changes in the attitude of teachers towards the content of the training as well as in the pedagogical content knowledge regarding experiments. Coaching with video material from the teachers' own lessons has also proven its worth in several studies (Schulz, 2011; Seidel et al., 2006; Wackermann, 2008). Schulz (2011) showed that a lesson-specific, individual coaching using videos from the teachers' lessons positively influences lesson quality, resulting in a higher learning gain for students. Thus, the learning effectiveness of a topic-specific coaching on quality characteristics of experimental phases at the action level of teachers and at the cognitive and affective level of students is proven.

Nevertheless, for an economic and generalisable teacher training the question has to be answered, if a training in groups independent from the topic of the lesson shows similar results.

RESEARCH QUESTION

The aim of this project is to evaluate an in-service teacher training which mainly focuses on the transfer of research results of Schulz (2011) addressing the optimisation of quality characteristics especially in experimental phases. In order to economise the educational intervention the project evaluates the effects of a non-content-specific training for groups of teachers. In this study, the following research question is addressed:

Does the intervention lead to changes in teachers' epistemological beliefs and in pedagogical content knowledge (PCK) concerning quality characteristics and practical performance in class?

In order to answer this question, appropriate instruments have to be developed and their psychometric criteria have to be determined. This leads to the following research question:

Are the developed test instruments objective, reliable and valid for measuring teachers' epistemic beliefs and pedagogical content knowledge (PCK)?

METHODS AND DESIGN OF THE PILOT STUDY

For measuring teachers' epistemic beliefs and pedagogical content knowledge (PCK) about experiments and their methodical implementation, two instruments were used. Hence, items assessing teachers' beliefs as a part of professional competence Baumert & Kunter (2011) and the PCK test items were constructed or adapted.

Concerning the instrument for measuring PCK, 26 items with four statements each were constructed on the basis of Tepner & Dollny (2014). Each of these statements had to be rated on a four-level Likert scale. In addition, the PCK-items were validated by an expert rating in which educational researchers of chemistry education were asked for their rating.

For the instrument on epistemic beliefs, 17 items with one statement each were selected and adapted from the instrument of Lamprecht (2011). The items that he used to assign teachers to one of the three types of teaching-learning convictions (training, discursive, mediation) were selected (Lamprecht, 2011). Each statement had to be evaluated on a five-level Likert scale.

The teachers of the sample ($N = 23$) were tested online with LimeSurvey. All items were rated in the same order. After the demographic part, the survey continued with the PCK-items and is completed with the items to measure epistemic beliefs. To continue the survey, the teachers were forced to make a choice.

PRELIMINARY RESULTS OF THE PILOT STUDY

In the PCK-test, the expert rating ($N = 3$) using a four-level Likert scale shows only moderate agreement ($\kappa_{Fleiss} = .45$), measured at the statement level for all 104 statements. For a dichotomous coding, summarising (slightly) agreeing and (slightly) disagreeing, the inter-rater reliability improves regarding all statements ($\kappa_{Fleiss} = .67$). Eliminating statements with a broad range in the expert rating left 72 statements. For those, the four-level coding shows an improved inter-rater reliability ($\kappa_{Fleiss} = .67$) and the dichotomous coding leads to a good reliability ($\kappa_{Fleiss} = .91$) without substantially reducing validity. Unfortunately, Rasch analysis of the results of the PCK-test ($N = 23$) leads to insufficient EAP reliability ($rel_{EAP} < .60$), independent from the number of statement and type of coding.

Data analysis of the test for the teachers' epistemic beliefs results in a two-dimensional model (see table 1). The first dimension consists of ten items regarding chemistry education. The second dimension consists of seven items regarding teaching chemistry.

table 1. comparison of unidimensional and two-dimensional model

model	deviance	AIC	chisq	df	p
unidimensional	936.62	1199.99	33.96	2	0
two-dimensional	902.66	1172.31			

For the two dimensions there are moderate to good EAP reliabilities and acceptable infit values. It is noticeable that the variance in the two dimensions is different (see table 2).

table 2. EAP reliability, variance and infit for both dimensions

dim1: chemistry education			dim2: teaching chemistry		
rel_{EAP}	variance	infit	rel_{EAP}	variance	Infit
.862	2.325	0.58 – 1.24	.602	0.162	0.86 – 1.50

Consequences for Main Study

Leading up to the main study, an increase in the sample size is necessary for both the experts and the teachers, since sporadic (poor) statistic parameters may also be related to the small sample size. In addition, it is checked whether the construct which the test instrument for PCK is based on is multidimensional. In any case, a revision of the instrument for PCK is absolutely necessary and at least recommended for the instrument on epistemic beliefs. Possibly, the performance tests for planning and reflecting lessons from the project ProfileP+ (Kulgemeyer et al., 2019) offer an alternative to the PCK test presented here.

OUTLOOK ON MAIN STUDY

First, the intervention materials for the group coaching were developed building upon the individual coaching used by Schulz (2011). The intervention will be evaluated following Lipowsky (2010), levels of evaluation. On the first level the participating teachers' reactions and ratings on the program content are evaluated. The second level assesses changes in teachers' cognition, especially beliefs and knowledge. On the third level practical changes in class are evaluated. Influences on students' knowledge, interests or beliefs are assessed on level four.

For the intervention study, we aim at a sample of 50 in-service chemistry teachers, who are not identical to the sample of the pilot study. Prior to and after the intervention, data for the levels 1 to 4 is collected and one chemistry lesson including an experiment of each participating teacher is videotaped and rated.

The teachers take part in a single day training of six hours intervention time (see figure 1). It starts with a presentation of research results of quality characteristics of chemistry lessons with experimental phases and methods of structuring teaching (Oser & Baeriswyl, 2001), followed by an instruction how to use video data for teaching improvement using a video of a scripted lesson. The remaining time the participating teachers work in groups of two teachers analysing scenes of their own video data, which were preselected by the researchers in order to identify quality characteristics, that are worth improving. Subsequently, they plan a new lesson regarding those identified characteristics.

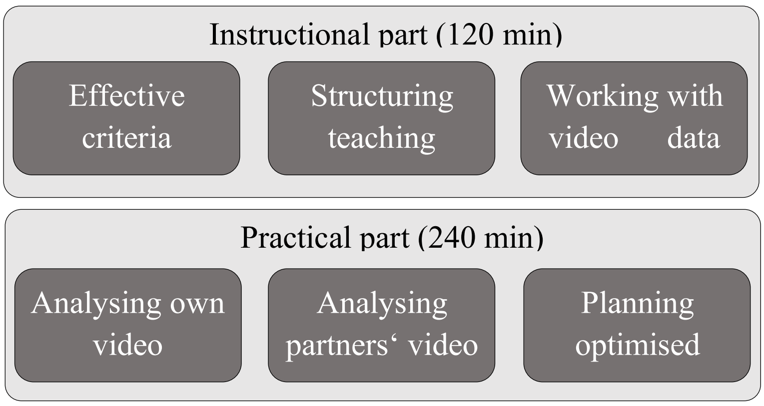

figure 1. Content of teacher training

This new lesson is videotaped a few weeks after the intervention, when post-data for evaluation level 1 and 2 is collected. In a follow-up-test three months after the intervention, medium-term effects of the intervention are assessed (see figure 2).

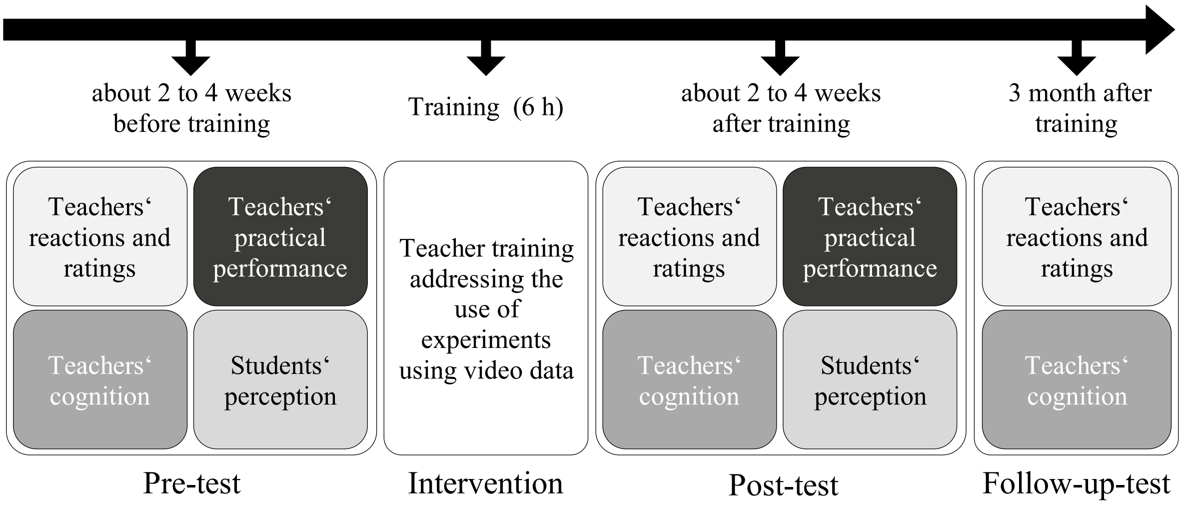

figure 2. Design of the intervention considering four levels of evaluation according to Lipowsky (2010)

Instruments

The success of the teacher training program is operationalised by the following variables considering four levels of evaluation (Lipowsky, 2010) (see figure 3):

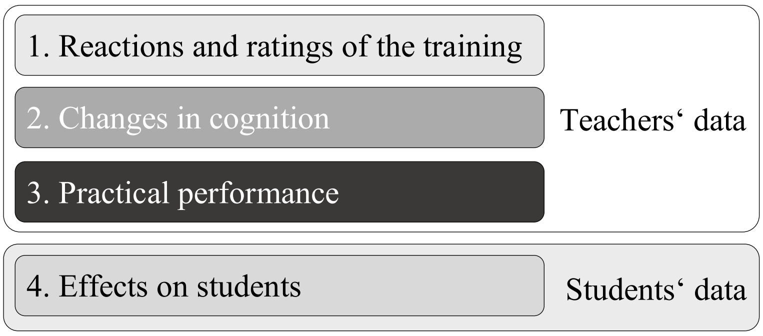

figure 3. Levels of evaluation according to Lipowsky (2010)

Level 1: The teachers' reactions and ratings of the training and its content are assessed by a questionnaire modified from Schmitt (2016).

Level 2: Teachers' changes in cognition are measured by two different instruments. On the one hand, data about their epistemological beliefs is collected by a survey adapted from Lamprecht (2011). On the other hand, teachers' PCK of experiments and their methodical implementation is collected by a self-developed test following Tepner & Dollny (2014).

Level 3: The teachers' practical performance is rated by video analysis applying the video coding system developed, validated and used by Schulz (2011).

Level 4: Data from the students' perception of quality of instruction is collected by a questionnaire also used by Schulz (2011).

EXPECTATIONS AND RESTRICTIONS

Because of the expected heterogeneity of topics and grade levels in the main study, no data of student's knowledge is assessed on evaluation level 4. Consequently, the effects of the intervention on student's knowledge cannot be proved. However, increased learning outcomes as a consequence of enhanced appearance of quality characteristics are already proven (Schulz, 2011).

REFERENCE LIST

Baumert, J., & Kunter, M. (2011). Das Kompetenzmodell von COACTIV [The model of competence of COACTIV]. In M. Kunter, J. Baumert, W. Blum, & M. Neubrand (Eds.), *Professionelle Kompetenz von Lehrkräften. Ergebnisse des Forschungsprogramms COACTIV* (pp. 29–54). Münster: Waxmann.

Börlin, J., & Labudde, P. (2014). Practical Work in Physics Instruction: An Opportunity to learn? In H. E. Fischer, P. Labudde, K. Neumann, & J. Viiri (Eds.), *Quality of Instruction in Physics. Comparing Finland, Switzerland and Germany* (pp. 111–128). Münster: Waxmann.

Kulgemeyer, C., Vogelsang, C., Borowski, A., Buschhüter, D., Enkrott, P., Kempin, M., et al. (2019). Entwicklung von Professionswissen und Unterrichtsperformanz im Lehramtsstudium Physik: Analysen zu valider Testwertinterpretation [Development of professional knowledge and teaching performance in physics teacher training: analyses of valid test value interpretation]. *Zeitschrift für Pädagogik, 71*(4), 473–491.

Lamprecht, J. (2011). *Ausbildungswege und Komponenten professioneller Handlungskompetenz: Vergleich von Quereinsteigern mit Lehramtsabsolventen für Gymnasien im Fach Physik. Studien zum Physik- und Chemielernen* [Educational pathways and components of professional competence: Comparison of lateral entrants and graduated student teachers in physics]. Berlin: Logos.

Lipowsky, F. (2010). Lernen im Beruf – Empirische Befunde zur Wirksamkeit von Lehrerfortbildung [Learning in profession - Emperical findings of efficacy of teacher training]. In F. H. Müller, A. Eichenberger, M. Lüders, & J. Mayr (Eds.), *Lehrerinnen und Lehrer lernen. Konzepte und Befunde zur Lehrerfortbildung* (pp. 51–72). Münster, New York, München, Berlin: Waxmann.

Oser, F. K., & Baeriswyl, F. J. (2001). Choreographies of Teaching: Bridging Instruction to Learning. In V. Richardson (Ed.), *Handbook of research on teaching* (pp. 1031–1065). Washington, DC: AERA.

Radtke, F.-O. (1996). *Wissen und Können* [Knowledge and skills]. Wiesbaden: VS Verlag für Sozialwissenschaften.

Schmitt, A.-K. (2016). *Entwicklung und Evaluation einer Chemielehrerfortbildung zum Kompetenzbereich Erkenntnisgewinnung* [Development an evaluation of a chemistry teacher training for the competence area acquirement of knowlegde]. Berlin: Logos.

Schulz, A. (2011). *Experimentierspezifische Qualitätsmerkmale im Chemieunterricht: Eine Videostudie* [Experiment-specific quality characteristics in chemistry]. Berlin: Logos.

Seidel, T., Prenzel, M., Rimmele, R., Schmidt, K., Kobarg, M., Herweg, C., & Dalehefte, I. M. (2006). Unterrichtsmuster und ihre Wirkungen: Eine Videostudie im Physikunterricht [Patterns in teaching and their effects: a video study in physics]. In M. Prenzel & L. Allolio-Näcke (Eds.), *Untersuchungen zur Bildungsqualität von Schule. Abschlussbericht des DFG-Schwerpunktprogramms BiQua.* Münster: Waxmann.

Tepner, O., & Dollny, S. (2014). Entwicklung eines Testverfahrens zur Analyse fachdidaktischen Wissens [Test development for analysing PCK]. In D. Krüger, I. Parchmann, & H. Schecker (Eds.), *Methoden in der naturwissenschaftsdidaktischen Forschung* (pp. 311–323). Berlin, Heidelberg: Springer.

Tesch, M., & Duit, R. (2004). Experimentieren im Physikunterricht - Ergebnisse einer Videostudie [Experimenting in Physics Lessons - Results of a Video Study]. *Zeitschrift für Didaktik der Naturwissenschaften;, 10*, 51–69.

Wackermann, R. (2008). *Überprüfung der Wirksamkeit eines Basismodell-Trainings für Physiklehrer* [Verification of the effectiveness of training addressing Choreographies of Teaching for physics teachers]. Berlin: Logos.

TEACHER KNOWLEDGE IN A PROFESSIONAL DEVELOPMENT COURSE IN A CURRICULAR REFORM IN BRAZIL

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In this paper we investigate early stages in the processes of implementation of a new curriculum centred on scientific literacy and inquiry-based science teaching for 1st through 9th grades in schools in Southeast Brazil. We have analysed discursive interactions during lessons of a six week long in-service Science Teacher Education course in which primary and secondary teachers developed an instrument to analyse and evaluate teachers' and students' instructional materials elaborated based on the new curriculum and used this instrument to propose changes before its final implementation in schools. Our aim is to understand what knowledge teachers mobilize when evaluating and proposing modifications in science curricular reform materials for teachers and for students. Our analysis shows the tensions between content and demands of the prescribed curriculum, as well as possibilities of practice in science classrooms, especially in relation to how teachers deal with changes in: (i) science educational goals and (ii) the role of teachers and students in knowledge construction in the classroom.

Keywords: Curriculum; Teacher professional development; Inquiry-based teaching

INTRODUCTION

For decades it has been acknowledged that teachers' learning is a long and complex process and that teachers' knowledge is multifaceted and intertwined with social context, experiences and beliefs (e.g. Ellis, Eduards & Samorinsky, 2010; Kincheloe, 1998; Putman & Borko, 1997; Schön, 1983; Shulman, 1986; Tardif, 2014; Zeichner; 1999). However, there are still concerns with hierarchical relationships between teachers' knowledge and academic/expert knowledge, perpetuated throughout the history of teacher education. In particular, curricular reforms – and professional development related to them – too often are oriented by a rationale of implementing "experts" views that can be more effective if they can "resist" to teachers' challenges and practices (i.e. teachers' proof curricula). Thus, they tend to ignore multiple actors involved in the process (e.g. Wallace, 2012) and/or to adopt perspectives of "standards setting" in classrooms that are centered in demanding/informing/teaching teachers and students, not in negotiating and/or arising (Kordalewski, 2000). Science education is no exception to this pattern. There is a consensus that science learning goes beyond subject matter, incorporating dimensions of scientific literacy (SL) like "doing science", "learning about science", and "addressing socio scientific issues" (Hodson, 2014, p. 2537). One of the approaches to promote scientific literacy in the classroom is inquiry-based science teaching (IBST) (National Research Concil, 2012), in which scientific practices and student engagement play a central role. In many countries, these ideas have influenced curriculum development (e.g. Next Generation Science Standards Lead States, 2013).

In this paper we investigate early stages in the processes of implementation of a new curriculum centred on SL and IBST in Southeast Brazil (São Paulo City Secretary of Education, 2017, 2018), as part of a national curricular reform (Franco & Munford, 2018; Marcondes, 2019; Brazilian Ministry of Education, 2017; Sasseron, 2018). The implementation process is still underway and has included several actions of teacher in-service education and elaboration of instructional science materials based on the inquiry cycle (Pedaste et al., 2015).

We have analysed discursive interactions during lessons of an in-service science teacher education course in which primary and secondary teachers developed an instrument to analyse and evaluate teachers' and students' instructional materials and used this instrument to propose changes before its final implementation in schools. Our aim is to better understand how teachers construct knowledge about science curricular change that is informed by key ideas in science education research. In particular we investigate: how do teachers use their knowledge when evaluating and proposing changes in science curricular reform materials?

Various studies have been conducted in the context of science curriculum implementation (e.g. Brown & Sadler, 2018). Frequently, teachers' learning is examined considering how they learn and/or adopt science curriculum/teaching approaches aspects (Wallace, 2012). In this paper teachers' knowledge is examined considering their actions when having some agency to propose changes, and act upon public policy initiatives.

METHOD

São Paulo is a city with more than twelve million habitants, located in Southeast Brazil. It has 555 schools, 12.000 primary teacher and 2.300 science teachers. The implementation of curriculum involved different instances of teacher development, as represented in Figure 1: courses for tutors (in orange), courses that these tutors teach to teachers (in green), and a course to evaluate instrutional material that was offered for both teachers and tutors (in purple). In blue, teachers in science classroom are represented and in red is the prescribed curriculum.

The study was conducted in a six-week long course (total of 24 hours) for 34 teachers from different schools in São Paulo (Brazil). Some of the participants were experienced and others were novice, and some teach at the primary school/elementary level (1st – 5th grades) whereas others at secondary level/middle school (6th-9th grades), and some acted as teacher educators. In the course, teachers: i) discussed and defined criteria for analysing the instructional material based on a preliminary analyses of 5th grade materials; ii) developed one instrument (a form) to analyse and evaluate teachers' and students' instructional materials of the curricular reform; iii) were grouped in accordance to grades they had chosen and used this instrument to analyse curricular materials (each group analysed eight learning sequence); iv) presented their proposals and evaluation to peers.

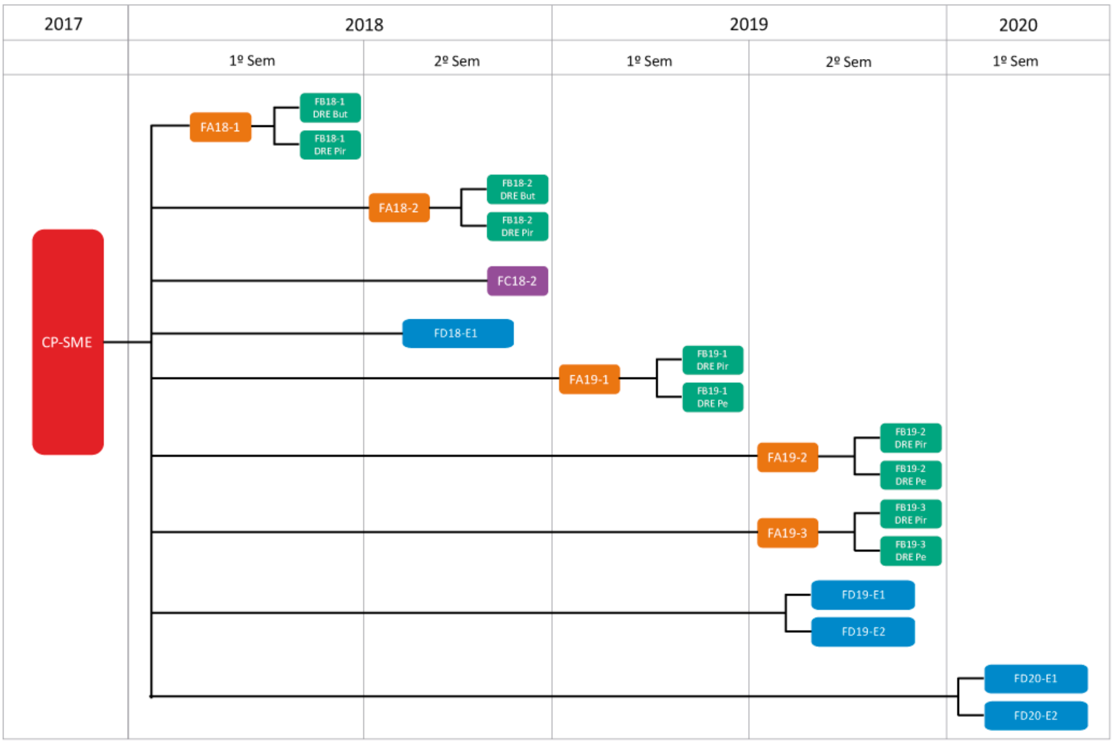

Figure 2. Professional Development Courses involved in Curricular Reform in São Paulo City. (Source: Authors).

The major data sources for this study were participant observation (Spradley, 1980) in science lessons with video/audio recording and field notes. Moreover, the instrument (the form) that teachers filled in during the lessons were analysed to better characterize what were the proposed changes. Our analyses focused on discussions in the groups of 2nd-3rd grade teachers and of 6th grade teachers. We selected events, considered telling cases (Mitchell, 1984), that made visible aspects of the process of evaluating and constructing knowledge about curriculum, in particular those related to inquiry-based teaching, scientific literacy and classroom practices. The discourse was transcribed word-by-word adopting the microethnography approach (Bloome, Carter, Christian, Otto & Shuart-Faris, 2005). Initially, the transcripts were analysed considering the content of discourse with focus on the types of knowledge teachers had been talking about (e.g. characteristics of students, prior experiences, readings about inquiry-based approaches). The categories were constructed during the analyses process.

In a second phase, informed by a social cultural perspective on teacher learning (Putnan & Borko, 1997; Ellis, Edwards, & Smagorinsky, 2010), we took Amanda Berry's (2007, 2008) notion of "tension" that she uses to describe teacher educator's practice and we adapted it to analyse discursive interactions in the context of the professional development course. In accordance with this author, the notion of "tension" has the potential to:

> capture the feelings of internal turmoil that many teacher educators experience in their teaching about teaching as they found themselves pulled in different directions by competing

> concerns, and the difficulties for teacher educators in learning to recognize and manage these opposing forces. (Berry, 2008, p. 32).

Figure 2 represents different types of tensions that are present in the experience of science teacher educators as proposed by Berry (2008, 2007).

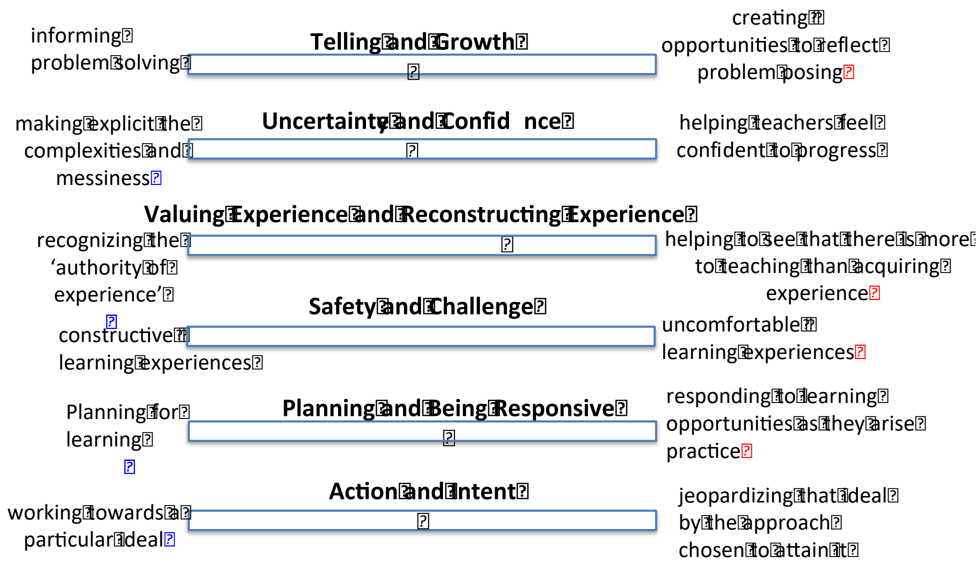

Figure 2: Representation of different categories of tensions in accordance with Berry (2007, 2008) (Source: Authors).

We reframed our initial research question about teachers' knowledge to the following analytical question: "What is the nature of the opportunities for learning to teach science that are constructed during a professional development course for curricular implementation?"

RESULTS AND DISCUSSION

To evaluate and propose changes in inquiry-based learning sequences (IBLS), teachers defined and used the following criteria: valorisation of the students' previous knowledge, adequacy and quality of the language, relevance of practical activities, adequacy of content and skills for the school grade, appropriateness duration, structure of the inquiry cycle, possibilities of student engagement, possibility of working with a diversity of students, adequacy of the orientations to the teacher, consistency between assessments and curriculum elements.

Some of these aspects may be considered as cultural myths (Tobin & McRobin, 1996), that is, they are references to enact science classes in a certain way, in accordance to certain beliefs about how a science class or a science curriculum must look like. The professional development space allowed these myths to surface and interactions between teachers, who had already applied the IBLS, brought up the difficulties, limitations and conceptions of scientific literacy and inquiry-based approach in classroom practices. Therefore, we considered that the aspects that teachers rose revealed tensions (Berry, 2007) between subject matter knowledge, theoretical knowledge demands of prescribed curriculum, and possibilities of science classroom practices.

Our analyses indicate that various types of knowledge were used to construct proposals for revising curricular materials. Frequently teachers' interpretations of the materials and suggestions were supported by their own experience at school, including knowledge about their students' knowledge or abilities (e.g. conceptual knowledge and teaching experiences teaching the lessons from the curricular materials).

Both when working in small groups or in whole class discussions, elementary school teachers often were more attentive to aspects of the written text in curricular materials. Proposals involving changes in written texts were very common in the group. For instance, when they analysed the 2nd grade materials for students, they engaged in a long discussion about the tittle of an activity in a sequence about the water cycle: "The water that was gone"[2]. One of the teachers argued that the title was telling the answer of the inquiry question and a tittle in the format of a question would be more appropriate. She also pointed that the very idea of "water going away" would be "the way kids would talk about it" and "you can imagine drops of water with little legs walking". Thus, this was an inappropriate tittle also to promote conceptual accuracy. They examined the activity and pictures that compose the activity, and pointed out that "the title should help them to see the drops", and proposed titles like "What changed in the mirror?" Moreover, they established relationships with knowledge from the discipline Portuguese/Reading and Writing. For instance, in the same sequence mentioned above, a teacher noticed that a practical activity were similar to a "the genre" food recipe. Later, a colleague noted that the way the text was presented it looked like a list, a genre that they usually did not work with students as much as they should.

The group of teachers working with students in transition to secondary/middle school (i.e. 6th grade) had one teacher who had developed almost all the activities they were discussing. In this case, discussions were often structured around asking him how he did it at his school and how things went. In one occasion he stated "I just know it because I worked with students this", and a colleague agreed. Sometimes details like the use of the materials would receive his attention, and often how students participated and reacted received attention. For instance, when discussing an astronomy activity, he advised colleagues that "You should use play dough" and, enacting what was supposed to be done, he commented that "When you actually do it, they [students] get curious. I found it a good practice. Easy and simple to visualize. They proposed a bunch of theories. They got very excited about it." In various occasions teachers talked about students or school characteristics.

The modifications in the material that received more emphasis in whole classroom discussions involved changes in the sequencing of activities or concepts that should be worked throughout the year.

[2] A Portuguese version of this inquiry-based learning sequence is available at https://curriculo.sme.prefeitura.sp.gov.br/sequencia/as-gotas-de-agua

Two of these aspects called our attention due both to the big discussion in the two groups that were analysed, and their relationship with SL and IBST. First, there were tensions around science educational goals. The new prescribed curriculum places a greater emphasis on socio-scientific issues and on the social and cultural aspects of the production of scientific knowledge. For example, when talking about the place the theme "water" had in the curriculum and in 3rd grade instructional materials, teachers considered that science should address the concepts involved in the water cycle as social issues like water pollution should be addressed in geography lessons. Another example involved teachers analysing a practical activity in the 6th grade material on the role of indirect evidence, imagination and prior knowledge of scientists in the construction of scientific knowledge. Their interpretation was that the activity played just a motivating role, but does not contribute to "learning about science". Although this perspective did not represent a hindrance to perform the activity, it had a different function from a perspective that broadens goals of science teaching. These two examples illustrate challenges for teachers in incorporating dimensions of scientific literacy.

The second aspect to be highlighted is related to teachers' and students' roles in this new curriculum. When they reported the application of practical activities proposed in the instructional material, teachers point out that the room had become more tumultuous when students take a more active role. This required more effort and another way of acting of the teachers themselves. Also regarding students' role of, teachers reported that students didn't feel confortable participating in activities that required interactions and collaboration between students to construct knowledge. In one of the events analysed, teachers in 3rd grade regretted that while some students were arguing, others copied the assignment.

Further analysis of the events, using Berry's notion of tension, evidenced the complexity of the learning opportunities that emerge in the context of professional development courses – an aspect that was not evidenced in the other analysis. As an example we will present aspects of the analysis of an event that took place with 6th grade teachers. One of the teachers, Lúcia, shares her experience of developing the mystery box activity[3] to teach about earth's internal layers as proposed in the instructional material[4].

In this event the interactions among teachers made visible multiple tensions. For instance, the tensions between *value and reconstructing* are presented as we contrast two dialogues that occurred. At the beginning of interactions, teachers discuss impressions about the activity:

Pedro: It is only ludic, right?
Lúcia: Yes.
Júlio: Yes, yes.
Pedro: It is a comparison.
Júlio: It is not very scientific, is it?
Pedro: No.

[3] This is a tradicional activity to explore inquiry-based science teaching approach. An example can be seen here https://media.bscs.org/mss/se/chapter_pdfs/science_as_inquiry_introductory_chapter_for_any_unit/sai_ch1.pdf
[4] A Portuguese version of this inquiry-based learning sequence is available at https://curriculo.sme.prefeitura.sp.gov.br/sequencia/a-terra-viva-formacoes-e-transformacoes-do-solo

These interactions evidenced how participants relied in what happens in their classes and their views to construct a comprehension of the activity without using SL and IBST to frame their understanding of the activity. However, later in the event Lúcia will take another direction:

> Lúcia: So, I... I understood that ... look, for example... here, you have to infer what is inside [the box] in [the same way//(...).
> Júlio: //as what is inside the Earth.
> Lúcia: In the same way that you have to infer, because there is no way to get inside [the Earth], so you have to imagine.

In this case, her understanding of the activity aggregates aspects of the notion of model and modelling related to IBST, practices that are introduced and discussed in the curriculum. Another learning opportunity emerges in another interaction, also involving Lúcia:

> Lúcia: (...) I said [to a student]: "Ok, you said that you thought that it was, let's suppose, a coin. But why did you think that?" Then, he had to argue why. Establish a relationship. So it is nothing like (...).
> Lúcia: Say something like "I think it is a glass, just because I think". Do you get it? (...).
> Lúcia: It had to have some support; otherwise it is not enough just to put it out there.
> Pedro: Yes. "Just because", anything, you cannot [do it].

Again, Lúcia supports his colleagues in understanding the activity by connecting her experience to aspects of IBST.

Another tension that we identified in the same event was related to *uncertainty and confidence*. On one hand Lúcia bring into the conversation "the complexities and messiness" of teaching:

> Lúcia: Now, look at this one, Mystery Box, (...) Did you do it?
> Júlio: no, no, no.
> Lúcia: You have to do it, but in one of these days that you are feeling very well.
> Pedro: but what did you put inside?
> Lúcia: Because they through the box in the air. I put a bunch of coins rapped in paper balls, got it?
> Pedro: aham
> Lucia: Then, they shake it. Thus, I did this activity in homeopathic doses.... One day in two classes... the other day in other two classes... because I wouldn't be able to do it in all my classes.
> Pedro: It's because it becomes too messy.

On the other hand, she helps her peers to feel confident about teaching the activity, and, consequently adopting a different approach that they are used to:

> Lúcia: The other day, there is this class… that is a class with excellent students in terms of behaviour… they do what I ask them. I said: "let's go downstairs". In the school we have three sports courts.
> Pedro: In the sports court?
> Lúcia: Yes. We have three sports courts, and one indoor court, and between them there's a courtyard.

> Pedro: Great... Then you can seat there?
> Lúcia: We made a circle.
> Pedro: It's good because it's different from what we usually do.
> Lúcia: So, it's good. This was the last class that I did it with. Maybe I would do it with the first one, if I had the courage to take the others outside. It would be less messy if they were in the courtyard.

These interactions and the tensions that emerge evidenced the role that peer interactions can have in learning to teach in the context of Professional Development Courses.

CONCLUSIONS

When teachers are in a situation where they take a more active role in proposing and analysing instructional materials, they have opportunities to make sense of their practices, bringing up tensions between subject matter knowledge, theoretical knowledge demands of prescribed curriculum, and possibilities of enacting in the science classroom. In the course analysed here, these tensions became explicit, and teachers had pointed out the relevance of training and a demand for an instructional material specifically produced for theoretical deepening, which shows the consciousness about these tensions and the need to discuss and problematize them, bring up the possibility to effectively support changes recommended by political reforms.

ACKNOWLEDGEMENT

This study is part of the project *"Multiple contexts of teachers learning in the curricular reform of São Paulo: Contributions to the science teachers' professional development"* funded by CNPq (440357/2019-5) and FAPESP (2019/16102-3). Thanks to the teachers and teacher educators for participating in the study.

REFERENCES

Berry, A. (2007). Reconceptualising teacher educator knowledge as tensions: Exploring the tension between valuing and reconstructing experience. *Studying Teacher Education: A journal of self-study of teacher education practices*, 3(2), 117-134. doi: 10.1080/17425960701656510.

Berry, A. (2008). *Tensions in teaching about teaching: Understanding practice as a teacher educator*. Dordrecht, Netherlands: Springer.

Bloome, D., Carter, S. P., Christian, B. M., Otto, S., & Shuart-Faris, N. (2005). *Discourse analysis and the study of classroom language and literacy events*: *A microethnographic perspective.* Mahwah: Lawrence Erlbaum Associates.

Brazilian Ministry of Education. (2017). *Base Nacional Curricular Comum: Ensino Fundamental*. Brasilia, Brazil: Author. Retrieved from http://basenacionalcomum.mec.gov.br/

Brown, D., & Sadler, T. (2018). Conceptual framing and instructional enactment of the Next Generation Science Standards: a synthesis of the contributions to the special issue. *Journal of Research in Science Teaching*, *55*(7), 1101–1108. doi: 10.1002/tea.21509.

Ellis, V., Edwards, A., & Smagorinsky, P. (Eds.). (2010). *Cultural-historical perspectives on teacher education and development*. New York: Routledge.

Franco, L.G., & Munford, D. (2018). Reflexões sobre a Base Nacional Comum Curricular: Um olhar da área de Ciências da Natureza. *Horizontes*, *36*(1), 158-170. doi: 10.24933/horizontes.v36i1.582.

Hodson, D. (2014). Learning science, learning about science, doing science: Different goals demand different learning methods. *International Journal of Science Education*, 36(15), 2534–2553. doi: 10.1080/09500693.2014.899722.

Kincheloe, J. L. (1998). Critical Research in Science Education. In B. Fraser & K. Tobin (Eds.), *International Handbook of Science Education* (pp. 1191-1205). London: Kluwer Academic Publishers.

Kordalewski, J. (2000). *Standards in the classroom: how teachers and students negotiate learning*. New York: Teachers College Press.

Marcondes, M.E. (2018). As Ciências da Natureza nas 1ª e 2ª versões da Base Nacional Comum Curricular. *Estudos Avançados*, 32, (94), 269-284. doi: 10.1590/s0103-40142018.3294.0018.

Mitchell, C. J. (1984). Typicality and the case study. In R.F. Ellens (Ed.). *Ethnographic research: A guide to general conduct* (pp.238-241). New York: Academic Press.

National Research Concil (2012). *A framework for K-12 science education: Practices, crosscutting concepts, and core ideas*. Washington, DC: National Academies Press.

Next Generation Science Standards Lead States. (2013). *Next generation science standards: For states, by states.* Washington, DC: The National Academies Press.

Pedaste, M., Mäeots, M., Siiman, L.A., Jong, T., Riesen, S.A.N., Kamp, E.T., ... Tsourlidaki, E. (2015). Phases of inquiry-based learning: Definitions and the inquiry cycle. *Educational Research Review*, *14*, 47–61. doi: 0.1016/j.edurev.2015.02.003.

Putnam, R. T., & Borko, H. (1997). Teacher learning: Implications of new views of cognition. In B. J. Biddle (Ed.), *International Handbook of Teachers and Teaching* (pp. 1223-1296). Boston: Kluwer Academic Publishers.

Sasseron, L. H. (2018). Ensino de ciências por investigação e o desenvolvimento de práticas: Uma mirada para a Base Nacional Comum Curricular. *Revista Brasileira de Pesquisa em Educação em Ciências*, *18*(3), 1061-1085. doi: 10.28976/1984-2686rbpec20181831061.

Schön, D. A. (1983). *The reflective practitioner: How professionals think in action*. New York: Basic Books.

Shulman, L. (1986). Those who understand: Knowledge growth in teaching. *Educational Researcher*, *15*(2), 4-14. doi: 10.3102/0013189X015002004.

São Paulo City Secretary of Education. Orientações didáticas do currículo da cidade: Ciências Naturais. São Paulo: Author, 2018. Retrieved from
http://portal.sme.prefeitura.sp.gov.br/Portals/1/Files/50720.pdf.

São Paulo City Secretary of Education. Currículo da Cidade: Ensino Fundamental: Ciências Naturais. São Paulo: Author, 2017. Retrieved from
http://portal.sme.prefeitura.sp.gov.br/Portals/1/Files/50633.pdf.

Spradley, J. P. (1980). *Participant observation*. New York: Holt, Rinehart and Winston.

Tardif, M. (2014). *Saberes docentes e formação profissional*. Petrópolis, RJ: Vozes.

Tobin, K., & McRobbie, C.J. (1996). Cultural myths as constraints to the enacted science curriculum. *Science Education*, *80*(2), 223-241. doi: 10.1002/(SICI)1098-237X(199604)80:2<223::AID-SCE6>3.0.CO;2-I.

Wallace, C.S. (2012). Authoritarian science curriculum standards as barriers to teaching and learning: An interpretation of personal experience. *Science Education, 96*(2), 291-310. doi: 10.1002/sce.20470.

Zeichner, K. (1999). The new scholarship in teacher education. *Educational Researcher*, *28*(9), 4-15. doi: 10.3102/0013189X028009004.

EXPLORING TEACHER'S BELIEFS AND ATTITUDES TOWARDS TEACHING PHYSICS DURING A LESSON STUDY INTERVENTION

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ABSTRACT
This study explored how the beliefs and attitudes of teachers towards the teaching and learning of physics were influenced by participation in a lesson study intervention. Data for this study was collected through semi-structured interviews, and lesson observations conducted with four teachers from three South African schools. Analysis of the data following teacher's participation in the lesson study intervention indicated that teachers became more confident, determined and prepared to teach difficult concepts regardless of the learning situation; openly acknowledged that classroom collaboration could benefit learners' learning, changed their expressed beliefs about learners' difficulties. These findings suggest that creating opportunities for teachers to take ownership of learning activities during professional development programs may positively influence their beliefs and attitudes, as they become more practical, confident and enthusiastic about teaching physics.

Keywords: Attitudes and Beliefs, Lesson study, Physics

INTRODUCTION

The poor performance and low enrolment of learners in physics-oriented courses could be attributed to teachers' beliefs and attitudes developed towards physics (Bhargava & Pathy, 2014; Masood, 2014; Osborne, Simon, & Collins, 2003). Attitude is an essential disposition that directs the nature of human behavior and relates to how individuals manage emotions that occur during the learning process. There has been a global concern on the effect of teachers' beliefs and attitudes on learners' performance. However, less has been written on how teachers change their beliefs and attitude toward teaching. Teachers' attitudes being a component of teachers' emotional dispositions could include constructs like conceptions and awkward behaviors of teachers towards teaching physical science as a subject. Physics is a science subject perceived by some teachers and learners to be too mathematically oriented, too extensive and mostly dependent on textbooks (Bhargava & Pathy, 2014; Masood, 2014). Research indicates that learners' performance and enrolment in physics have been reflecting a decline over many years probably due to the abstract nature of the subject (American Association of Physics Teachers (AAPT, 2013). Teachers' emotional dispositions towards the teaching of science have been well documented (Ualesi & Ward, 2018). Thus, it is an important component required for improving learner's performance, as well as empowering physics teachers' quality and effectiveness. For instance, research has shown that some science teachers lack the educational background in science and consequently, fail to engage learners in hands-on practical activities that are physics-oriented (George, 2017; University of Vermont, 2018).

More so, Hannula, Di Martino, Pantziara, Zhang, Morselli, Heyd-Metzuyanim, Lutovac, Kaasila, Middleton, Jansen, and Goldin (2016) claims that there is a dialectical relationship between teachers' attitudes, beliefs and their classroom practice, as well as how their beliefs changes. Hence, the attitude of science teachers which could be formed by their belief about how learners learn, value teachers hold, classroom management practice, the nature of their scientific knowledge and instruction plays a significant role in improving the quality of physics teaching. Thus, the aim of this paper is to report on how teachers' participation in a lesson study intervention influenced teachers' beliefs and attitudes to teaching the physics part of the FET physical science curriculum within the South African context.

This paper report results from a larger study that focused on improving the teaching of electricity and magnetism in South Africa (Author, 2018). This study is informed by the notion that attitude is a structure of an individual's belief system (Jones & Carter, 2013). Research indicates that teacher's belief system has a direct implication on their classroom actions, which may improve or discourage learners' learning and academic performance (Loucks-Horsley, Stiles, Mundry, Love, & Hewson, 2009). For this reason, it is important to identify and clarify teachers' beliefs influencing their attitudes towards teaching physics (Haney & Lumpe, 1995). Research question: How do teachers' beliefs and attitudes towards teaching Electricity and Magnetism develop during participation in a Lesson Study intervention?

METHOD

A qualitative inquiry using an exploratory case study design was adopted in this study (Yin, 2014). A purposive and convenient sampling was employed in this study to capture specific attributes of four teachers from city and rural schools, knowing that it does not represent the whole population of physical sciences teachers in South Africa (Cohen, Manion & Morrison, 2007; Maxwell, 2013). Teachers participated in a five weeks intervention program designed to improve their teaching of electricity and magnetism. The various phases of the intervention program gave teachers the opportunity to collectively reflect, analyze, plan and discuss difficult physics topics within a community of practice. Teachers engaged in lesson study activities aimed at equipping them with a responsive classroom approach (Lewis& Hurd, 2011). Data were collected using interviews, and lesson observations, and analyzed by content analysis.

THEORETICAL FRAMEWORK

This study is underpinned by the theoretical construct of the adult learning theory (Knowles, 1980). The adult learning theory provides guiding principles that helps to understand how Lesson study as a professional development program was used to introspectively gain insight into teachers' personal beliefs and attitudes towards physics teaching (Peltz & Clemons, 2018). These guiding principles includes teachers' understanding of what learners needs to know, the role of learners' experience, learners' self-concept, learners' orientation to learning, readiness and motivation to learn (Knowles, 1980; Palis & Quiros, 2014). Within the context of this study, Lesson study was chosen and adapted as an In-school training approach to support the development of teachers' scientific skills and abilities in teaching physics.

Lesson study is a research-oriented practice that has successfully contributed to the high-quality teaching and learning practice in the Japanese educational system (Huang, Takahashi, & da Ponte, 2019). Doig and Groves (2011) indicated that the jointly organized classroom lessons conducted during lesson study often tend to develop attitudes, beliefs and understanding among participants. Thus, the various activities implemented during the collaborative phase of the lesson study intervention provided new experiences that created a unique learning opportunity for the teachers. However, the application of teachers' learning during the lesson study intervention was more evident in their ability to solve problems related to learners' difficulties and misconceptions in electricity and magnetism. However, the basis of adult learning theory in this study lies on teachers' motivation, interest, and capacity to work collaboratively; and this collaborative effort proved instrumental to the voluntary change that was observed in teachers' competencies in terms of their individual attitude and opinion about teaching and addressing learners' difficulties in physics.

RESULTS AND DISCUSSION

Data for the study presented in this paper were gathered from the analysis of teachers' interviews, lesson observations and reflective writing. Teachers in this study were observed during the adapted Lesson Study intervention. Prior to the commencement of this study, teachers expressed feelings of unpreparedness which was associated with teachers' lack of interest on specific topics they don't understand, thus affecting their attitude when teaching these topics to learners. For example, Mbali mentioned that she usually avoids answering questions from learners whenever she was teaching the concepts related to electromagnetism. However, the planning and reflection phase of the lesson study intervention helped her to become more prepared and confident, thereby increasing teachers' competency and positive attitude towards teaching physics concepts that appear difficult and confusing.

> *Participating in this program has helped me to a greater extent in bringing down this wall I have built around me when teaching electromagnetism which I initially don't answer some questions that learners tend to ask. I just teach and leave* (Mbali interview).

During the initial interview, Lenox indicated little concern about learners' problems in electromagnetism since learners are not assessed in the final Grade 12 examinations.

> *When we moderate for marking, we hardly consider electromagnetism as a difficult topic because learners are not assessed on that topic at the matric level* (Lenox interview).

This remark revealed a low level of enthusiasm and competence in teaching electromagnetism, caused by his belief. However, during the lesson observations, Lenox did show enthusiasm when teaching the collaboratively planned lesson. Prior to the lesson study, teachers rarely reflect on the effectiveness of their classroom instruction and learners' response to activities. For instance, the initial reply of teachers when reflecting on the difficulties of learners showed that all teachers demonstrated an undesirable attitude towards reflective practice. Nonetheless, two of the teachers mentioned that their rate of reflection shifted during participation in the study. During the initial consultation session with teachers, Martha mentioned that she only reflects and certainly explains a lesson again if she noticed that learners seem not to grasp the fundamental concepts relating to the topic that was taught.

> *I do my reflection whenever I have this feeling that I had a bad lesson and I just go back to re-explain the lesson again but during our first meeting, Mr. Alex's suggestion on the idea of allowing learners to observe, draw and discuss the magnetic field lines around the magnet made me realize that I could develop new methods of teaching the same lesson if I take my time to critically reflect on the previous method used. (Martha, interview)* .

However, participating in the Lesson Study intervention created an experience that helped teachers to reflect on their existing beliefs about learners' difficulties and their teaching methods, as they became open to alternative approaches, thereby improving their willingness to learn and adjust their instructional practices. For example, analysis of Martha's response shows that she often participates in compassion-based reflective actions, but taking part in this lesson study intervention improved her attitude and level of reflective practice. This was observed during the first phase of the intervention program, where she engaged in a relational analysis that accompanied a dialogue during the lesson study consultation meeting. It appears from the preceding findings that lesson study could, however, help teachers to critically examine their values and teaching attitudes, and thus improve their reflective practice. This finding supports Rock and Wilson's (2005) view that Lesson Study improves reflexivity in teachers.

The opportunity to reflect on their attitude towards teaching physical sciences impacted their perception and views about teaching physics concepts that are critical and more challenging to individual teachers.

CONCLUSIONS

In summary, findings of this study indicate that teachers' attitudes towards their classroom teaching was improved through their increased confidence level, increased level of reflection, improved pedagogical knowledge and skills. However, teachers informed attitudes did not always lead to improving their classroom effectiveness.

The result obtained with respect to this should not be generalized due to the small sample used. Nevertheless, results indicate that engaging teachers in research-based activities and giving teachers the opportunity to take ownership of learning opportunities during professional development is a promising way of fostering positive attitudes towards teaching physics within the South African context.

ACKNOWLEDGEMENT

This research is framed within the findings from a Ph.D. study conducted at the University of Pretoria. The support of the University's Postgraduate Research Support Bursary during the completion of the larger study is appreciated.

REFERENCES

American Association of Physics Teachers (2013). *Critical need for support of professional development for the teaching of Physics in K-12 Schools*. Retrieved on 28 April 2013 from www.aapt.org.

Bhargava, A. & Pathy, M. (2014). Attitude of student's teachers towards teaching profession. *Turkish Online Journal of Distance Education, 15*(3), 27-36.

Cohen, L., Manion, L., & Morrison, K. (2007). *Research methods in education (6th ed.)*. New York, NY: Routledge. ISBN 0-203-02905-4

Doig, B., & Groves, S. (2011). Japanese lesson study: Teacher professional development through communities of inquiry. *Mathematics teacher education and development*, *13*(1), 77-93.

George, M. J. (2017). Assessing the level of laboratory resources for teaching and learning of chemistry at advanced level in Lesotho secondary schools. *South African Journal of Chemistry*, *70*, 154-162.

Haney, J. J., & Lumpe, A. T. (1995). A teacher professional development framework guided by reform policies, teachers' needs, and research. *Journal of Science Teacher Education,* 6, 187- 196.

Hannula, M. S., Di Martino, P., Pantziara, M., Zhang, Q., Morselli, F., Heyd-Metzuyanim, E., Lutovac, S., Kaasila, R., Middleton, J.A., Jansen, A., & Goldin, G. A. (2016). *Attitudes, Beliefs, Motivation and Identity in Mathematics Education: An Overview of the Field and Future Directions*. (ICME-13 Topical Surveys). Cham: Springer International Publishing. https://doi.org/10.1007/978-3-319-32811-9

Huang, R., Takahashi, A., & da Ponte, J. P. (2019). Theory and Practice of Lesson Study in Mathematics. Switzerland, AG: Springer.

Jones, M. G., & Carter, G. (2013). Science teacher attitudes and beliefs. In *Handbook of research on science education* (pp. 1081-1118). Routledge.

Knowles MS 1980. *The modern practice of adult education: From pedagogy to andragogy*. Englewood Cliffs, NJ: Cambridge Adult Education.

Lewis, C. C. & Hurd, J. (2011). *Lesson Study step by step: How teacher learning communities improve instruction*. Portsmouth, NH: Heinemann.

Loucks-Horsley, S., Stiles, K. E., Mundry, S., Love, N., & Hewson, P. W. (2009). *Designing professional development for teachers of science and mathematics*. Thousand Oaks, CA: Corwin Press.

Masood, S. S. (2014). How to control the decrease in Physics enrolment? *arXiv preprint arXiv:1405.6442*. Retrieved from https://arxiv.org/abs/1405.6442.

Maxwell, J. A. (2013). Qualitative research design: An interactive approach (3rd ed.). *Applied social research methods, 41*. Thousand Oaks, CA: Sage

Osborne, J., Simon, S., & Collins, S. (2003). Attitude towards science: a review of the literature and its implications. *International Journal of Science Education, 25*(9), 1049-1079.

Palis, A. G., & Quiros, P. A. (2014). Adult learning principles and presentation pearls. *Middle East African journal of ophthalmology*, *21*(2), 114.

Peltz, D. P., & Clemons, A. C. (Eds.). (2018). *Multicultural andragogy for transformative learning*. Hershey PA, USA: IGI Global.

Rock, T. C., & Wilson, C. (2005). Improving teaching through lesson study. *Teacher education quarterly*, *32*(1), 77-92.

Ualesi, Y. & Ward, G. (2018). Teachers' Attitudes Toward Teaching Science in a New Zealand Intermediate School. *Australian Journal of Teacher Education*, 43 (6). Retrieved from http://dx.doi.org/10.14221/ajte.2018v43n6.3

University of Vermont (2018). "Teachers lacking educational background in science use inquiry-oriented instruction least: Not using the pedagogical approach heralded by the National Research Council could be linked to unfilled STEM jobs." ScienceDaily. ScienceDaily, 2 July 2018. Retrieved from: <www.sciencedaily.com/releases/2018/07/180702094100.htm>.

Yin, R. K. (2014). Case study research: Design and methods (5th ed.). Thousand Oaks, CA: Sage.

IN-SERVICE CHEMISTRY TEACHERS' PCK OF ELECTROCHEMISTRY: A CASE IN SÃO PAULO, BRAZIL

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The aim of this study is to investigate chemistry teachers' PCK of galvanic cells through a mixed-method case study. The sample consisted of 128 in-service chemistry teachers from São Paulo, Brazil, and the data were collected using an adapted version of the PCK of Electrochemistry Test. Teachers' responses to each question were analysed in a five-point scale reflecting the PCK quality. Then, raw scores were analysed by Rasch Partial Credit Model and the teachers were stratified in five levels using the Scale Characteristic Curves methodology. The outcomes of this study revealed that teachers had a good or medium score in questions about learner prior knowledge, curricular salience and difficult aspects to teach; and low score in questions about representations use and conceptual teaching strategies. Concerning the teachers stratification, most of the teachers are in the low levels (3 in the 'no shown', 28 in the 'limited' and 82 in the 'basic'). Thus, in general, teachers presented low scores on the PCK of Electrochemistry Test and, consequently, it is necessary, in the Brazilian context, the production and teaching of continuous professional development courses that covered this topic.

Keywords: pedagogical content knowledge, teaching of electrochemistry, Rasch analysis

INTRODUCTION

In the literature, there have been emerging studies to better understanding the complexity in electrochemistry teaching. In the Brazilian context, Nogueira, Goes, and Fernandez (2017) claim chemistry teachers, students, and textbooks show difficulties in understanding the redox reactions simultaneity and the difference between galvanic and electrolyte cells. In addition, Marcondes, Souza, and Akahoshi (2017) emphasize that although chemistry teachers focus on teaching galvanic cells, this teaching is superficial as these teachers do not prioritize concepts such as salt bridge and half-cell reactions. Therefore, to teach electrochemistry, teachers should improve their knowledge of students' alternative conceptions about electrochemical phenomena, their knowledge about curricular saliency, and their own difficulties in understanding electrochemistry subject matter.

The aspects aforementioned can be studied from the perspective of Pedagogical Content Knowledge (PCK). This knowledge was proposed by Shulman (1986) and is "the ways of representing and formulating the subject that make it comprehensible to others" (p. 9) and also "an understanding of what makes the learning of specific topics easy or difficult" (p.9).

From Shulman's PCK definition, some researchers proposed PCK models (e.g Magnusson, Krajcik & Borko, 1999, Rollnick et al., 2008). Between these models, we decided to use the

Topic Specific PCK model (Mavhunga, 2012) as this one focuses on the subject matter knowledge in a topic-specific level. According to this model, PCK has the following components: a) leaner prior knowledge (LPK); b) curricular saliency (CSL); c) what is difficult to teach (DFT); d) representations (REP); e) conceptual teaching strategies (CTS).

To better know PCK quality of in-service chemistry teachers from São Paulo state, Brazil, in teaching galvanic cells, a central idea of Electrochemistry, this study has the aim to investigate chemistry teachers' PCK of galvanic cells.

METHODOLOGY

The research design to investigate chemistry teachers' PCK of galvanic cells was based on a mixed-methods case study (Creswell & Clark, 2017). In this paper, we will focus on the quantitative part.

Sample

The sample consisted of 128 in-service high school chemistry teachers from São Paulo State, Brazil. The teachers selection was conducted through convenience sampling (Creswell, 2012): almost all of them were personally asked to answer the test when they attended professional development courses offered by the authors; the other teachers were asked by email to answer the test.

Chemistry teachers' characteristics as major degree, gender, and professional experience can be seen in Table 1.

Table 1. Chemistry teachers' characteristics.

Major degree					Gender	
Chemistry	Biology	Science	Physics	Others	Male	Female
96	14	06	02	10	56	72

School kind				Experience teaching Electrochemistry		
Public	Private	Both	NA	Yes	No	NA
108	02	17	01	90	36	02

Experience time				
Mean	S.E.	Range	Minimum	Maximum
15	7.1	35	1	36

Instrument

We collected the data using an adapted version of the PCK of Electrochemistry Test (A-PCKET; Ndlovu, 2014). The adapted version has 07 open-ended questions addressing the TSPCK categories proposed by Mavhunga (2012), namely: Curricular Saliency, What is difficult to teach, Representations, Students Prior Knowledge, and Conceptual Teaching Strategies.

The main modifications we did in the test were: (i) removing Electrolytic Cells questions to focus only in Galvanic Cells, since the latter is more emphasized by Brazilian chemistry teachers (Marcondes, Souza, & Akahoshi 2017) and; (ii) reducing the number of questions to shorten the test accomplishment time. An overview of the A-PCKET can be seen in Table 2.

Table 2. Description of the A-PCKET questions.

Nº	PCK component	Purpose	Source
1	CSL	Identifying and sequencing central ideas in electrochemistry teaching	Adapted of Ndlovu (2014)
2	CSL	Identifying the main chemistry topics necessary for teaching electrochemistry	Adapted of Ndlovu (2014)
3	DFT	Identifying the main difficulties in electrochemistry teaching	Adapted of Ndlovu (2014)
4	REP	Identifying good and bad aspects of representations and how to use them in teaching	Adapted of Ndlovu (2014)
5	LPK	Identifying students' alternative conceptions about oxidation, reduction, cathode, and anode.	Elaborated by authors
6	LPK	Identifying students' alternative conceptions about electrons flow and salt bridge.	Adapted of Ndlovu (2014)
7	CTS	Elaborating a class to confront students' alternative conceptions about galvanic cells	Elaborated by authors

Data analysis

We scored the teachers' responses to the PCKET items using a rubric corresponding to each question. This rubric have a five-point scale reflecting the PCK quality: 0 to 'not manifested' PCK; 1 to 'limited'; 2 to 'basic'; 3 to 'developed' and; 4 to 'exemplary'. The raw score was analysed thought Rasch Partial Credit Model (Boone, Staver & Yale, 2014) using the Winsteps© Rasch Measurement 4.4.1 (Linacre, 2019) software.

Two parameters were used to verify if the test fit the Rasch Model and, consequently, if it is valid to assess the high school chemistry teachers from São Paulo: the mean-square (MnSq) and z-standardized (ZStd) outfit statistics. Moreover, the reliability of the persons and of the questions was calculated.

At last, the teachers were stratified in five strata (the same of the rubric) according to their PCK score. To do that, we used the Scale Characteristic Curve (SCC) methodology (Dogan, 2018). In this methodology, all items characteristic curves are summed to obtain a scale characteristic curve.

RESULTS AND DISCUSSION

Instrument quality

The MnSq and ZStd outfit values asses if the empirical data agree with the expected values given by the Rasch Model. The recommended values are: $0,5 < MnSq < 1,5$ or $-2,0 < ZStd < 2,0$ (Kirschner, et al. 2016). As we can see in Table 3, all questions were between the expected values. Concerning the test reliability, question and person reliability were both calculated. According to Linacre (2018), it is recommended values, respectively, greater than 0.9 and 0.8. The test also achieves the recommended values in this aspect.

Table 3. Questions fit, questions reliability and persons reliability.

Question	MNSQ outfit	ZSTD outfit	Questions reliability
1 (CSL)	1.07	0.55	0.93
2 (CSL)	1.00	0.05	
3 (DFT)	1.15	1.13	**Persons reliability**
4 (REP)	0.93	-0.39	
5 (LPK)	0.96	-0.1	0.81
6 (LPK)	0.83	-1.19	
7 (CTS)	0.83	-0.90	

To increase the test validity, the predictive validity was analysed as well. In this analyse, the theoretical score ordering of teachers is compared with the empirical one (Linacre, 2018). Since the A-PCKET is about Electrochemistry teaching, we expected teachers without a chemistry degree to have low scores. As can be seen in the Item-person map shown in Figure 1, most of the teachers without a chemistry degree are below the teachers' mean (teachers in the square). Moreover, the teachers with the lowest scores are those without a chemistry degree. Thus, the order of theoretical scores, based on the PCK theory, is equal to the empirical one and, therefore, the test validity is increased.

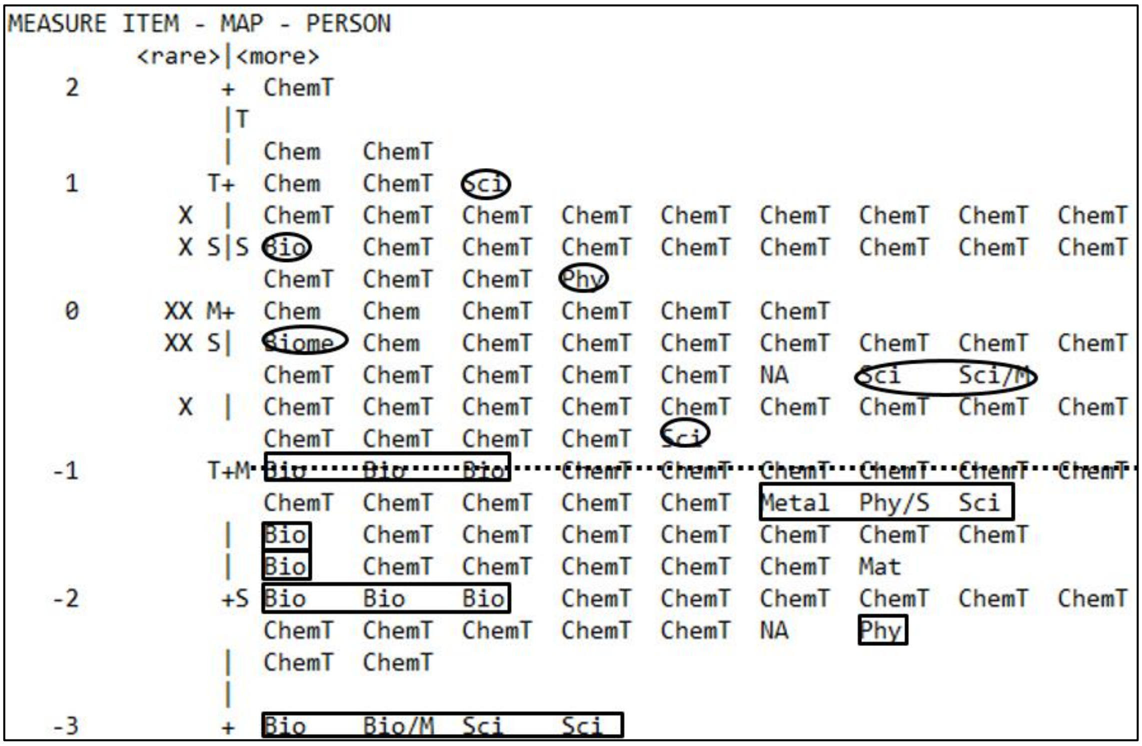

Figure 1. Item-person map emphasizing the scores of teachers without major in Chemistry.

Note: The dashed line represents the teachers' mean. Teachers in the square have a score below the mean. Teachers in the circle have a score above the mean. "Chem" is chemistry, "Sci" is science in elementary classes, "Phy" is physics, "Bio" is biology, "Metal" is metallurgical engineer, and "Biome" is biomedicine science.

Since the test showed fit values (MnSq and ZStd outfits), reliabilities and score ordering (predictive validity) into the expected, we claim the A-PCKET produced validity results and can be used in the São Paulo context.

Items difficulties

Regarding teachers' performance, they had medium scores in DFT, CSL and LPK questions (consequently, these questions had a smaller measure of difficulty), as shown in Table 4. REP and CTS questions proved to be very hard questions and had the highest difficult measure. Since the ability to use representations and conceptual teaching strategies requires the integration of the other components (e.g. using some representations to confront some student difficult) (Rollnick & Mavhunga, 2014), it is expected that those questions to be the most difficult.

Table 4. The measure of questions difficulties and teachers' knowledge.

	1 (CSL)	6 (LPK)	3 (DFT)	5 (LPK)	2 (CSL)	7 (CTS)	4 (REP)	Questions mean	Teachers mean
Measure	-0.65	-0.25	-0.25	-0.09	0.05	0.40	0.79	0.00	-0.99

About the difficulty of the test in general, when the test is easy for teachers, the teachers mean is higher than questions mean; otherwise, if the test is difficult, the teachers mean is lower. Comparing in our case, in Table 3 it is possible to see that PCKET is very difficult for teachers. These results agree with research reports: electrochemistry is, despite teachers' experience, a very difficult topic to teach (Ndlovu, 2014, Rollnick & Mavhunga, 2014).

Teachers stratification

The resulting SCC originated by teachers' answers to A-PCKET is shown in Figure 2. In the Scale Characteristic Curve (Dogan, 2018), the x-axis is the teachers' score in the test, the y-axis shows the expected number of items teachers scored on each curve, and the points where one curve intersects other are the cut-off criteria. For example, a teacher with a measure of 1.6 (the last cut-off point) is more likely to score "exemplary" and "developed" in three questions and "basic" in one.

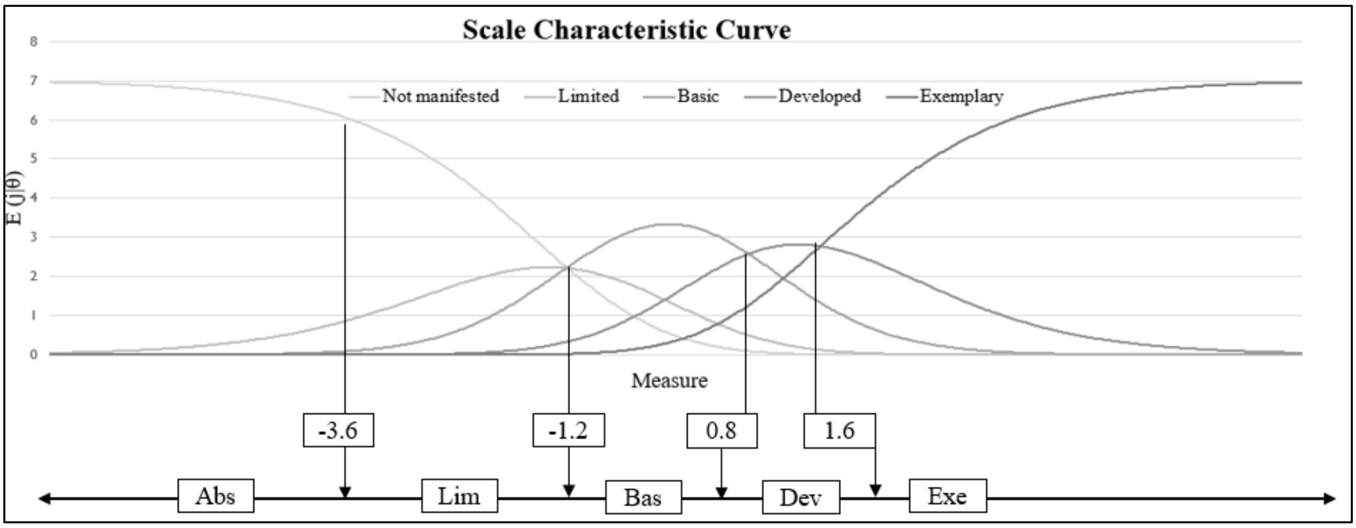

Figure 2. Scale characteristic curve originated by teachers' answers to A-PCKET.

As can be seen in Figure 2, the SCC has three cut-off points related to the intersection of the curves (-1.2, 0.8, and 1.6). However, in addition to these points, we also added one more: -3.6.

We did that because we consider that to manifest a PCK in the test, teachers must get at least one question with a "limited" score. If teachers score all questions with 'not manifested', we consider that teachers did not manifest PCK in the test situation.

Thus, with these four cut-off points, we have five PCK levels. In the first one, 'not manifested', teachers get a 'not manifested' score in all questions. In the second one, 'limited', teachers get at least one item with a 'limited' score, but could have some items with 'basic'. In the third one, 'basic', teachers get mainly 'basic' score and have chances to get 'limited' and 'developed' scores. In the fourth level, 'developed', teachers get mainly developed score and could get 'basic' and 'exemplary'. In the last level, 'exemplary', teachers get more 'exemplary' and 'developed' scores.

The teachers distribution in those five levels can be seen in Figure 3. It is perceived the teachers' low scores on A-PCKET also is reflected in PCK levels: most of the teachers have limited or basic PCK level.

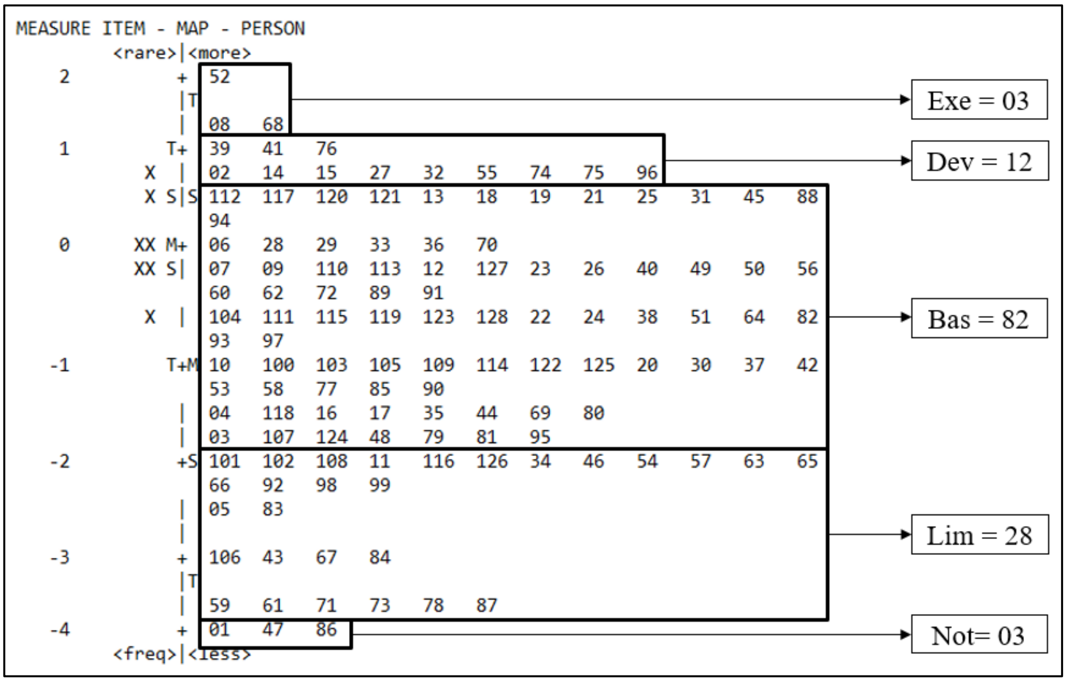

Figure 3. Teachers stratification in four levels: limited, basic, developed, and exemplary.

CONCLUSION

From the outfit, reliability and predictive validity results, it is possible to see that the adapted version of PCKET (Ndlovu, 2014) was able to be used in the São Paulo context and allows us to investigate in-service chemistry teachers' PCK of galvanic cells. The score of teachers was medium in five questions: identifying central ideas and previous content to teach electrochemistry (questions 1 and 2); identifying difficulties aspects to teach electrochemistry (question 3), and recognizing learner prior knowledge about electrons flow/salt bridge and oxidation/reduction (question 5 and 6). Moreover, teachers present great difficulty in two questions: assessment and use of representations (question 4); proposed a conceptual teaching strategy (question 7). Therefore, in general, teachers presented low scores on PCKET, and most of them have limited or basic level on PCK of electrochemistry.

There are two possible explanations for the teachers' low score on PCKET: lack in subject matter knowledge (SMK), which does not allow the PCK development (Rollnick et al., 2008) and; lack in the integration of PCK components, which results in an isolated and, consequently, undeveloped PCK. In this sense, the investigation of the teachers' SMK and integration between PCK components is necessary and is the next step in our research.

Besides that, we will conduct a qualitative multiple case study to investigate the differences between teachers' PCK level. In this sense, we will choose some teachers from each strata and each group of teachers will be a case. From this, we expected to get a better understanding of how PCK of Electrochemistry can be developed though the different levels and then propose continuous professional development courses covering this topic, mainly in use of representations and conceptual teaching strategies.

ACKNOWLEDGEMENT

The authors are grateful to the financial support granted by São Paulo Research Foundation (FAPESP), grants #2013/07937-8 and #2016/14138-2.

REFERENCES

Boone, W., Staver, J. R., & Yale, M. S. (2014). *Rasch analysis in the Human Sciences*, Dordrecht: Springer.

Creswell, J. W. (2012). *Educational research: Planning, conducting, and evaluating quantitative and qualitative research* (4th ed.). Boston, MA: Pearson.

Creswell, J. W., & Clark, V. L. P. (2017). *Designing and conducting mixed methods research*. Thousand Oaks: SAGE.

Dogan, E. (2018). An application of the Partial Credit IRT Model in identifying benchmarks for Polytomous Rating Scale Instruments. *Practical Assessment, Research & Evaluation*, 23(7).

Kirschner, S. et al. (2016). Developing and evaluating a paper-and-pencil test to assess components of physics teachers' pedagogical content knowledge. *International Journal of Science Education, 38(8)*, 1343–1372.

Linacre, M. K. (2018). *A user's guide to Winsteps Rasch-Model computer programs*. Chicago: Winsteps.com

Linacre, M. K. (2019). Winsteps© Rasch Measurement (Version 4.4.1) [Computer software]. Chicago: Winsteps.com. Retrieved from: http://www.winsteps.com

Magnusson, S., Krajcik, J., & Borko, H. (1999). Nature, sources and development of pedagogical content knowledge for science teaching. In: J. Gess-Newsome, N. G. Lederman (Ed.), *Examining pedagogical content knowledge*. Dordrecht: Kluwer Academic Publishers.

Marcondes, M. E. R., Souza, F. L., Akahoshi, L. H. (2017). Conteúdos de eletroquímica e focos de ensino evidenciados por professores de Química do Ensino Médio. *Enseñanza de Las Ciencias, Extra*, 5673–5678.

Mavhunga, E. (2012). *Explicit inclusion of topic specific knowledge for teaching and the development of PCK in pre-service science teachers* (doctor's thesis). Faculty of Humanities, University of the Witwatersrand, Johannesburg.

Ndlovu, M. (2014). *The design of an instrument to measure physical science teachers' topic specific pedagogical content knowledge in electrochemistry* (master's thesis). Faculty of Science, University of the Witwatersrand, Johannesburg.

Nogueira, K. S. C., Goes, L. F., & Fernandez, C. (2017). As limitações de ensino-aprendizagem associadas ao conteúdo redox nos eventos brasileiros. *Enseñanza de Las Ciencias*, *Extra*, 4197–4202.

Rollnick, M. & Mavhunga, E. (2014). PCK of teaching electrochemistry in chemistry teachers: a case in Johannesburg, Gauteng Province, South Africa. *Educación Química, 25(3)*, 354–362.

Rollnick, M., Bennett, J., Rhemtula, M., Dharsey, N., & Ndlovu, T. (2008) The place of subject matter knowledge in pedagogical content knowledge: a case study of South African teachers teaching the amount of substance and chemical equilibrium. *International Journal of Science Education, 30(10)*, 1365–1387.

Shulman, L. S. (1986). Those who understand: Knowledge growth in teaching. *Educational Researcher*, *15(2)*, 4–14.

ORIENTATION TO TEACHING INTRODUCTORY ELECTRICITY – AIMS AND MOTIVES OF TEACHERS

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This study investigates the aims and motives regarding the teaching of introductory electricity of 34 physics teachers from parts of Austria and Germany. According to the model of teacher professional knowledge and skill, teacher's beliefs and orientations act as amplifiers and filters when it comes to personalising professional knowledge during their actual teaching practice. The construct of Orientation to Teaching Science (OTS) as one type of such filters serves as a theoretical basis for this study. According to Magnusson, Krajcik, & Borko (1999), an orientation presents a "general way of viewing and conceptualising science teaching". However, recent research suggests that OTS can differ from topic to topic. Hence, the goal of this study is to search for first hints of topic-specific teaching orientations among the teachers participating in a design-based research project on introductory electricity. As a first step we administered an open-ended questionnaire to 34 teachers in parts of Austria and Germany to identify their aims and motives regarding teaching introductory electricity at middle school. The results of the subsequent qualitative content analysis and their relation to Orientation to Teaching Science are reported in this article.

Keywords: Teacher Professionalism, Teacher Thinking, Teaching Practices

INTRODUCTION

The resources teachers draw upon in their daily teaching routine have been one focus in science education research in the past decades. Nearly each study regarding teachers' resources that influence teaching mentions (Shulman, 1987) initial conceptualization of pedagogical content knowledge (PCK). Nevertheless, there was little consensus among science education researchers how PCK should be conceptualised (Loughran, Mulhall, & Berry, 2004; Magnusson, Krajcik, & Borko, 1999). One approach to specifying PCK was developed during the first PCK-Summit held in 2013, which resulted in the formulation of "the model of teacher professional knowledge and skill (TPK&S)" (Berry, Friedrichsen, & Loughran, 2015). The innovations resulting from this frequently-called "consensus model" is a differentiation between personal PCK and skills on the one hand and topic-specific professional knowledge (TSPK) on the other hand as well as a distinction between teachers' PCK and their beliefs and orientations. In this model, beliefs and orientations act as amplifiers and filters that personalise knowledge, which teachers have acquired during their studies and years of teaching practice. As Gess-Newsome (2015) puts it, this knowledge must pass through the lens of teachers. This idea of amplifiers and filters may also account for findings that show that for example professional development does not have a direct effect on teachers' classroom practice (Gess-Newsome, 2015).

THEORETICAL FRAMWORK AND RESEARCH QUESTIONS

In recent years, many studies regarding teachers' beliefs, especially epistemological beliefs, have been conducted. However, the concept of Orientation to Teaching Science (OTS) and its role as an amplifier or filter is underrepresented in research. According to Magnusson, Krajcik and Borko (1999), an "orientation presents a general way of viewing science teaching" and "serves as a conceptual map that guides instructional decisions". However, in an extensive review of literature, Friedrichsen et al. (2011) identified four major problems concerning OTS: "Using OTS in different or unclear ways", "Unclear or absent relationship between orientations and other PCK model components", "Assigning science teachers to one of the nine orientations proposed by Magnusson et al. (1999)" and "Ignoring the overarching orientation component". However, they identify a consensus about three dimensions of OTS. These are (1) beliefs about the goals and purposes of science teaching, (2) beliefs about the nature of science and (3) beliefs about science teaching and learning. Furthermore, Campbell, Melville and Goodwin (2017) found first hints that OTS is, like TSPK, topic specific. Subsequently, the conceptualisation of Orientation to Teaching Science only as an overarching, topic-independent set of beliefs is not satisfactory. We think of OTS as an overarching concept, similar to the description given by Magnusson et al. (1999), but there might be further subcategories of OTS that especially influence the teaching-style of various topics within a subject. Hence, we propose a topic-specific orientation to teaching science, in the case of introductory electricity "orientation to teaching introductory electricity (OTIE)".

The main aim of our study, which is part of a DBR project on teaching introductory electricity in middle schools (Haagen-Schützenhöfer, Burde, Hopf, Spatz, & Wilhelm, 2019) is to investigate whether this conceptualisation is meaningful and if this topic-specific orientation can be captured. To do so, in a first step we administered an open-ended questionnaire to 34 teachers in parts of Austria and Germany to identify their aims and motives regarding the instruction of introductory electricity. Doing so, we want to gain first insights about the topic-specificity of the participants' beliefs about the goals and purposes of teaching introductory electricity and their beliefs about teaching and learning introductory electricity on a superficial level. We interpret the answers to the questions in the questionnaire as hints regarding the teachers' beliefs. Furthermore, these insights form the basis for in-depth interviews, which are not reported in this article. Hence, the analysis was guided by the following research questions:

RQ1: What are the most important key ideas/aspects teachers want to convey in their introductory electricity lessons?

RQ2: How do the participating teachers rate the importance of the use of models, experiments and calculations for their teaching and students' learning of introductory electricity and what are the reasons for their rating?

DESIGN & METHODS

This study is embedded in a large DBR project on introductory electricity carried out in parts of Austria and Germany. In the first year of this project, participating teachers followed their usual approach to introductory electricity in 7^{th} and 8^{th} grade middle school. Different types of data were collected for this study during this period, the results presented in this article are a small part of the overall project. After teaching introductory electricity, participating teachers were asked to fill in an online-questionnaire. In total, 34 physics teachers (M_{age} = 40.4 years, SD_{age} = 9.9 years, N_{female} = 15, N_{male} = 19, $M_{teachexp}$ = 13, $SD_{teachexp}$ = 7.48) filled in the online-questionnaire. Among other questions, which are not reported in this article, the teachers were asked about certain aspects of their introductory electricity lessons which correspond with the research questions of this article. These questions were:

1. What are the three most important key ideas you want to convey in your introductory electricity lessons?
2. a) How important are models for teaching introductory electricity?
   b) What are the reasons for your rating in 2a)?
3. a) How important are experiments for teaching introductory electricity?
   b) What are the reasons for your rating in 3a)?
4. a) How important are calculations for teaching introductory electricity?
   b) What are the reasons for your rating in 4a)?

The first question was formulated as an open-ended question, whereas questions two to four were two-tiered questions. In the first tier, the teachers were asked to rate the importance of models/experiments/calculations in general on a likert scale ranging from one (not important) to four (very important). In the second tier, the teachers were asked for the reasoning behind their rating. All open-ended questions were analysed by means of qualitative content analysis (Mayring, 2010).

FINDINGS & RESULTS

In this section, the results of the ratings from the likert scale items as well as the resulting categories from the qualitative content analysis are reported.

Important key ideas when teaching introductory electricity

In order to answer research question one, the answers regarding the question "What are the three most important key ideas you want to convey in your introductory electricity lessons?" were analysed inductively, some answers were assigned to two categories. The resulting categories are shown in Figure 1. The colour coding represents the priority of the answers from the teachers, the percentages refer to all 34 teachers.

The distribution of the categories shows that the participating teachers follow quite different key ideas in their introductory electricity lessons, since there is no predominant category. Electricity in everyday life is the most frequently mentioned category (53% of all teachers), followed by introducing a model representation of electric current (42%) and thematising the basic quantities voltage, current and resistance (38%). In addition to categories which are specific to introductory electricity, some teachers also mentioned more general key ideas like conducting experiments (24%), enjoying physics (12%) and performing measurements (9%). Only one teacher (3%) mentioned understanding the Nature of Science as one of the three most important key ideas.

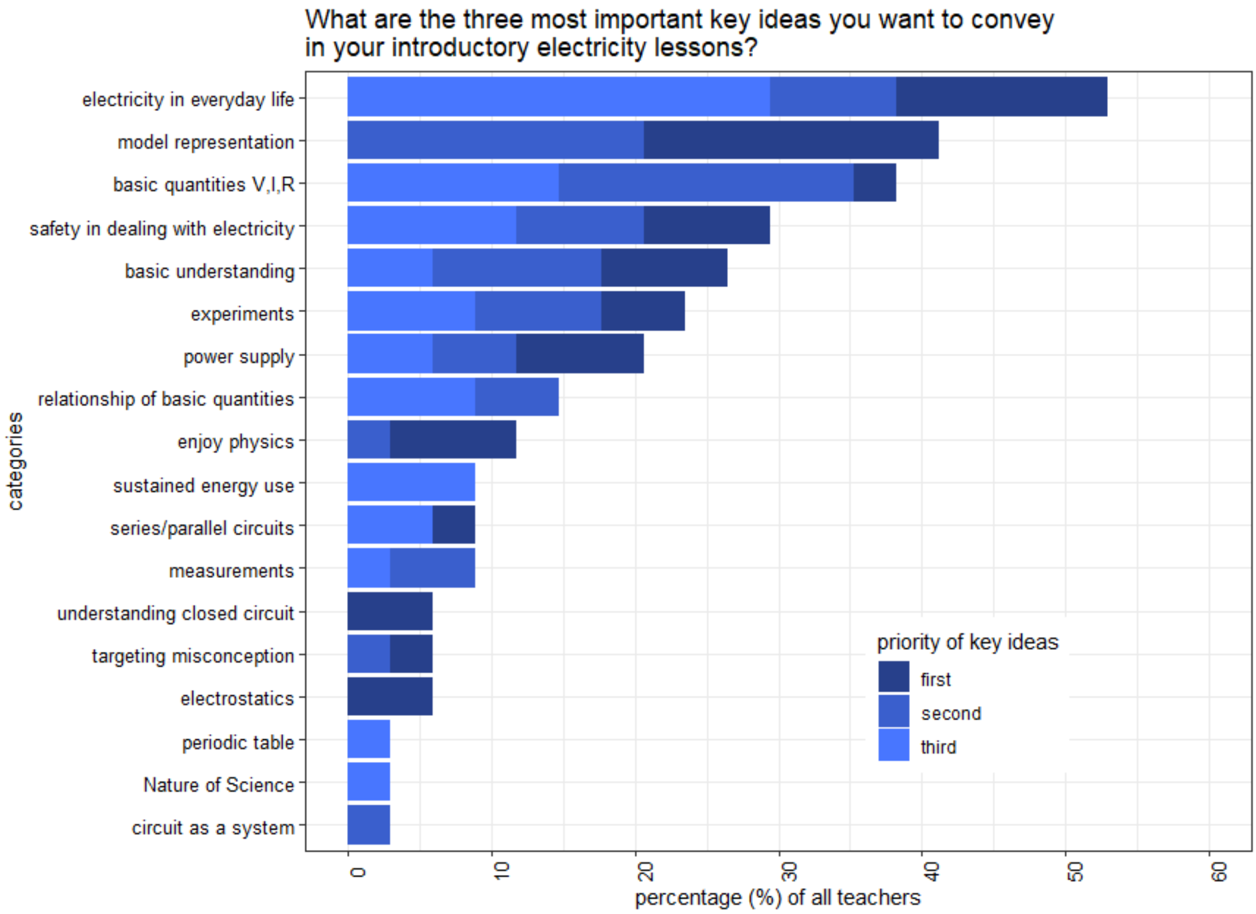

Figure 1. Teachers' answers regarding the question "What are the three most important key ideas you want to convey in your introductory electricity lessons?"

Perceived importance of calculations, experiments and models for teaching introductory electricity

In this section, the distribution of the ratings regarding the questions “How important are models/experiments/calculations for teaching introductory electricity?” are presented. In the subsequent sections, the teachers’ reasonings behind their rating are discussed. The distribution of the ratings is shown in Figure 2.

Regarding the perceived importance of models, almost all of the participating teachers rate the use of models as very (56%) or rather important (38%). A similar result is reported for the perceived importance of experiments, where 59% of all teachers rate experiments as very important for teaching introductory electricity and 35% rate it as rather important.

The results concerning the question “How important are calculations for teaching introductory electricity?” are rather heterogeneous. About half of the teachers rate calculations as rather (47%) or very (6%) important, whereas the other half of the teachers rate calculations as rather not (41%) or not (6%) important.

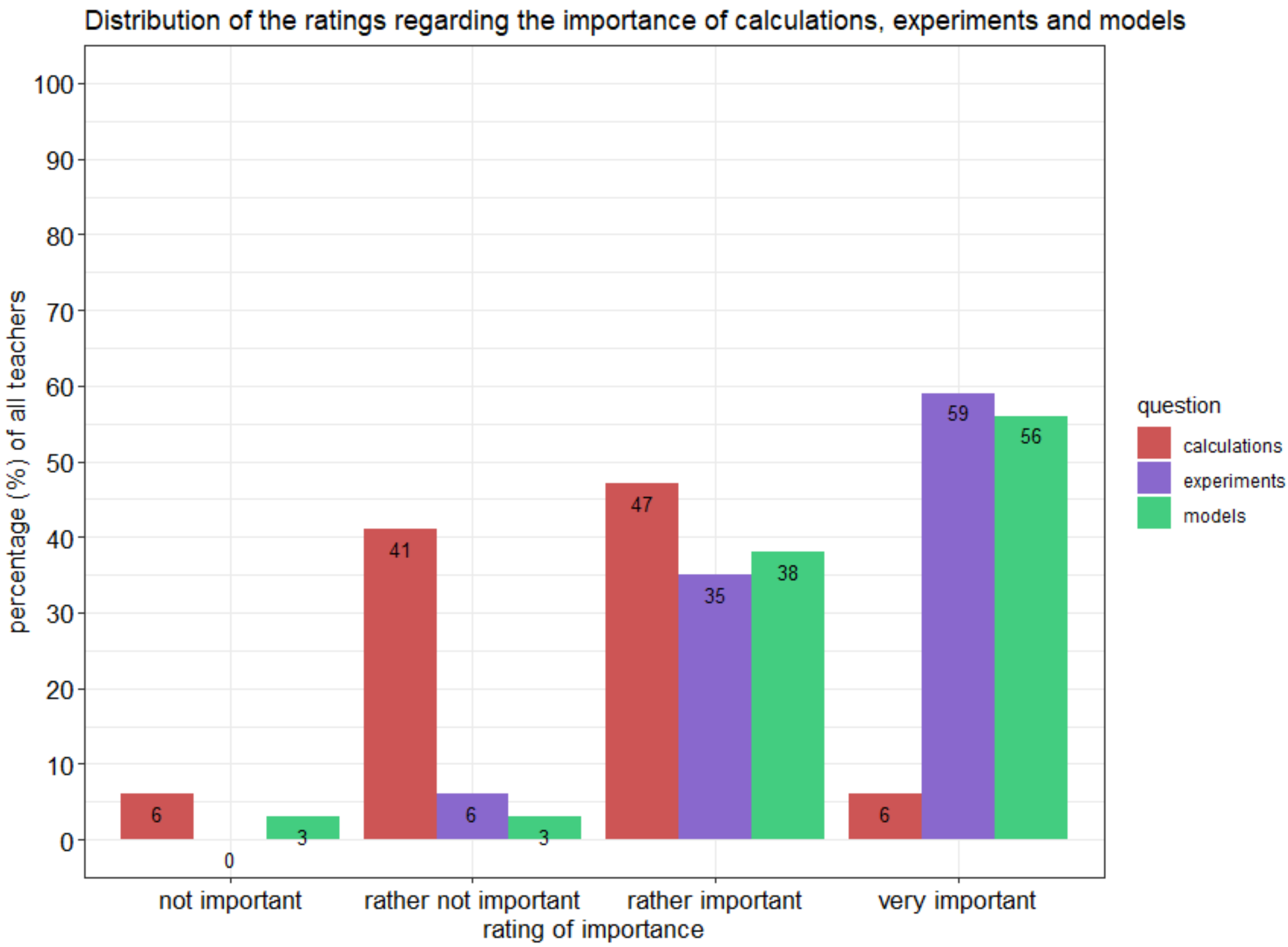

Figure 2. Distribution of the teachers' ratings regarding the importance of calculations, experiments and models for teaching introductory electricity

Perceived importance of models for teaching introductory electricity

Figure 3 shows the resulting categories of the reasoning behind the rating regarding the importance of models. Answers from three teachers were assigned to two categories, resulting in a total amount of 37 codes. However, the percentages reported in Figure 3 refer to the 34 teachers. 65% of the teachers report "models illustrate the abstract" as their reasoning behind their rating, all of them rated models as rather or very important. Answers attributed to this category also frequently mention that electric current is invisible and hence needs to be represented using a model. Hence, this category can be seen as topic-specific for electricity.

In contrast, the categories "models as an important part of physics" (26%) and "models facilitate learning" (18%) are rather general, topic-independent categories. Additionally, one teacher argues that models are not important for introductory electricity because they are too complicated for children at this age (grade 7 and 8). Another teacher argues that models are not central for his or her teaching without any further explanation.

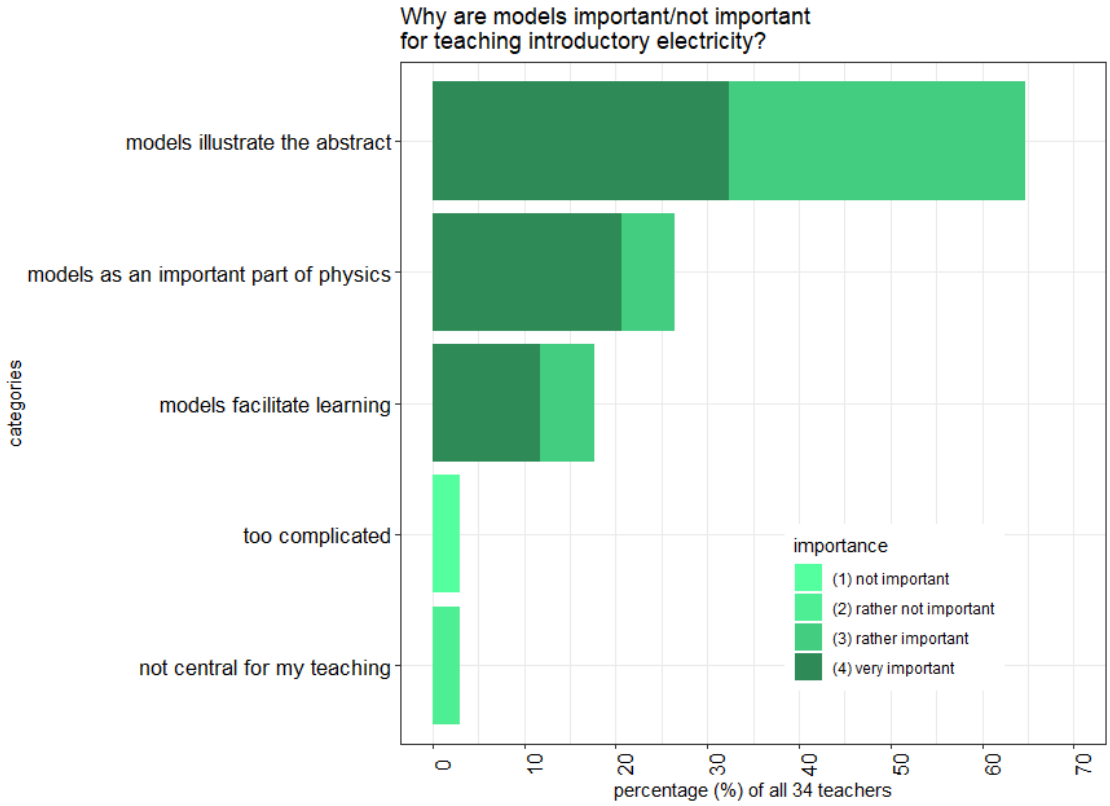

Figure 3. Teachers' reasonings regarding the question "Why are models important/not important for teaching introductory electricity?" The rating refers to the general importance of models for teaching introductory electricity, while the categories represent the different reasonings behind the rating of the importance

Perceived importance of experiments for teaching introductory electricity

Almost all of the teachers rate experiments as rather (35%) or very (59%) important for teaching electricity, whereas only two teachers (6%) rate them as rather not important. The latter group argues that experiments are overestimated for learning content knowledge, as shown in Figure 4. Again, the answers from some teachers were assigned to multiple categories, however the percentages in the figure refer to the 34 teachers. Although there is consensus among the teachers that experiments are important, the reasons for their opinion are quite diverse.

Similar to the findings concerning the use of models, some reasonings for the use of experiments are of a topic-specific nature whereas others are more general and topic-independent. For example, the most dominant category “experiments facilitate learning” (32%) is a general category and reasonings that were assigned to this category do not refer to any topic-specific aspects. This also applies to the category “interest/motivation” (24%). Reasonings assigned to this category explain that experiments spark interest or improve the motivation of students. However, the categories “electric current is invisible” (32%) or “experience electricity phenomena” (9%) are clearly topic-specific for (introductory) electricity. An additional, interesting, finding is that while teachers perceive models as important for teaching introductory electricity because models are an important part of physics, experiments are important due to other reasons. Only one teacher emphasises that experiments are important because they are a crucial part of physics.

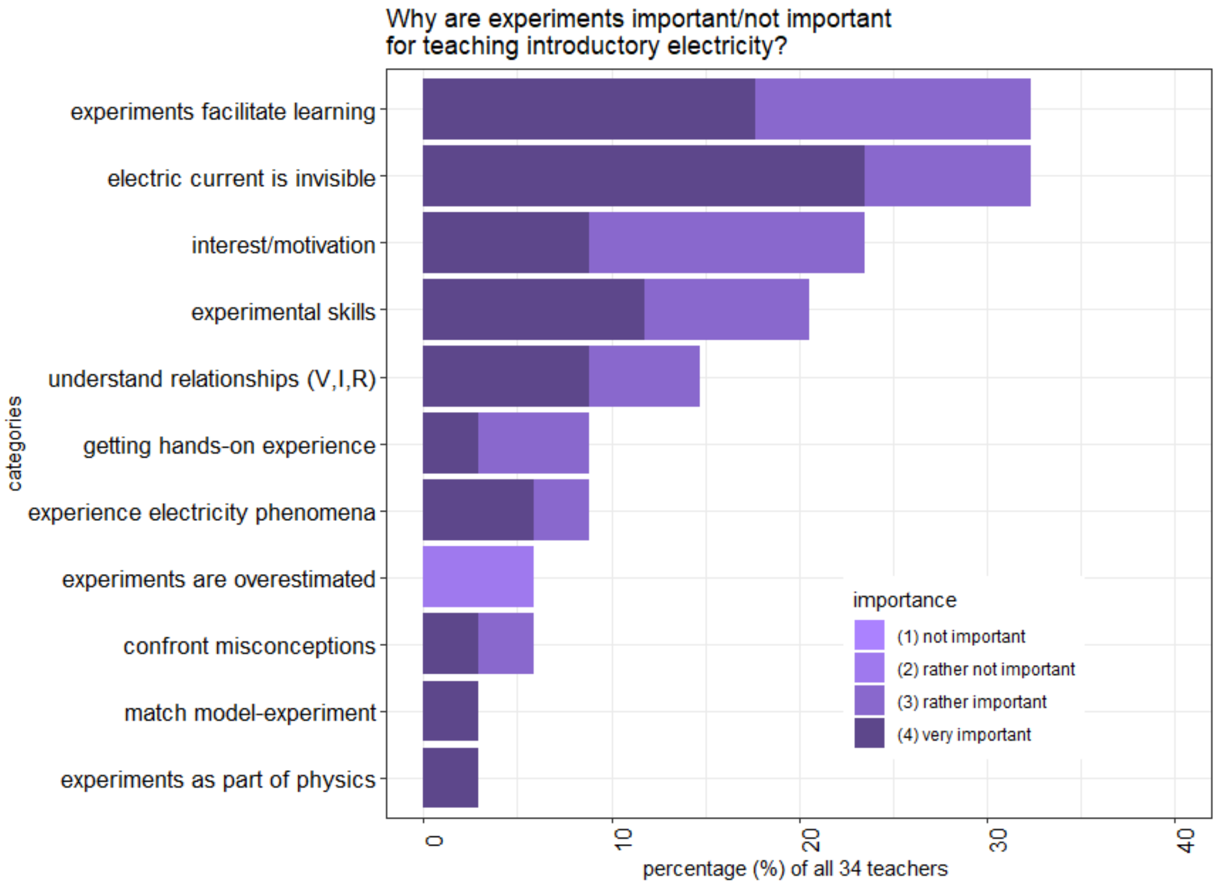

Figure 4. Teachers' reasonings regarding the question "Why are experiments important/not important for teaching introductory electricity?" The rating refers to the general importance of experiments for teaching introductory electricity, while the categories represent the different reasonings behind the rating of the importance

In total, the resulting categories concerning the use of experiments can be attributed to three overarching themes:

1. Experiments facilitate learning, interest and motivation
2. Experiments make electric current “visible” or “perceptible”
3. Experiments are important for hands-on experience and experimental skills of students

Perceived importance of calculations for teaching introductory electricity

Since the results regarding the reasoning behind the rating of the importance of calculations for teaching introductory electricity are diverse, the resulting categories are presented in two separate figures. Figure 5 shows the resulting categories for teachers who rated calculations as rather or very important. Figure 6 shows the results for teachers who rated calculations as rather not or not important. The percentages displayed again refer to the total amount of 34 teachers.

These resulting categories presented in Figure 5 and Figure 6 indicate that a conceptual or qualitative understanding of introductory electricity is more important for many teachers (38% in total) than performing quantitative calculations. Interestingly, these reasonings can be found for teachers who have rated calculations as rather important (15%) but also rather not or not important (23%). None of the teachers explains his or her rating of the importance with topic-specific reasons.

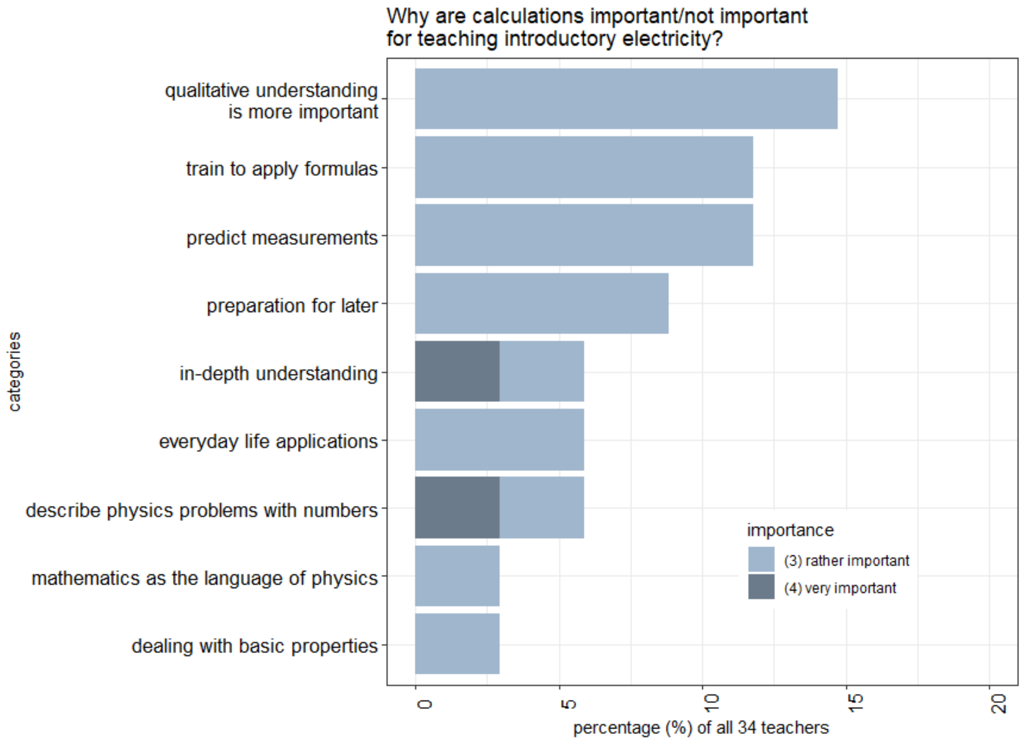

Figure 5. Teachers' reasonings regarding the question "Why are calculations important/not important for teaching introductory electricity?" The figure shows reasonings behind the ratings "rather important" and "very important". The rating refers to the general importance of calculations for teaching introductory electricity, while the categories represent the different reasonings behind the rating of the importance

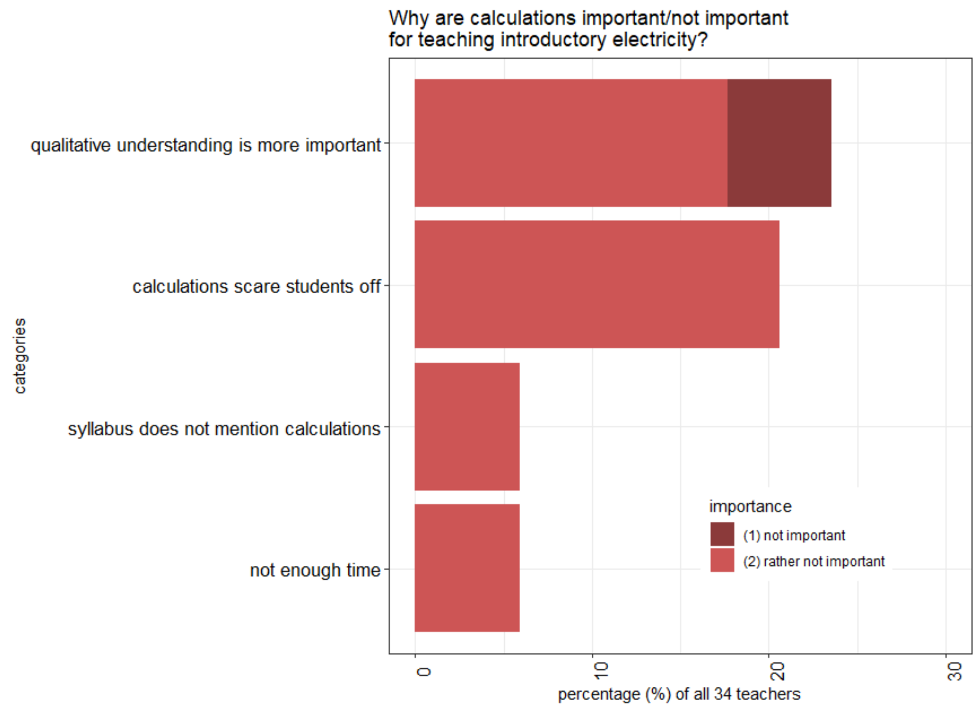

Figure 6. Teachers' reasonings regarding the question "Why are calculations important/not important for teaching introductory electricity?" The figure

shows reasonings behind the ratings of "rather not" and "not important". The rating refers to the general importance of calculations for teaching introductory electricity, while the categories represent the different reasonings behind the rating of the importance

DISCUSSION UND CONCLUSION

The findings presented in the previous section will be discussed now with respect to their topic-specificity and in relation to two dimensions of the conceptualisation of Orientation to Teaching Science proposed by Friedrichsen et al. (2011). The two dimensions we focus on are beliefs about the goals and purposes of science teaching and beliefs about teaching and learning science. Although the reasonings and answers to the open-ended questions of questionnaire can neither represent nor describe the teachers' beliefs thoroughly, the presented results can act as first hints whether there are certain topic-specific elements to the afore mentioned beliefs.

We interpret the answers to the question "What are the three most important key ideas which you want to convey in your introductory electricity lesson?" as indicators for the participants' beliefs about their most important goals and purposes of introductory electricity teaching. The results presented in the previous section indicate that there are some general goals or aims teachers follow, for example to "enjoy physics" or to understand the "Nature of Science". However, there are also goals or key ideas which are topic-specific. For example, reasonings that were assigned to the category "safety in dealing with electricity" are topic-specific reasonings which do not refer to a specific concept (e.g. voltage) but rather represent why it is important to teach introductory electricity in general.

This can only be seen as a first hint that teachers' individual beliefs about the goals and purposes of teaching science vary for different topics in some aspects. Still this leaves room for the idea that the teaching style of a single teacher, for example how they approach experimental work, might differ between two topics. This idea can be illustrated with a concrete example: A teacher may have a different approach to experiments when teaching electricity and mechanics because he/she believes that experimental work is more important when teaching electricity since the students need to learn how to handle electricity safely. We think that this idea should be addressed in future research.

While we certainly cannot provide a detailed picture about the teachers' beliefs about science teaching and learning, the perceived importance of models/experiments/calculations for teaching introductory electricity is certainly related to the participating teachers' beliefs about science teaching and learning. The results regarding the perceived importance of both experiments and models indicate that teachers' beliefs about science teaching and learning may have topic-specific elements. For example, some teachers highlight that experiments are important when teaching introductory electricity because electric current is "invisible" or models are important because they illustrate the abstract (like electric current).

Overall, this implies that studies that intend to capture Orientation to Teaching Science need to consider a potential topic-specificity. Future studies should further explore whether teachers' orientations to teaching science differ for different topics.

The findings reported in this article are furthermore interesting for researchers focusing on curriculum innovation. While it is broadly known and accepted that general beliefs about teaching and learning science influence the implementation of curricula and/or teaching materials, this might also be true for beliefs about teaching and learning a specific topic. Imagine developing a curriculum for introductory electricity which heavily focuses on electricity in everyday life but neglects experiments and models of electric current. It might very well be possible that the fidelity of implementation (O'Donnell, 2008; Stains & Vickrey,

2017) of this curriculum might subsequently be non-satisfactory since most of the teachers think that models and experiments are important for teaching and learning introductory electricity and hence divert from the proposed curriculum.

REFERENCES

Berry, A., Friedrichsen, P. [Patricia], & Loughran, J. (Eds.) (2015). *Re-examining Pedagogical Content Knowledge in Science Education*. New York, NY: Routledge.

Campbell, T., Melville, W., & Goodwin, D. (2017). Science teacher orientations and PCK across science topics in grade 9 earth science. *International Journal of Science Education*, *39*(10), 1263–1281. https://doi.org/10.1080/09500693.2017.1326646

Friedrichsen, P. [Patrica], van Driel, J. H., & Abell, S. K. (2011). Taking a closer look at science teaching orientations. *Science Education*, *95*(2), 358–376. https://doi.org/10.1002/sce.20428

Gess-Newsome, J. (2015). A model of teacher professional knowledge and skill including PCK: Results of the thinking from the PCK Summit. In A. Berry, P. Friedrichsen, & J. Loughran (Eds.), *Re-examining Pedagogical Content Knowledge in Science Education.* New York, NY: Routledge.

Haagen-Schützenhöfer, C., Burde, J.-P., Hopf, M., Spatz, V., & Wilhelm, T. (2019). Using the electron-gas model in lower secondary schools - a bi-national Design-Based-Research-Project. In E. McLoughlin & P. van Kampen (Eds.), *Concepts, Strategies and Models to Enhance Physics Teaching and Learning* (1st ed., pp. 3–12). Cham: Springer International Publishing; Imprint Springer.

Loughran, J., Mulhall, P., & Berry, A. (2004). In search of pedagogical content knowledge in science: Developing ways of articulating and documenting professional practice. *Journal of Research in Science Teaching*, *41*(4), 370–391. https://doi.org/10.1002/tea.20007

Magnusson, S., Krajcik, J., & Borko, H. (1999). Nature, Sources, and Development of Pedagogical Content Knowledge for Science Teaching. In Springer Netherlands (Ed.), *Examining pedagogical content knowledge* (pp. 95–132).

Mayring, P. (2010). Qualitative Inhaltsanalyse. In G. Mey & K. Mruck (Eds.), *Handbuch Qualitative Forschung in der Psychologie* (pp. 601–613). Wiesbaden: VS Verlag für Sozialwissenschaften / Springer Fachmedien Wiesbaden GmbH Wiesbaden.

O'Donnell, C. L. (2008). Defining, Conceptualizing, and Measuring Fidelity of Implementation and Its Relationship to Outcomes in K–12 Curriculum Intervention Research. *Review of Educational Research*, *78*(1), 33–84. https://doi.org/10.3102/0034654307313793

Shulman, L. (1987). Knowledge and Teaching: Foundations of the New Reform. *Harvard educational review*, *57*, 1–23.

Stains, M., & Vickrey, T. (2017). Fidelity of Implementation: An Overlooked Yet Critical Construct to Establish Effectiveness of Evidence-Based Instructional Practices. *CBE Life Sciences Education*, *16*(1). https://doi.org/10.1187/cbe.16-03-0113

TEACHER-LEADERS' LEARNING WHILE LEADING A PLC OF PHYSICS TEACHERS – THE CASE OF THE INQUIRY-BASED LABORATORY

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Teacher-leaders (TLs) play a major role in teachers' Professional Development (PD) and in building effective Professional Learning Communities (PLCs). However, the PD of the TLs themselves is rarely discussed in the literature. This study examined the learning of high-school physics TLs in a program involving PLCs. The program has been operating since 2012, using a "Fan Model": the TLs participate in a PLC led by a team from the Weizmann Institute of Science (TL-PLC), while they simultaneously teach in high school and lead regional PLCs of physics teachers all over Israel. We extended the Interconnected Model of Professional Growth (Clarke and Hollingsworth, 2002), adjusted it to the professional world of physics TLs, and used it to study the learning of three TLs that were chosen as case studies. We studied for four years (2014-2017) the changes in their knowledge, attitudes, and practice, in the context of the inquiry-based laboratory. For each case study we created a chronological map based on our Extended Interconnected Model of Professional Growth. The results show significant changes in the three TLs' knowledge, attitudes, and practice, and their ongoing professional growth. The TLs' learning was promoted by the mechanisms of "Enactment" and "Reflection", which were implemented in the program in a specific rational order and at appropriate times, in all the aspects of the TLs' practice. The alternating meetings, every other week, of the TL-PLC and the regional PLCs, helped to integrate the TLs' learning into their practice, both as teachers and as PLC leaders. The TLs successfully implemented the inquiry-based activities in their teaching routine for a long period. Our results enhance our understanding of the TLs' learning, as well as features in the program that promoted it, and can contribute to the design of effective PD programs for both teachers and TLs.

Keywords: Continuing professional development; Learning Communities; Laboratory Work in Science.

INTRODUCTION

It is widely agreed that effective teachers' Professional Development (PD) programs should be ongoing, challenging, focused on student learning, and situated in teachers' practice (Borko, 2004; Darling-Hammond & Richardson, 2009; Desimone, 2009). Professional Learning Communities (PLCs) are an essential component of high-quality PD (Grossman, Wineburg & Woolworth, 2001; Shulman, 1997; Vescio & Adams, 2015). Teacher-Leaders (TLs) play a major role in teachers' PD and in building effective PLCs (Klentschy, 2008; National Academies of Sciences, 2015; York-Barr & Duke, 2004). However, the PD of the TLs themselves is rarely discussed in the literature (Criswell, Rushton, McDonald & Gul, 2017; Even, 2008). This study is part of a larger research (Levy, Bagno, Berger & Eylon, 2018) aimed at bridging this gap.

We examined the PD of high-school physics TLs that participated in a program involving PLCs. The program has been operating since 2012, by using a "Fan Model" (described in Fig. 1): the TLs participate in a PLC led by a team from the Weizmann Institute of Science (TL-PLC), while they simultaneously teach high-school physics and lead regional PLCs of physics teachers.

Figure 1. The "Fan Model" used in the PLCs program

The TLs' learning is "evidence-based": They enact each new instructional activity in their classes and in the regional PLCs, collect and analyze data about students' and teachers' learning, as well as reflect collaboratively on the evidence from classes and from the regional PLCs. Each PLC operates by face-to-face meetings lasting 4 hours each, twice a month during the school year. In the 2019 school year there were 24 TLs in the program, and 12 regional PLCs with about 250 high-school physics teachers.

The context of the current study is inquiry-based laboratory, aimed at moving away from the widespread contrived instructional laboratory (Abrahams, 2015) towards inquiry-oriented activities that represent aspects of authentic research, and give students more responsibility for their work (American Association of Physics Teachers, 2015; Etkina et al., 2010). Each inquiry-based activity lasts two lab-lessons, in which the students work collaboratively in small groups, and experience a variety of inquiry practices, such as asking questions, formulating hypotheses, planning and carrying out experiments, analyzing data, constructing explanations, and finally sharing their results with the whole class. The inquiry-based activities were new to all TLs and fundamentally differed from their traditional teaching methods, pushing them beyond their "comfort zone".

Theoretical frameworks for research on TLs' PD should take into consideration the multiple contexts of their practice, both as teachers and as PLC leaders. Situative perspectives serve as a powerful research tool, taking into account both the individual teacher-learners and the social systems in which they participate, including PLCs (Borko, 2004; Putnam & Borko, 2000). Our theoretical framework is based on the Interconnected Model of Professional Growth (Clarke & Hollingsworth, 2002), shown in Fig. 2. This model recognizes the complexity of teachers' learning and suggests the perspective of teachers as active learners who shape their professional growth through reflective participation in PD programs and in practice.

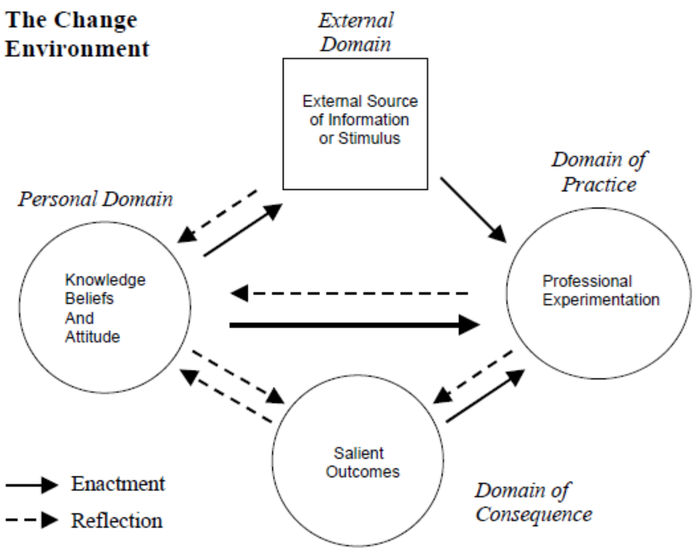

Figure 2. The Interconnected Model of Professional Growth (Clarke & Hollingsworth, 2002)

According to the model, four distinct domains encompass the teacher's world: the Personal Domain, referring to teacher's knowledge, beliefs and attitudes; the Domain of Practice, referring to professional experimentation; the Domain of Consequence, referring to salient outcomes, such as student learning or student motivation, and changes at the school level; and the External Domain, referring to sources of information, stimulus or support. A change in one domain is translated into another domain through the mediating processes of "Reflection" and "Enactment", which are represented in the model as arrows linking the domains.

We extended Clarke & Hollingsworth's model to an Extended Interconnected Model of Professional Growth (EIMPG), adjusted it to the professional world of physics TLs, and used it to study the TLs' professional growth, focusing on changes in their knowledge, attitudes and practice in the context of the inquiry-based laboratory.

Our main research questions are as follows: 1) what changes occurred in the TLs' knowledge, attitudes, and practice, in the context of inquiry-based laboratory; 2) how were these changes related to features of the PLCs' program?

METHODS

This longitudinal study lasted four years (2014-2017). We used a case-study methodology that provided us with a prolonged and in-depth exploration of processes in the TLs' learning within the different aspects of their practice: their classrooms, their school, and the regional PLC that they led. Three TLs: Roy, Dana, and Sofia, were chosen for the case studies. All three are high-school physics teachers, who joined the program in different years, and differed from each other regarding their background as teachers and as TLs. Dana joined the TL-PLC in 2014, after 19 years as a teacher, and had no former experience as a TL. Sofia and Roy joined the TL-PLC in 2012. Sofia has been a teacher for 25 years, has been a district teachers' facilitator for 15 years, and has participated in many former PD programs. Roy has been a teacher for 18 years, graduated from a special M.Sc. program designed for excellent physics teachers, and had no former experience as a TL. Thus, Sofia was a senior teacher and had leadership experience, whereas the other two did not; Roy had research experience, whereas the other two did not.

Data were collected from a variety of sources, e.g., video records of TL meetings, reflection papers, interviews, and annual portfolios. The data related to Roy, Dana, and Sofia in the context of the inquiry-based laboratory were sorted and categorized (using Atlas.ti software) according to the different domains of the EIMPG, focusing on the different aspects of the TLs' practice. The mediating processes of "Enactment" and "Reflection" were identified, numbered in chronological order, and presented in a map that was created for each case study. The categorization, as well as the EIMPG maps, were validated by four researchers. Our results were discussed with Roy, Dana, and Sofia.

RESULTS

Roy, Dana, and Sofia's professional growth over the four years, both as teachers and as PLC leaders, was a complex, ongoing process. We will first examine the changes in the knowledge, attitudes, and practice of each case study in the context of the inquiry-based laboratory, using the EIMPG maps. Then we will consider features of the PLCs' program that promoted these changes.

Changes in Roy's knowledge, attitudes, and practice

The EIMPG map for Roy, in the context of the inquiry-based laboratory, is shown in Fig. 3. The mediating processes of "Enactment" and "Reflection" are represented, respectively, as solid and dashed arrows linking the different domains of the EIMPG. The colors denote different aspects of Roy's professional experimentation: as a teacher in class, as a TL in school, as a TL in the regional PLC, and as a member of the TL-PLC.

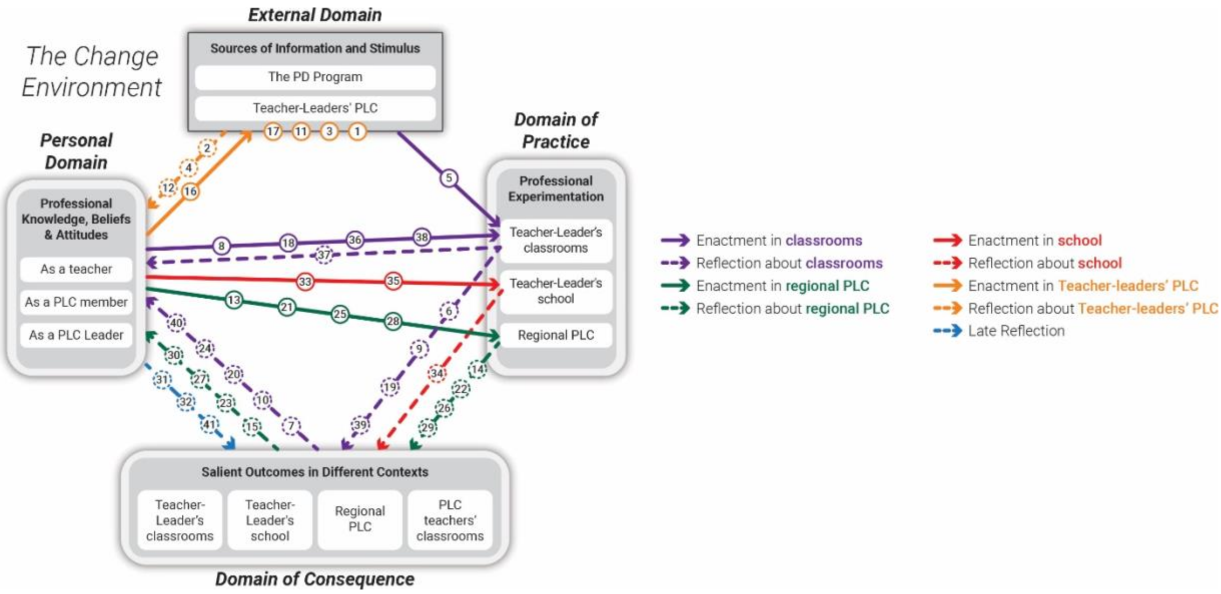

Figure 3. Roy's EIMPG Map

Roy's initial experience with an inquiry-based lab activity was as a learner in the TL-PLC (1). His reflection was (2):

> *I had the notion that an inquiry-based lab is a long and grandiose process, and requires expensive instruments. I really liked the experience today of inquiry with such simple equipment.* (Roy's reflection paper 1, September 2014).

At the following TL meeting, Roy experienced another inquiry-based lab activity (3) and reflected on that experience (4):

> *Our group had a frustrating half an hour because it took us a long time to figure out how to take measurements. It made me feel like my students when they face difficulties in the lab… It was an important experience for me.* (Roy's reflection paper 2, September 2014).

A few days later, Roy enacted his first inquiry-based activity in a 12^{th} grade lab-lesson (5), described the outcomes (6), and referred to the challenges that he faced (7):

> *I wasn't sure what to emphasize in the class discussion: the needed lab-skills? The theoretical aspects? I'm afraid my students remained confused".* (Interview, September 2014).

Roy enacted the same activity in another 12^{th} grade class (8) and reflected on it (9 and 10):

> *The students focused on the challenge of taking measurements and getting results. This second experience in class made me ask myself what are the main goals of this activity and when is the best time to enact it.* (Interview, October 2014).

After his third experience at the TL meeting (11), Roy reflected (12):

> *It was the first time I really understood the whole process of inquiry and now I feel much more confidence with it.* (Roy's reflection paper 3, November 2014).

Then Roy enacted an inquiry-based lab activity in his PLC for the first time (13) and reflected on it (14-15):

> *The teachers really liked this activity. They enjoyed the team work and said that the challenges that they faced were frustrating*. (TL meeting, November 2014).

Roy also advised other TLs how to enact the activity in their regional PLCs (16), and the challenges were discussed with the leading team (17). Roy's map presents many more sequences of "Enactment" and "Reflection" (18-32; 36-41), both in his classes and in the regional PLC. He helped other teachers in his school to enact inquiry-based activities as well (33-35), and was pleased with the outcomes.

The repeating enactments, following changes in Roy's knowledge and attitudes, were more mature, and included personal adaptations of the activities. Roy reflected on the changes in his attitudes towards the inquiry-based laboratory:

> *At the beginning of the year I thought that inquiry activities require a lot of time and expensive equipment. However, after all my experimentations this year, I definitely changed my opinion – we can do inquiry activities even with the limited time we have and also with cheap and simple equipment. I even managed to persuade the teachers at my school and at my PLC to use inquiry activities.* (Roy's portfolio, July 2015)

In addition, Roy gained more confidence as a TL:

I feel much more confident now. Here I am leading teachers, they try the new activities in their classes and they come back with positive feedback. It makes me feel that I can influence both teachers and students. (Interview, April 2016).

Roy, attributed great importance to his experiences in class before the enactment in the regional PLC:

We must try everything in class before introducing it in the PLC. It helps us find the best way to enact each activity. For example, how much time is needed for the inquiry activity, what difficulties are expected? When I tell the teachers that I tried it with my students and it worked well, it motivates them to try it in their classes too. (Interview, July 2016)

Roy successfully implemented the inquiry-based activities in his teaching routine, developed new inquiry-based activities for his students, and shared these activities with the other TLs.

Changes in Sofia's knowledge, attitudes, and practice

Sofia's EIMPG map is shown in Fig. 4. Sofia participated in a former summer PD and had some experiences with inquiry-based activities, which are not presented in the map. Her first experience in that context within the PLCs' program was at the TL meeting (1), and she reflected on that experience (2):

It was very challenging because our results were different from our predictions, and we struggled to understand our mistake. I really enjoyed the activity, but I don't think I will use it with my students. It is too complicated. (Sofia's reflection paper 1, September 2014).

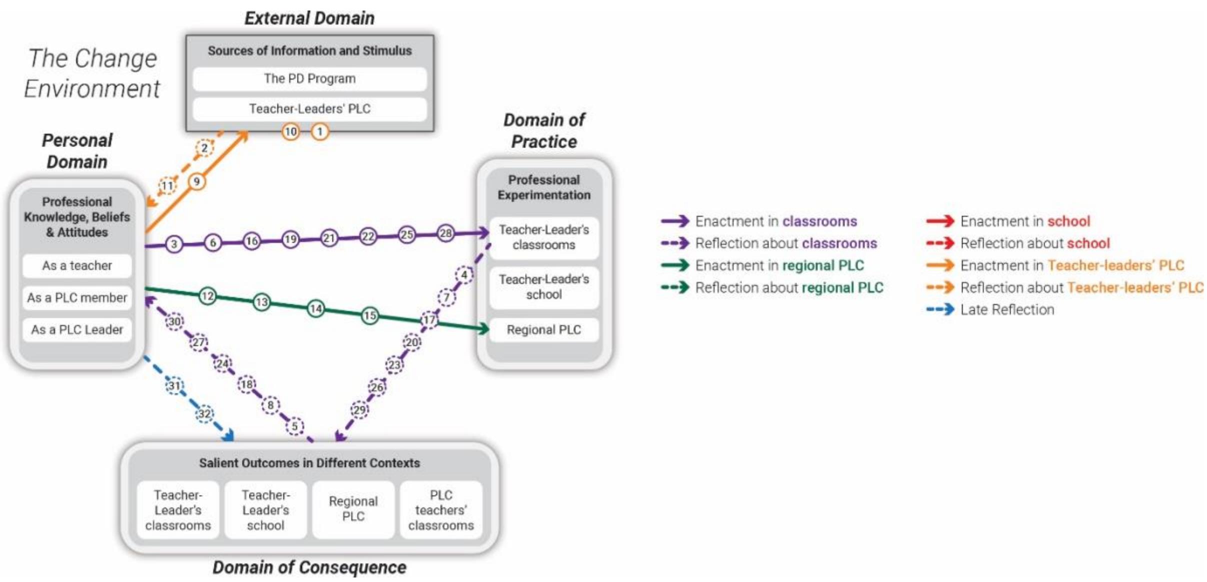

Figure 4. Sofia's EIMPG Map

Sofia made some changes in a traditional activity that she used before, designed it as an inquiry-based activity, and enacted it in her 9th grade class (3). Her reflection was (4 and 5):

Each group decided on its own inquiry question… It was interesting for me to realize that some of them understood the experimental system and some of them didn't…We had a rich discussion regarding measuring skills, and it was amazing. (TL meeting, October 2014).

Sofia enacted another inquiry-based activity in another class (6) and reflected (7 and 8):

> *It was so good! I am enthusiastic about this way of working in the lab.* (Interview, October 2014).

At the TL meeting, Sofia suggested how to design another familiar experiment as an inquiry-based activity (9). In the following TL meeting, she experienced another new activity (10) and reflected on it (11):

> *I really like it; I intend to use it with my students next week*. (TL meeting, November 2014).

Sofia enacted some inquiry-based activities in her regional PLC (12-15), but did not reflect on these experiences. She kept using inquiry-based activities in class for a long period, and her EIMPG map presents multiple enactments and reflections (16 - 32).

Changes in Dana's knowledge, attitudes, and practice

Dana's EIMPG map is shown in Fig. 5. Dana's initial experiences with inquiry-based activities were as a learner in the TL-PLC (1 and 2). She reflected on these experiences (3):

> *We felt like students. It was very frustrating that we didn't manage to take measurements at first*. (Dana's reflection paper 2, September 2014).

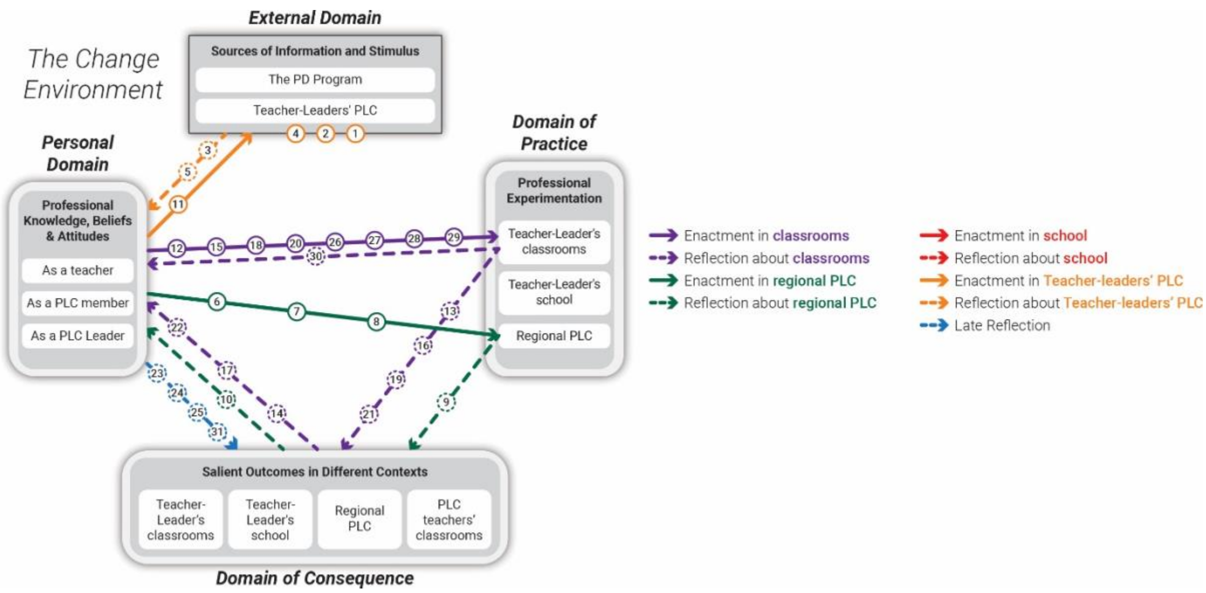

Figure 5. Dana's EIMPG Map

Dana experienced a third inquiry-based activity in the TL-PLC (4), and her reflection this time was (5):

> *I think that this activity is easier for students.* (Dana's reflection paper 3, November 2014).

She enacted two of these activities in the regional PLC and reflected on them (6-10):

> *The teachers were enthusiastic about this new approach of inquiry-based lab activities*. (TL meeting, January 2015).

Unlike Roy and Sofia, who immediately implemented the inquiry-based activities in their classes, Dana needed to undergo several experiences, both in the TL-PLC and in the regional

PLC, in order to enact an inquiry-based activity for her class for the first time. She shared her plans with all the TLs (11), enacted the activity in her 11th grade class (12-13), and reflected about what motivated her to do so (14):

> *I heard the other TLs and the teachers in my regional PLC reflecting on their experiences after they had begun to use inquiry-based activities with their students, and I told myself that I can't stay behind.* (Interview, January 2015).

After many sequences of "Enactment" and "Reflection" (15-31, January 2015 – July 2017), in different classes, Dana learned how to implement the inquiry-based activities successfully and continued to do so, in many variations, even after three years.

Features of the PLCs' program that promoted changes in the TLs' knowledge, attitudes, and practice

Roy, Dana, and Sofia implemented the inquiry-based laboratory in their teaching routine, in spite of the many challenges, and the changes in their practice lasted for more than three years. Examination of their EIMPG maps reveals that individual pathways exist for Dana, Sofia, and Roy's professional growth, as well as several similar patterns in all three EIMPG maps. For example, (1) repeating sequences of "Enactment" and "Reflection", in a certain order, which promoted changes in the Personal Domain, in the Domain of Practice, and in the Domain of Consequence; (2) experiences in the TL-PLC, accompanied by personal and collaborative reflection, and a change in the Personal Domain; (3) interactions between the Personal Domain and the External Domain, indicating the important role of the TL-PLC as a meaningful learning environment. We suggest that these similar patterns are related to features of the PLCs' program.

The TLs' learning, and the changes in their knowledge, attitudes, and practice, were promoted by the mechanisms of "Enactment" and "Reflection". The implementation of "Enactment" and "Reflection" in the program in a specific rational order and at appropriate times, in all aspects of the TLs' activity, enhanced their long-term professional growth.

The engaging experiences of the TLs in all aspects: as learners at TL meetings, as high-school physics teachers, and as regional PLCs' leaders, encouraged them to try the new activities in their classes, and to acquire the confidence needed for their successful implementation in class as well as in the PLCs.

The alternating meetings, every other week, of the TL-PLC and the regional PLCs helped to integrate the TLs' learning into their practice, both as teachers and as TLs. The evidence from the TLs' own classes, from the classes of other TLs, and from the PLC teachers' classes, provided the TLs with a wide perspective about the new activities. The collaborative reflection enabled the TLs to share insights, successes, and difficulties, and to get support, both moral and practical, from their peers and from the leading team.

The "Fan Model", as well as the features of the PLCs program, provided the TLs with opportunities to actively investigate their teaching and leading, consistently reflect on their practice and its consequences, and learn from one another in a supportive and non-judgmental environment.

DISCUSSION AND CONCLUSIONS

Roy, Dana, and Sofia's professional growth demonstrate professional "growth networks", as defined by Clarke and Hollingsworth (2002), who distinguished between local or short-term changes and lasting, long-term, teacher growth. Our results contribute an important aspect: the professional growth of TLs. In all three case studies the mediating processes of "Enactment" and "Reflection" were, as in the Clark & Hollingsworth's model, mechanisms that promoted changes in the knowledge, attitudes, and practice of the TLs. Roy, Dana, and Sofia's learning was based on their enactments and multiple reflections as learners at TLs' meetings, as high-school physics teachers, and as regional PLCs leaders.

The interactions we found between changes in the TLs' knowledge and changes in their practice demonstrate the significance of the construct "Knowtice" (a combination of Knowledge and Practice), introduced by Even (2008), which applies to the learning and development of physics TLs who lead regional PLCs.

Our results indicate the challenges of developing physics TLs as reflective practitioners, as described by Criswell et al., 2017, highlight the special needs of physics TLs, and emphasize the importance of responding to their needs and challenging their habits and views (Etkina, Gregorcic & Vokos, 2017; Timperley, Wilson, Barrar & Fung, 2008), particularly in the context of inquiry-based activities (Holmes & Wieman, 2018; Luft, 2001).

The TL-PLC turned out to be a meaningful and enriching learning environment. The supportive and non-judgmental environment helped the TLs to dare to try new things and cope with the challenges they were facing. These results support PLCs as a sustained, practice-based, and collaborative setting for effective teachers' PD (Vescio & Adams, 2015), in particular a TL-PLC.

Can the cases of Roy, Dana, and Sofia be generalized to other TLs in the program? Case studies always raise this question. However, the results of this study are in line with our research regarding the TLs in our program (e.g., Levy, Bagno, Berger & Eylon, 2018).

Having a better understanding of the learning processes and professional growth of physics TLs can contribute to the design of effective PD programs for both teachers and TLs.

REFERENCES

Abrahams, I. (2015). Laboratories, Teaching in. In R. Gunstone (Ed.), *Encyclopedia of science* education (pp. 559-561). Dordrecht, The Netherlands: Springer.

American Association of Physics Teachers. (2015). *Recommendations for the undergraduate physics laboratory curriculum.* AAPT Committee on Laboratories, American Association of Physics Teachers, College Park, MD.

Borko, H. (2004). Professional development and teacher learning: Mapping the terrain. *Educational researcher, 33*(8), 3-15.

Clarke, D., & Hollingsworth, H. (2002). Elaborating a model of teacher professional growth. *Teaching and teacher education, 18*(8), 947-967.

Criswell, B. A., Rushton, G. T., McDonald, S. P., & Gul, T. (2017). A clearer vision: Creating and evolving a model to support the development of science teacher leaders. *Research in Science Education*, 1-27.

Darling-Hammond, L., & Richardson, N. (2009). Research review/teacher learning: What matters? *Educational leadership*, *66*(5), 46-53.

Desimone, L. M. (2009). Improving impact studies of teachers' professional development: Toward better conceptualizations and measures. *Educational researcher*, *38(3),* 181-199.
Etkina, E., Karelina, A., Ruibal-Villasenor, M., Rosengrant, D., Jordan, R., & Hmelo-Silver, C. E. (2010). Design and reflection help students develop scientific abilities: Learning in introductory physics laboratories. *The Journal of the Learning Sciences*, *19*(1), 54-98.
Etkina, E., Gregorcic, B., & Vokos, S. (2017). Organizing physics teacher professional education around productive habit development: A way to meet reform challenges. *Physical Review Physics Education Research, 13*(1), 010107.
Even, R. (2008). Facing the challenge of educating educators to work with practicing mathematics teachers. In B. Jaworski & T. Wood (Eds.), *The international handbook of mathematics teacher education: The mathematics teacher educator as a developing professional* (pp. 57-73). Rotterdam, The Netherlands: Sense.
Grossman, P., Wineburg, S., & Woolworth, S. (2001). Toward a Theory of Teacher Community. *The Teachers College Record*, *103*, 942-1012.
Holmes, N. G., & Wieman, C. E. (2018). Introductory physics labs: We can do better. *Physics today, 71*(1), 38-45
Klentschy, M. (2008). Developing teacher leaders in science: Attaining and sustaining science reform. *Science Educator*, *17*(2), 57-64.
Levy, S., Bagno, E., Berger, H., & Eylon, B. S. (2018). Physics Teacher-Leaders' Learning in a National Program of Regional Professional Learning Communities. In A. Traxler, Y. Cao, & S. Wolf (Eds.), *Physics Education Research Conference Proceedings*, Washington, DC.
Luft, J. A. (2001). Changing inquiry practices and beliefs: The impact of an inquiry-based professional development programme on beginning and experienced secondary science teachers. *International Journal of Science Education*, *23*(5), 517-534.
National Academies of Sciences, Engineering, and Medicine, (2015). Science Teachers Learning: *Enhancing Opportunities, Creating Supportive Contexts*. Washington, DC: The National Academies Press.
Putnam, R. T., & Borko, H. (2000). What do new views of knowledge and thinking have to say about research on teacher learning?. *Educational researcher*, *29*(1), 4-15.
Shulman, L. S. (1997). *Communities of learners and communities of teachers*. Monographs of Mandel Institute, No. 3. Jerusalem: Mandel Foundations.
Timperley, H., Wilson, A., Barrar, H., & Fung, I. (2008). *Teacher professional learning and development*. Ministry of Education, Wellington, New Zealand.
Vescio, V., & Adams, A. (2015). Learning in a professional learning community: The challenge evolves. In D. Scott and E. Hargreaves (Eds.), *The Sage handbook of learning* (pp. 274-284). New York and London: SAGE Publications.
York-Barr, J., & Duke, K. (2004). What do we know about teacher leadership? Findings from two decades of scholarship. *Review of educational research, 74*(3), 255-316.

A NANOSCALE SCIENCE AND TECHNOLOGY TRAINING COURSE: PRIMARY TEACHERS' LEARNING ON THE LOTUS AND GECKO EFFECTS

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Lotus and gecko effects are considered as appropriate for introducing Nanoscale Science and Technology (NST) topics in compulsory education. Under this lens, we investigate primary teachers' (PTs) learning on the two effects after their participation in a NST training course. PTs completed a written questionnaire before and after the implementation. The analysis of the responses revealed that PTs' explanations shifted from a sensory perception-based to a more scientific view level. The common explanations involved the structural aspects of the two effects. Other abstract concepts such as forces were less internalized.

Keywords: primary school, in-service teacher training, teacher thinking

INTRODUCTION

Nanoscale Science and Technology (NST) consist of a modern field that focuses on the understanding of the behavior of materials having length scale in the range of 1-100nm, often denoted as the nanoscale. Due to the progress in the nanoscale materials domain, a plethora of applications in several sectors (materials science, electronics, medicine, etc) can be witnessed (Kumar & Koumbhat, 2016). A significant number of these advancements come from the field of biomimetics. Self-cleaning windows, superhydrophobic textiles have been driven by the inspiration from the superhydrophobic property of the lotus leaf (lotus effect). Efficient adhesive tapes, robots that can climb vertically, super adhesive gloves that may be used by firemen replicate the strong adhesion of the gecko lizards on to ceilings (gecko effect) (Bhushan, 2010).

Figure 1 and 2 represent aspects of the two effects. The lotus leaves present structural multi-scale roughness, having micro-bumps and nano-bumps which are covered with epicuticular wax, resulting in a high repellence between water droplets and the surface (Figure 1). Superhydrophobic lotus leaf exhibits self-cleaning properties showing high static water contact angle and low contact angle hysteresis (Kim et al 2018). The gecko lizard possesses one of the most effective adhesion mechanisms in nature regarding to its body mass. One single toe of the gecko consists of microscale hair-like structures (called setae). Each seta ends to even smaller structures, the spatulae, whose width lies at the nanoscale dimension (Figure 2). When they come into contact with the ceiling a large number of van der Waals forces are sufficient enough for the gecko to defy gravity and adhere on the ceiling (Bhushan, 2010).

Introducing nanophenomena of the natural world and their related applications such as those described above are considered suitable for introducing salient NST concepts (e.g. size dependent properties, forces & interactions) to school students ("easy to digest" approach, Lin et al., 2015, p. 25). This approach has a positive impact to students' interest and it has the potential to excite and inspire schoolchildren about modern and future innovations. Both the effects have been included under the umbrella of the NST concept "Nanophenomena in the natural world", which has been acknowledged as a core concept for primary nano-education (Lin et al., 2015; Blonder & Sakhnini, 2016).

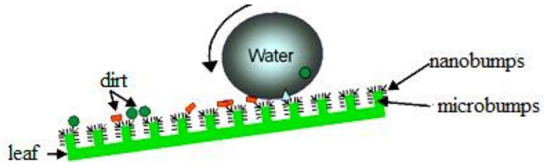

Figure 1. Representation of the lotus effect.[5]

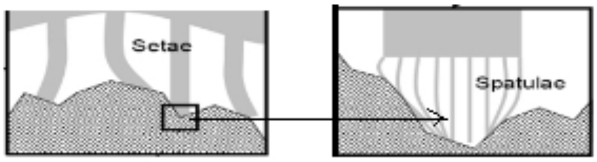

Figure 2. Representation of the gecko effect.[6]

However, in practice introducing NST at the primary level can turn out to be challenging. A major cognitive barrier for learning NST is the lack of intuition. The problem is conceptual & practical; objects –concepts are hard to visualize, difficult to describe, their relationships to the observable world can be counterintuitive (Sabelli et al., 2005, p.3). There is a consensus amongst scientists and educators in the field of NST that education of NST concepts relies on models and modeling. To be specific using, creating and understanding aspects of the nature and role of models are considered as a means for the construction of knowledge in nanoscale science education (Daly & Bryan, 2010).

Apart from the cognitive barriers, teacher preparation has been recognized as salient research topic. Undeniably, teachers play a pivotal role in the integration of NST in education. However, research findings indicate that teacher acknowledge their insufficient content knowledge about NST whereas several studies address that NST content learning is a critical aspect of teachers' learning. Research findings indicate that In order to help teachers to increase their understanding of fundamental NST concepts, they have to engage in appropriate learning environments (Healy 2009; Bryan et al., 2015).

Taking into account the above considerations we have designed and implemented a NST training course in order to educate primary teachers (PTs) about concepts and phenomena at the nanoscale, among them the lotus and the gecko effect. In this paper, we examine whether the course changed PTs' knowledge concerning the two effects. The research question that guided this study was: Did PTs' explanations about the lotus and gecko effects get improved after their participation in the NST training course?

RESEARCH METHODOLOGY

The training course consisted of nine lessons. The first five lessons were structured in a way to scaffold PTs to approach the nanoscale via macro- and micro- scale. During the sixth, seventh and eighth lesson lotus and gecko effects were introduced. The content of the two effects was transformed so that it could be approached by the primary teachers. Specifically, we introduced concepts that were related to their structural and physical properties (Kim et al., 2018). The former included micro- and nano-bumps/ setae-spatulae for the lotus and gecko effect respectively. The latter (physical properties) included concepts such as superhydrophobicity, self cleaning, contact angle, surface contact area for the lotus effect and electrical force and

[5] http://bioimicryreport.blogspot.com/2014/02/lotus-leaves-inspire-self-cleaning.html

[6] https://www.powershow.com/viewfl/ff23b-ZDc1Z/Gecko_Adhesion_powerpoint_ppt_presentation

surface contact area as well for the gecko effect. In addition for both of the effects, relevant applications that had clear connections to the everyday life were introduced. For example, the lotus effect was connected to superhydrophobic and self cleaning fabrics and the gecko effect to gecko pads and sticky gloves (table 1).

The lotus effect lesson can be divided into two phases. During the first phase, primary teachers collected data by studying animations, drawings and electron micrographs and by conducting experimental activities as well in order develop understanding about the salient concepts that relate to the phenomenon. During the second phase, they created and presented to the class their own models, that represented certain aspects such as, the structure of the surface leaf in the micro- and nano- scale, the superhydrophobicity, the self cleaning property, the contact angle etc (table 1). In figure 3, a group of teachers using a protractor measures on a printed image the contact angle between the water droplet and a wooden surface in order to clarify whether the surface is hydrophobic or hydrophilic. Figure 4 associates with the second phase of the lotus effect lesson. A group of teachers builds a concrete model using everyday materials, such as wooden sticks, egg cartons etc.

Table 1: The content and the activities that were conducted by the PTs during the lotus and gecko effect lessons.

The lotus effect lesson		
Lessons	Content	Activites
Lesson 6 -7	● Structure of the surface leaf in the micro- and nano- scale ● Superhydrophobicity ● Self cleaning property ● Contact angle ●Surface contact area ● Applications in everyday life	● Collecting data studying animations, drawings, electron micrographs & experimental activities ● Discussion ● Models Creation & Presentation: Suggest their own models in order to represent aspects of the lotus effect
The gecko effect lssson		
Lesson 8	● Structure of the gecko feet in the micro- and nano-scale ● How the gecko can adhere to a ceiling ● Applications in everyday life ● Surface contact area between surfaces	● Collecting data studying animations, drawings & electron micrographs ● Discussion ● Demonstration to the PTs of a model (Figure 7)

The gecko effect lesson consisted of two phases also. In the first phase, teachers collected information about the effect studying animations, drawings and electron micrographs (Figure 5). Then the whole discussed about the structure of the gecko feet in the micro- and the nano-scale, the mechanism that the gecko lizard exploits in order to adhere to the ceiling and about related applications in everyday life. In the second phase, the educator demonstrated a concrete model in order to represent the importance of the gecko foot structure in the maximization of the surface contact area between the foot and the ceiling (Figure 6).

Figure 3. A teacher measures the contact angle of the surface and the droplet.

Figure 4. A group of PTs create a model to represent the lotus effect.

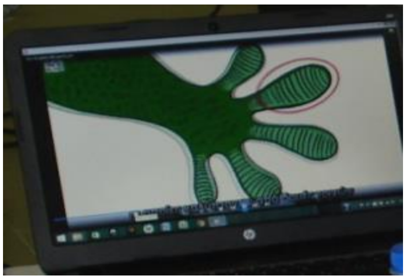

Figure 5. A snapshot of a video that PTs studied in order to collect data about the gecko effect.

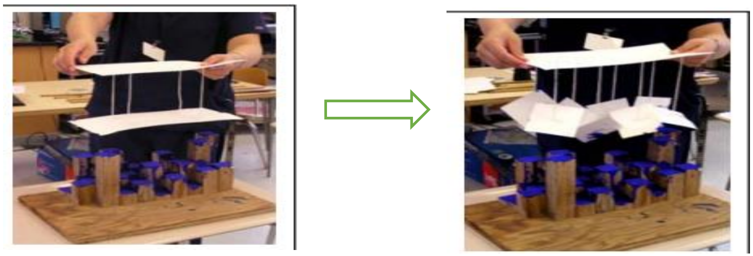

Figure 6. The model that was demonstrated in order PTs to develop understanding about the importance of the surface contact area to the adhesion of the gecko lizard to ceilings.

A total of 13 PTs (9 female) of several primary schools of Northern Greece participated in the training course. The years of teaching experience ranged from 6 to 21 years with a mean of 15 years.

A pre-post written questionnaire consisting of 7 items was created in order to assess primary teachers' NST knowledge. In this study, we present the first results from the two items that corresponded to the lotus and gecko and effect respectively. (i) Explain by using your own words and/or by a drawing *the spherical shape of a water droplet that rests on the leaf surface,* (ii) Explain by using your own words and/or by a drawing *the ability of the lizard to "stick" to surfaces even if upside down.* We consider that these two items can serve as a means for examining PTs' learning about key learning goals of the lotus and gecko effects' units: PTs to understand the superhydrophobic and strong adhesion property of the lotus and the gecko effects respectively and to appreciate the importance of the micro- and nano-scale in the determination of the two properties.

PTs' written responses were analyzed using the content analysis method. Specifically, within the participants' responses, significant words or phrases that provided a coherent explanation about the two effects were highlighted (Flick, 2009).

RESULTS

The table below depicts the words or phrases that were included in PTs' explanations concerning the lotus effect before and after the implementation.

Table 2. Terms that PTs expressed before and after the implementation in order to explain the lotus effect.

Explanation	PRE (terms)		POST (terms)	
Surface	Smooth, soft surface	7	Terms associated with the structure of the surface leaf in the micro- and nano- scale (micro- & nano-bumps)	6
	Hair-like structure	1		
Phenomena			Terms related with hydrophobicity	6
			Surface contact area	3
			Contact angle	1
Forces	Forces	3	Terms related with Forces	1
	No explanation	2	Vague terms about the structure	1

It is evident that PTs at the beginning of the training, expressed mostly perception-based explanations, such as the leaf has a soft or a smooth surface, while 4 of them attributed the spherical shape of the droplet to hair-like structure or to forces between the droplet and the leaf, without specifying the nature or the origin of these forces. After the training, PTs expressed their interpretation in much richer form, including several notions of the scientific knowledge, referring (for example) to the structure of the leaf in the micro- and the nano-scale and the superhydrophobic wetting state. As far as the drawings that PTs provided, either they did not draw any aspect of their explanation, either they provided vague drawings (Figure 7 left part). After the implementation, PTs draw exclusively the structural characteristics of the leaf at the micro- and nano-scale, fact that demonstrates explanations that are far from the sensory perception (Figure 7 right part).

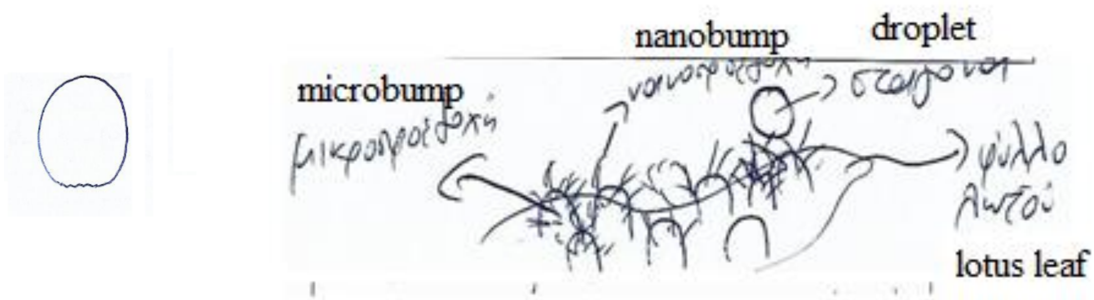

Figure 7: Representative drawings PTs provided in order to represent the lotus effect before (left) and after (right) the implementation.

Concerning the gecko effect at the beginning the highest concentration of PTs' explanations included adhesion mechanisms influenced by systems that are used in our daily life to hang objects, such as suction cups, claws and glue (Table 3 left part). After the training, PTs departed from intuitive-type of reasoning, and similar to the "lotus-effect" case, they expressed interpretations in much richer form, including several elements of scientific knowledge. For example, they referred explicitly to the structure of the toe at the micro- and the nano- scale and to the surface contact area (Table 3, right part). Furthermore, 4 PTs attributed the gecko adhesion to electrical forces, whereas 3 PTs characterized them as “attractive”.

Table 3. Terms that PTs expressed before and after the implementation in order to explain the gecko effect.

Interpretation	PRE (terms)		POST (terms)	
Intuitive	Claws, suction cups, glue	16		
Surface	Rough wall surface	3	Terms regarding the structure in the micro- and nano- scale (seate-spatulae)	11
			Surface contact area	8
Forces	Forces	1	Electrical forces	4
			Attractive forces	3
	No explanation	2		

In Figure 8, a representative drawing that was created by a PT in order to explain the adhesion property of the gecko lizard is presented. The drawing in the left part depicts suction cups on the gecko toe. In the left part, the same PT drew the structure in the micro- and the nano- scale.

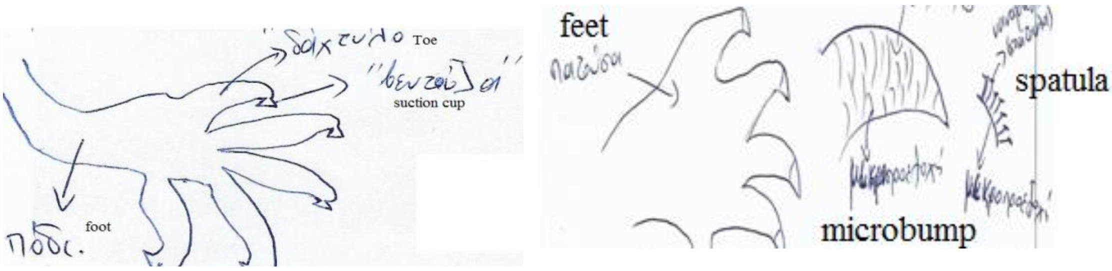

Figure 8. Representative drawing PTs provided in order to represent the gecko effect before (left) and after (right) the implementation.

DISCUSSION

Concluding, the focus of this study was to investigate primary teachers’ learning on lotus and gecko effects after their participation in a NST training course. It consists of a preliminary analysis, which aims to highlight the terms that PTs used in order to explain the two effects before and after their participation in a NST training course. Until now, little has yet been published about teachers’ learning on NST concepts and phenomena, and we anticipate that this research to contribute to this missing.

Our findings indicate that for both of the effects there was a shift from perception- or daily experience – based explanations to more informed ones, relevant with nano-related vocabulary. We consider this as an encouraging finding that shows that PTs’ explanations actually got improved after the instruction.

For both of the effects, primary teachers seem to meet no difficulties to acknowledge the structural aspects, since they used relevant terms. However, concepts related to physical properties (surface contact area, contact area, electrical forces) aspect were more underestimated. This finding indicates that PTs met some difficulties to explain how the structural properties affect the behavior of the effects. Similar results are obtained from the related literature (e.g. Bryan et al.2012; Sockman et al. 2012)..

In particular, the difficulties regarding the role of the structure to minimize/maximize the surface contact area (lotus and gecko effect respectively) were less for the case of the gecko effect explanation (table 2 and 3 right part). This finding suggest that appropriate model-based inquiry activities, such as the demonstration via a concrete model regarding the increase of the surface contact area that occurs in the gecko effect may foster effective understanding (figure 6). Of course, a further research is needed to support this view.

In addition, for the gecko effect case, aspects regarding the type of forces that act upon the gecko lizard were less reported. This finding suggests the need to support PTs to develop understanding specifically about this aspect of the effect.

REFERENCES

Bhushan, B. (2010). *Springer handbook of nanotechnology.* Heidelberg: Springer-Verlag.

Blonder, R., & Sakhnini, S. (2016). What Are the Basic Concepts of Nanoscale Science and Technology (NST) that Should Be Included in NST Educational Programs? In K. Winkelmann, & B. Bhushan (Eds.), *Global Perspectives of Nanoscience and Engineering Education* (pp. 117-127). Cham: Springer.

Bryan, L.A., Magana, A.J., & Sederberg, D. (2015). Published research on pre-college students' and teachers' nanoscale science, engineering, and technology learning. *Nanotechnology Reviews, 4*, 7-32. doi: 10.1515/ntrev-2014-0029.

Bryan, L.A., Sederberg, D., Daly, S., Sears, D., & Giordano, N. (2012). Facilitating teachers' development of nanoscale science, engineering, and technology content knowledge. *Nanotechnology Reviews,1*, 85-95.

Daly, S., & Bryan, L. A. (2010). Model use choices of secondary teachers in nanoscale science and engineering education. *Journal of Nano Education, 2*, 76-90.

Healy, N. (2009). Why Nano Education? *Journal of Nano Education, 1*, 6-7.

Flick, U. (2009). *An introduction to qualitative research*. Thousand Oaks, CA:Sage Publications Limited.

Kim, W., Kim, D., Park, S., Lee, D., Hyun, H., & Kim, J. (2018). Engineering lotus leaf-inspired micro- and nanostructures for the manipulation of functional engineering platforms. *Journal of industrial and engineering chemistry*, *61*, 39-52.

Kumar, N., & Kumbhat, S. (2016). *Essentials in nanoscience and nanotechnology*. Hoboken, NJ, John Wiley & Sons.

Lin, S. Y., Wu, M. T., Cho, Y. I., & Chen, H. H. (2015). The effectiveness of a popular science promotion program on nanotechnology for elementary school students in I-Lan City. *Research in Science & Technological Education, 33,* 22-37

Manou, L., Spyrtou, A., Hatzikraniotis, E., & Kariotoglou, P. (2018). Content transformation for experimental teaching nanoscale science and engineering to primary teachers. *Journal of Physics: Conference Series , 1076*, 1-10. doi :10.1088/1742-6596/1076/1/012006.

Sabelli, N., Schank, P., Rosenquist, A., Stanford, T., Patton, C., Cormia, R., και συν. (2005). Report of the workshop on science and technology education at the nanoscale. *Draft Technical Report* . Menlo Park: CA: SRI International.

Sockman, B. R., Ristvey, J., & Jones, C. S. (2012). Student Understanding of Nanoscience through the Gecko's Surface to Surface Interactions. *International Journal of Engineering Education*, *28*, 1068-1077.

PRIMARY SCHOOL TEACHERS EXPERIENCE OF THE DIGITALIZATION OF TEACHING

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The aim of this study is to understand primary school teachers' experience of the ongoing process of digitalization of teaching. The study is done in a Swedish context and includes eight interviews with teachers from six different municipal schools. The results showed that the teachers were positive toward integration of technology and that some of the teachers experienced an increased use of digital teaching, which is in line with the recently revised school curriculum. However, they reveal a lack of prerequisites for digital teaching that can hinder the goals to be fully achieved; these are of both internal and external character and emphasizing, among others, the need to increase the elements of digital teaching in the teacher education programs, as well as offer competence development courses for active teachers.

Keywords: ICT enhanced teaching and learning, Primary school, Educational reform

INTRODUCTION

Discussions about digitalization and the school system have been on the agenda in the Swedish context for a while now. As a result of these discussions the government presented a national digitalization strategy which included an update of the school curriculum, taking effect from July 1, 2018 (The Swedish ministry of education and research, 2018). The overarching goal with the strategy is to position Swedish schools in the lead when it comes to capitalizing on opportunities for digitization. This means to use "the possibilities of digitization in the best way to achieve a high digital competence among children and pupils and to promote knowledge development and equivalence." (The Swedish ministry of education and research, 2017, p. 4). The introduction of digital teaching in the curriculum presents new challenges for the schools. Above all, using digital technology has gone from being a voluntary teaching method to be a compulsory component in all activities. For example, it means that all schools have to acquire materials to meet the requirements and that all the staff at Swedish primary schools have been commissioned to implement digital tools in their teaching. It also states that it is the principal's responsibility to follow up the school's results and to ensure that teachers receive the skills training required to reach the national goals, including learning from each other and conducting a discussion to develop the education. As the revised regulation of the curriculum was only recently presented, the process of change and adaptation is in its initial phase.

By turning our attention to teachers at six different municipal schools in Sweden, we wanted to understand more where in the digitalization process the schools are, as well as how teachers initially relate to digitalized teaching.

THEORETICAL FRAMEWORK

The main purpose with the introduction of digital tools in schools is to raise students' performance. But in order for this to happen, the technology needs to be used in a way that makes learning more efficient. According to Blackwell et al (2013), researchers disagree on the positive effect of digital education and this in turn affects teachers' use in their teaching. Hylén (2013) explains that the disagreement may be due to the fact that technology use in the school has been too scarce for studies to prove positive results. Furthermore, Hylén says that since many schools introduced one computer per student, the positive results have increased. The introduction of digital education will not provide improved results immediately and Hylén emphasizes that when new technology is presented, it may take years before the positive development begins to take shape. This is affected by other issues such as, for example, the technology, service agreements, licenses, competence development and more. According to this author, studies indicate that the importance of school management taking an active role in the transformation is great and therefore it is important that teachers and school leaders discuss together how the new working methods should be adapted to the new situation.

Drivers and barriers for ICT implementation

Several important factors for how the teachers implement and use technology in education have been discovered in earlier research. Drossel et al. (2017) emphasize factors such as the degree of collaboration between colleagues, the teachers' self-confidence in the use of digital tools, and the teachers' attitudes towards the use of technologies in education. They further suggest that understanding the teachers' attitudes towards information and communications technology (ICT) is important for a successful implementation of digital tools aimed at improving student results. In other words, the teachers are key figures in the implementation process. This view is also reported by Hylén (2013) who argues for competence development among teachers as necessary to impact their attitudes, and by Tallvid (2014) who emphasizes that teachers are the ones that need to realize the objective, even when the initiatives most often come from school leaders or policymakers. Perrotta (2013) argues that there is a clear connection between teachers' perception of school management's support in technology education and their perception of usability. Also, the school culture affects teachers' experiences and expectations of the use of technology, perhaps even more than what the teacher's personal qualities, such as age, gender and teacher experience, do. The same finding was done by Li et al. (2018), showing that teachers' professional competency and perception of benefits on use of ICT are significant factors affecting the actual use in student-centered education; teacher cooperation is affecting teachers' perceptions on use of digital contents for student-centered education; and endogenous teacher level factors such as teacher's job satisfaction and self-confidence are affecting teachers' perception on the use of ICT for student-centered education.

Just as research has demonstrated several important factors for successful implementation, a number of barriers that teachers encountered when integrating technology in the curricula have also been found. Ertmer (1999) sorted these barriers into first-order barriers and second-order barriers. First-order barriers refer to the barriers which are external to teachers such as lack of access to hardware and lack of support. Second-order barriers are internal to teachers, such as the teacher competence and willingness. Ertmer highlighted that if teachers were to become "effective users of technology, they will need practical strategies for dealing with the different types of barriers they will face."

METHOD

This study was conducted during the winter of 2018 at six different municipal schools in Stockholm County, Sweden. Our initial step to reach out to the schools were to contact the principal at each school with a request for primary school teachers whom to talk with. All together eight semi-structured interviews were conducted, respectively with five female, and three male teachers. Each interview lasted for approximately 30 minutes and were recorded and annotated. The interview consisted of seven main questions, each of them followed by sub-questions and asked the teachers, among other things, to answer questions that related to their view on digital competence, the introduction of digitalization in the curriculum at their specific school, and to give examples of perceived challenges with the implementation of digitalization. The recording was approved by the respondents by signing an interview agreement. In the case teachers could not be available for a face-to-face interview, we also prepared to conduct telephone interviews. This happened for half of the interviews.

The teachers' work experience ranged between 6 months and 32 years, and all were involved in teaching several different subjects (such as English, Swedish, social science, mathematics, and science). Teacher 7 (T7) had only six months experience and could thus not reflect about the time preceding the curriculum revision. For further information see Table 1.

Table 1. Participants in the study. Last column shows the tools the teachers have access to and the school's strategy of for instance a 1:1 relationship between number of computers and students.

Teacher	Gender	Age (years)	Teaching experience (years)	Interview	Digital tools and profile
T1	Female	30	7	Telephone	iPad, 1:1
T2	Female	55	18	Telephone	Desktop computer, 1:1
T3	Female	54	32	Face-to-face	iPad, 1:2
T4	Female	38	6	Face-to-face	iPad, Bee bots
T5	Male	39	7	Face-to-face	Desktop computer, 1:1
T6	Male	30	2	Face-to-face	iPad
T7	Male	25	<1	Telephone	iPad
T8	Female	31	7	Telephone	iPad

FINDINGS

In the following section the teacher's views are presented. First, we account for the teacher´s attitudes, then how they relate to the term digital competence. This is followed by their view of their own opportunities for educational development. Then we identify their experienced barriers towards digital teaching. The section ends with a summary of the teachers' reflections on their own digital teaching.

Teachers´ attitudes

All the teachers in this study showed an interest in digitalization of teaching. However, this result might have been affected by the selection process. One might expect that the teachers who showed interest in participating in a study about digitalization in teaching, also have a higher interest in general of the subject.

Digital competence

The way digital competence was understood among respondents could be described as multifaceted given the various perspectives presented during the interviews. While some teachers explained digital competence as knowledge of handling digital tools, other participants formulated themselves using words to describe the ability of understanding how digitalization affect students´ everyday life. For example, T5 explained digital competence to be "that students can deal with a computer, be able to communicate, use a computer when writing, use a search engine, be source critical.".

The most common way to motivate the presence of digital tools was by arguing that schools need to keep up with the society. An example is T4 who explained that the reason for it to be important is that the schools need to keep up with the surrounding society and that digitalization is part of this work. In addition, T8 also expressed digitalization as a way of "following reality".

Background in digital teaching

The teachers generally lacked formal education in how digital tools can be used. They viewed the lack of training as negative, pointing towards that they are expected to keep up with the technological developments but are not offered strategies to handle this. However, the fact that six out of eight teachers responded that their teacher education did not include any course on digital competence was excepted as several of them had worked as teachers for many years. Only two of the teachers had worked less than six years, and in both these cases ICT had been included in their training. However, both these teachers regarded this insufficient as they did not consider the courses to be adequate as they were only introduced to digital tools and were not taught in what and how digital tools should be used in practice. One of the teachers had only used digital tools it in connection with science subjects, thus lacking knowledge on how to use digital tools in other subjects.

All, except for one teacher, had been offered voluntary courses on digital tools by their employer. The courses have been given in various forms, from courses lead by a colleague at the school to courses outside the workplace during afternoons. Despite this, seven of the teachers brought up that the courses only go on for a limited time and then they experience a lack of continuity.

Only one teacher, T1, had a work situation that differed considerably. T1 was part of an IT group at the school, which works actively with digitalization issues. However, there is no reduction in time or compensation for the extra work, resulting in that T1 was not entirely satisfied with the support from the management side.

Perceived barriers – access and time

Even though most of the teachers in this study were employed at schools where digital tools such as smartboards, bee-bots, computers and tablets have been around for a long time, they all agreed that the implementation of teaching using such tools was still problematic. Two main reasons, were mentioned, namely access and time, and both of these were beyond their influence and control.

Regarding access to technology, teachers from two of the six schools stated that they do lack digital tools that facilitate digital teaching. To solve the lack of technology, in a school task where students were to make stop-motion movies, T4, who only had one iPad to share among 30 pupils, confessed that she lets the students borrow her own mobile phone. The reason was that she felt she had no other option. Another implication mentioned by T6 was the access to educational software. As the school had a business agreement and rented tablet computers all teachers had to go through the external company in order to install and download applications.

Regarding time allocated to teaching with technology, all eight teachers said that there is a widespread interest among colleagues and themselves to use technologies, however the time to develop their competence does not exist. And so far, none of the participants had been given time to develop their digital skills. Rather, it has been introduced as an addition to the tasks that teachers already have. This can, according to the respondents, in turn inhibit the teachers who need support in their planning of digital teaching.

Reflections on their own digital teaching

The teachers were asked to estimate the amount of their own use of digital tools along a 10 graded scale and to compare their use today with their use the previous school year (T7 had only been employed for six months and could therefore not make the comparison). Four of the teachers estimated their use to be higher today, one had not changed, and two estimated their use to be lower today than last year. In total, only a small increase in use of digital tools can be seen after the point where the new requirements took effect.

When the teachers were asked about the positive side of the use of digital tools, six of them mentioned that digital tools increase the motivation of students and makes it easier to obtain commitment in the classroom. One specific example mentioned by T7 was how they in geography class used the three-dimensional map provided by Google. The map, which makes it possible to rotate and view a point of interest from different angles had resulted in less confusion among the students and that he as a teacher spends less time on explanations. T5 provided an example from math class and emphasized how the use of digital tools had improved the students understanding of math. T1 highlighted that the use of digital tools had made it easier for teachers to work with different subjects simultaneously. Both T1 and T4 mentioned the possibility for students to create their own material, and T2 and T5 emphasized increased collaboration in the classroom as students helped each other. Digital tools were also described in positive terms by T2 who explained that students engaged themselves with digital tools in anticipation of help from the teacher. Similar situations were described by T1 and T3, as both stated that students used the tools to look for information while waiting for the teacher to arrive. Furthermore, the teachers reported on advantages with digitalization of teaching in terms of easier administration tasks such as that student assessment had become smoother (T5), it was easier for the teachers to take contact with students after school hours via e-mail (T4, T5), and it was easier to share documents (T4, T5).

Although much of what was mentioned during the individual interviews were similar opinions, there were also things that differed. One such difference was whether the use of digital tools affects students' written language: T6 emphasized that digital tools helped students in their writing development by providing the opportunity for the student to concentrate on the content of the story, such as developing the action of the story. T5 experienced that the students´ written language had approached the speech language when they write. The reason to this, as understood by T5, was that the students read shorter texts online than they would do on paper.

DISCUSSIONS AND CONCLUSIONS

The results showed that the teachers were positive towards the integration of digital teaching in the curriculum, and they also showed a positive attitude towards using it in their own teacher practice. However, the teachers experienced both external and internal barriers to the integration, such as lack of time (external), lack of technology (external) and lack of knowledge (internal).

Since digital education now is a requirement in Swedish primary schools, teachers must be given the opportunity to work towards more digitized education. This emphasizes the need to implement courses or increase the elements of digital teaching in the teacher education programs, as well as offer competence development courses for active teachers. Another suggestion, based on the results from this study, is to find means for having continuous meetings with colleagues, which has been pointed out as an important factor for personal development. This is also in line with the changes in the school curriculum pointing towards the principal's responsibility to ensure that teachers receive the skills training required (The Swedish ministry of education and research, 2017). Having access to further education should also be seen as an opportunity for the teachers to develop their own strategies to deal with the different types of barriers they will come across (Ertmer, 1999)

This study has contributed to understanding the factors affecting Swedish primary school teachers' perception on digital teaching after the implementation in the school curriculum. Although untried, the authors expect that the findings may have a wider validity as many countries now face similar challenges.

ACKNOWLEDGEMENT

We would like to thank the Teacher education and the Department of Media Technology at Södertörn University for financing attendance at ESERA.

REFERENCES

Blackwell, C. K., Lauricella, A. R., Wartella, E., Robb, M. & Schomburg, R. (2013). Adoption and use of technology in early education: The interplay of extrinsic barriers and teacher attitudes. *Computers & Education*, 69, 310--319. https://doi: 10.1016/j.compedu.2013.07.024.

Drossel, K., Eickelmann, B., & Schulz-Zander, R. (2017). Determinants of teachers' collaborative use of information and communications technology for teaching and learning: A European perspective. *European Educational Research Journal*, 16(6), 781-799.

Ertmer, P. A. (1999). Addressing first-and second-order barriers to change: Strategies for technology integration. *Educational technology research and development*, 47(4), 47-61.
Li, S., Yamaguchi, S., & Takada, J. I. (2018). Understanding factors affecting primary school teachers' use of ICT for student-centered education in Mongolia. *International Journal of Education and Development using ICT*, 14(1).
Perrotta, C. (2013). Do school-level factors influence the educational benefits of digital technology? A critical analysis of teachers' perceptions. *British Journal of Educational Technology*, 44(2), 314-327.
The Swedish Ministry of Education & Research (2018). Curriculum for the compulsory school, preschool class and school-age educare. Retrieved from https://www.regeringen.se/4a9d9a/contentassets/00b3d9118b0144f6bb95302f3e08d11c/nationell-digitaliseringsstrategi-for-skolvasendet.pdf
The Swedish Ministry of Education & Research (2017). Nationell digitaliseringsstrategie för skolväsendet. Retrieved from https://www.skolverket.se/publikationer?id=3984
Tallvid, M. (2016). Understanding teachers' reluctance to the pedagogical use of ICT in the 1: 1 classroom. *Education and Information Technologies,* 21(3), 503-519.

BRINGING BIOINFORMATICS TO SECONDARY EDUCATION: A WORKSHOP FOR SCIENCE TEACHERS

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Having in mind the technological world we live in, scaffolding teachers to integrate computer-based resources in their classes is an important endeavour when it comes to teacher professional development. In this context, a workshop on bioinformatics to address gene regulation, molecular biology and genomics in high school gathered a group of 18 high-school science teachers. Following the workshop, the participants answered a questionnaire aiming to diagnose teachers' perceptions about bioinformatics; to identify the main constrains that are preventing teachers from successfully implementing bioinformatics in their classes; and to evaluate the potential to integrate basic bioinformatics exercises in their educational practices. Data were subjected to descriptive statistics and to content analysis. The results showed that the teachers attending the workshop were highly motivated and interested in learning more about bioinformatics and about strategies to integrate bioinformatics in their classes. Despite teachers highlighted the adequacy of bioinformatics to the educational context, most of them mentioned that their academic background was not sufficient to confidently implement bioinformatics-based exercises in their classes. Teachers claimed for more training courses in this area and approximately half of the participants admitted that schools are equipped with the necessary resources to integrate bioinformatics. Overall, this study emphasizes the importance to foster more initiatives to integrate bioinformatics in secondary education curriculum and highlights the need to increase the offer of teachers' training on bioinformatics.

Keywords: Computer Based Learning, Teacher Professional Development, Technology in Education and Training

INTRODUCTION

Despite technology is now acknowledged as a helpful tool for teaching and learning science, many science teachers got their academic qualifications for teaching at a time in which technology, namely computers, were rarely used or inaccessible for most of the people. It is therefore with no surprise that in-service teachers feel uncomfortable or not motivated to use computers in their classrooms, being urgent to scaffold teachers to develop their Technological Pedagogical Content Knowledge (TPACK) (Koehler & Mishra, 2009; Mumtaz, 2000).

Having this need in mind, professional development programs for science teachers should focus on helping them to integrate the use of the technology in the teaching practices. An opportunity to integrate computers and digital resources as a didactic tool based on real research procedures is to approach genomics and molecular biology based-on bioinformatics tools (Chiovitti et al., 2019; Gelbart & Yarden, 2006; Martins, Fonseca, & Tavares, 2018; Nunes, Júnior, Menezes, & Malafaia, 2015). Despite genomics being one of the most important revolutions of late 20th century and at the beginning of this century, the lack of literacy on genomics and molecular biology in the general population is reported in several studies (Eklund, Rogat, Alozie, & Krajcik, 2007; Kirkpatrick, Orvis, & Pittendrigh, 2002; Kolarova, 2011; Lock, 1996; Tarver, 2010). While an effort is being made to integrate bioinformatics in high-school science curricula in different countries, it is unquestionable that more teacher's training opportunities in bioinformatics is needed (Attwood, Blackford, Brazas, Davies, & Schneider, 2017; Kovarik et al., 2013; Machluf, Gelbart, Ben-Dor, & Yarden, 2017; Marques et al., 2014).

In this context, the workshop "*From DNA to Genes and to Comparative Genomics: Bioinformatics in the classroom*" was aimed to instruct science teachers about the suitability of bioinformatics activities to their teaching practices. Teachers were challenged to explore bioinformatics-based exercises particularly chosen to teach basic molecular biology concepts, to address gene regulation and to discover the usefulness of comparative genomics (Martins, Fonseca, & Tavares, 2018). This training workshop on bioinformatics allowed to boost teachers' TPACK, since teachers developed their technological knowledge by learning how to use bioinformatics tools and, concomitantly, they enlarged their pedagogical and content knowledge, by discussing new strategies to teach curricular contents and additionally introduce key concepts in genomics such as Open Reading Frame (ORF) or Basic Local Alignment Tool (BLAST) (Martins & Tavares, 2018). The workshop was promoted in the context of an international meeting for teachers (Casa das Ciências, 2018) that occurred in Portugal in 2018.

OBJECTIVES

The main objectives of this study were to diagnose teachers' perceptions about bioinformatics; to infer the potential of its integration in educational practices; and to identify the main constrains that are preventing teachers to successfully implement bioinformatics in their classes.

RESEARCH QUESTIONS

This study was driven by two main research questions: "*Which are the teachers' perceptions about bioinformatics and its integration in science teaching practices*?" and "*Which are the main constrains that are preventing teachers from integrating bioinformatics in their teaching practices*?"

METHODS

Participants

The sample included 18 science teachers (14 female and 4 male) from 14 different schools that voluntarily enrolled at the workshop. Seven of the 18 teachers hold a master's degree. Participants have an average of 26.61± 7.48 years of teaching experience. Between 2016 and 2018, 4 teachers taught at elementary school level (students between 12-15-year-old), 6 taught at secondary school level (students between 16-18 years old) and 8 taught both elementary and secondary school levels.

Materials

Framed within the curriculum for biology in secondary education (Council, 2013), the four hours workshop "*From DNA to Genes and to Comparative Genomics: Bioinformatics in the classroom*" drives teachers to explore the potential of bioinformatics as a didactic tool to approach contents, such as the organization and regulation of genetic material, and to carry out evolutionary inferences. From an *in silico* analysis of a DNA sequence it is proposed to identify genes and to determine the putative functions of their products. Additionally, using comparative genomics platforms such as *MaGe – Magnifying Genomes* (MicroScope), the participants were challenged to evaluate the presence of certain genes in different taxonomic groups aiming to infer evolutionary relations. This activity contributes to a holistic approach to genomics, genes and proteins, as well as to propose evolutionary hypotheses (Martins, Fonseca & Tavares, 2018). Each teacher was asked to bring their personal computers to carry out the exercises.

To diagnose teachers' perceptions about bioinformatics and its integration in science teaching practices as well as to identify the main constrains that are preventing teachers from integrating bioinformatics in their classes, a specifically designed questionnaire, adapted from the survey previously described by Martins, Lencastre and Tavares (2018), was implemented. The questionnaire, including 35 questions in various formats, namely dichotomous, Likert-type (ranged from 1 to 5) and open-ended questions, and is divided into three parts: *Part A*: socio demographic data; *Part B*: assessment of teachers' training and academic background on bioinformatics, and appraisal of teachers' attitudes towards bioinformatics integration and of their perceptions regarding workshop attendance; *Part C*: teacher's opinions about the questionnaire: objectivity, comprehension of the items, and suggestions.

In Part B, questions were designed according to the objectives defined for this study. Questions 1 and 5 (Q1; Q5) were aimed to diagnose teachers' definition of bioinformatics as well as to characterize the importance of bioinformatics to the current research. The assessment of teachers' interest and perceived knowledge about bioinformatics were addressed through questions Q3, Q12.1., Q12.2. Another dimension evaluated was teachers' perspectives on the importance of integrating bioinformatics in their teaching practices as well as to identify the main obstacles to this integration. In this regard, questions Q2, Q6, Q7, Q9, Q9.1., Q9.1.1., Q10, Q11, Q12.3., Q12.4. were included in the questionnaire. Question Q8 was intended to characterize the use of technology in the classroom by teachers. Lastly, and having in mind the main findings of previous studies highlighting the importance of promoting teachers training actions in the area of bioinformatics (Machluf et al., 2017; Machluf & Yarden, 2013; Martins, Lencastre, & Tavares, 2017, 2018), questions Q4.1., Q4.2., Q12.5., Q13, Q14, Q15, Q16 and Q17 were introduced to characterize the impact of the workshop on teachers perceived knowledge about bioinformatics as well as to evaluate the workshop, identifying the potential of the action but also having feedback on possible improvements.

Teachers rated the questionnaire as an objective instrument (4.76±0.44) and easy to understand (4.76±0.44). One participant added the following suggestion for improvement: "*In question 12.4., you should specify if the classes are lectures or if they are practical classes of biology* *including wet lab and experiments*". This suggestion will be taken into consideration in future questionnaires.

Data Collection and Analyses

The questionnaire was implemented after the attendance of the workshop, i.e. when participants finished the proposed exercises. The aims of the research as well as the objectives of the questionnaire were explained to teachers who voluntarily agreed to answer the survey. Descriptive statistical analysis was performed for quantitative data (Punch, 2009). For qualitative data, a thematic content analysis of the participants' responses to open-ended questions was carried out (Roberts, 2015; Schuster & Weber, 2006).

RESULTS AND DISCUSSION

Teachers' background on bioinformatics

The majority of the teachers (94.44%) correctly defined bioinformatics (Q1), and one teacher mentioned that bioinformatics is "*a didactic tool for science classes*". Among all listed notions (49), teachers mentioned frequently the following: informatics (12.62%), biology (8.74%), data (6.8%), tools (6.8%) and applications (4.85%). This analysis revealed that teachers recognized the scope of bioinformatics as the scientific field which develops or uses tools and applications of informatics to understand the biological data, which fits well with a general definition of bioinformatics (Luscombe, Greenbaum, & Gerstein, 2001; Sadek, 2004).

Teachers revealed to be interested in bioinformatics (Q3) and recognized its importance for scientific advances (Q5) (Figure 1). However, teachers considered that their academic background is not sufficient to feel prepared to teach using bioinformatics tools (Q12.1.) and highlighted the added-value of professional training (in-service) (Q12.2.) to implement bioinformatics activities in their classes (Figure 1). These results are in line with the literature (Machluf, Gelbart, & Yarden, 2012; Machluf & Yarden, 2013; Martins, Lencastre & Tavares, 2018; Wood & Gebhardt, 2013) and reinforce the importance of promoting initiatives of professional development oriented for bioinformatics training.

Attitudes towards bioinformatics integration

The importance of integrating bioinformatics in elementary (Q6) and secondary education (Q7) was highlighted by the participants (Figure 1), as well as the potential to use bioinformatics both at Biology classes and Information and Communications Technology (ICT) classes (Q2), mentioned by 77.78% of the teachers. It is acknowledged that bioinformatics-based activities foster students' hybrid abilities in computation and biology, nurturing a wide range of skills such as using bioinformatics to find, retrieve and organize data by identifying an appropriate data repository, to understand evolutionary related processes or to develop their critical thinking namely in which concerns open data access (Foster & Sharp, 2007; Mariano, Martins, Santos, & Minardi, 2019; Oliver et al., 2012; Sayres et al., 2018).

The majority of teachers (94.44%) assumed to use computers to explore online resources in their classes (Q8), but only 5 out of 18 (27.78%) revealed to have autonomously explored bioinformatics resources in order to implement them in their classes (Q9). Among the teachers who had previously explored bioinformatics resources, 3 out of 5 (60%) actually implemented the activities in their classes (Q9.1.). The two teachers who did not (40%), listed as the main reasons "*Lack of computers available*" and "*The need to better understand the explored bioinformatics tools". However, their intention is "to apply the activities in the classroom soon*" (Q9.1.1.).

Around half of the participants (55.56%) considered that the school/institutions where they were teaching have the necessary conditions to integrate bioinformatics-based activities in their classes (Q11), which is in agreement with recent reports indicating that most schools in Europe are equipped with technological devices (European Comission, 2013). In contrast with this result, the main constrains identified by teachers to carry out the implementation of bioinformatics activities in the classroom (Q10) were: computers (7.87%) and internet (6.74%). Only 2 out of 18 teachers (11.11%) revealed positives attitudes regarding the possible constrains that can arise when implementing bioinformatics in their classroom mentioning that "*cannot identify any constrains. The school has the necessary resources (…) and students are motivated*" and "*the management of the time is possible especially in the 11th grade*". 66.67% of the participants indicated that the main constrains to implement bioinformatics-based activities in their classrooms were related with logistics aspects (resources and time) answering that "*computers are lacking in schools*"; "*the number of students per class is too high*"; "*the internet connection is weak*"; and "*bioinformatics resources are not in Portuguese*". Teachers mentioned that schools are well prepared to carry out bioinformatics exercises, however logistics aspects were mentioned as the main hinder to not apply these tools in the classrooms. This result stresses the importance to better characterize schools' reality in which concerns technology use.

16.67% of the participants identified both logistic constrains and lack of teacher's confidence as the main difficulties to implement the proposed approached in the classroom. Teachers emphasized their lack of confidence to approach some curricular topics using bioinformatics resources and highlighted their need to acquire specific training, which is corroborated by other studies (Cebesoy & Oztekin, 2018; Machluf & Yarden, 2013; Martins, Lencastre & Tavares, 2018). One teacher (5.56%) mentioned that "*The complexity of some processes and their interpretation by the students requires strong orientation and motivation, which should be taken into account when organizing the activity.*" This perspective was included in category: Constrains related with the student's performance.

Furthermore, the data showed that teachers considered that planning and implementing bioinformatics-based activities is more time-consuming and requires more resources than other activities (Q12.3.; Q12.4.) (Figure 1). These notions can be related with the lack of opportunities for teachers' training in bioinformatics. Training is crucial for teachers to feel more acquainted with bioinformatics tools and to clarify that planning and implementing bioinformatics-based activities can be framed within the time schedule for a class (90 minutes) as described by Martins, Fonseca and Tavares (2018). Another reason that can explain this result is the absence of didactic bioinformatics resources in Portuguese. In fact, the idiom of the majority of the platforms and of the exercises available is English which was previously reported as a barrier to non-English speakers (Machluf & Yarden, 2013; Martins, Lencastre & Tavares, 2017, 2018). This result highlights the importance of creating a portfolio of bioinformatics-based activities, in this case adapted to Portuguese, and making it available for the educational community in other to emphasize the adequacy of integrating bioinformatics in educational approaches.

Perceptions regarding workshop attendance

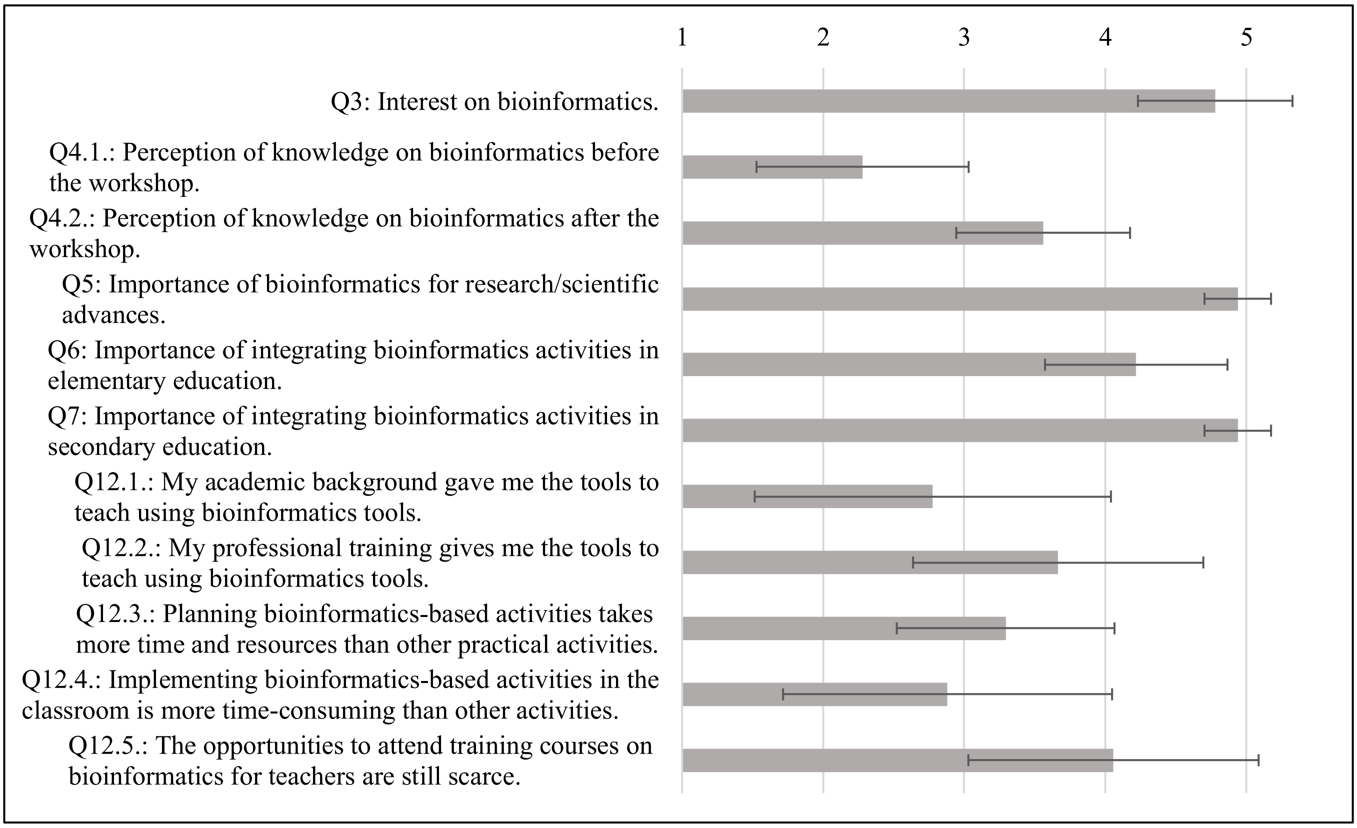
A careful analysis of teachers training on bioinformatics was carried out having in consideration the previous results reported by Martins, Lencastre & Tavares (2017, 2018), by Machluf et al. (2012, 2013) and by Marques et el. (2014). Despite the interest of all the participants in attending training courses on bioinformatics for teachers (Q16), it was mentioned that the availability of these courses is still very scarce (Q12.5.) (Figure 1). In fact, the importance of adequate teachers training in this scientific field, is further supported by the higher perception teachers have about their knowledge in bioinformatics after attending the workshop (Q4.2.), in comparison with that perception before the workshop (Q4.1.) (Figure 1).

Regarding the workshop itself, teachers were asked about the reasons that motivate them to attend this workshop and to choose this workshop among others (Q13). They were asked to list the main difficulties found when they were performing the workshop activities (Q14) and suggestions were collected in how to improve the workshop (Q15).

The 18 participants listed the main reasons that motivated them to attend the workshop (Q13). By carrying out an analysis of the five most frequent words mentioned, it was possible to list: class (6.84%); application (5.98%); classroom (5.13%); learn (4.27%); and utilization (4.27%). This general analysis suggests that teachers wish to learn how to apply and how to use the bioinformatics tools in their classes. Adding to this analysis, it was possible to identify three main categories of answers. "*To learn to apply*" – was mentioned by three participants (16.67%). These participants revealed that they chose this workshop in order to learn "*how to implement the tools of these area*" in their classrooms. Six out of the 18 participants (33.33%) highlighted as the main reason to attend this workshop "*Curiosity*". Teachers justified their attendance as an opportunity to learn more about bioinformatics, by curiosity and because they were "*interested in related topics such as genetics and all the fields that are related with DNA*". This result reinforces teachers' interest in this scientific topic. The third category is particularly important in the context of this study: "*The need of updating*". Mentioned by 9 participants (50.00%), this category included answers such as "*I felt the need of learning about this area* (…) *and to explore bioinformatics in a scientific and right perspective*" or "*I urgently need to improve my skills* (…) *to follow the quick development of these applications* (…) *and to implement them with my classes*". This result is in line with the considerations about the urgency of training courses reported above. Teachers are interest in this scientific area and the adequacy of the proposals to the schools is recognized, although they do not feel prepared to proceed with the implementation of the tools without previous specialized training (Machluf & Yarden, 2013; Martins, Lencastre & Tavares, 2018; Shuster, Claussen, Locke, & Glazewski, 2016; Wood & Gebhardt, 2013).

In which concerns with the main difficulties found by the participants while performing the activities of the workshop (Q14), three categories of answers were defined. 50.00% of the participants (9 out of 18) listed as the main difficulties' technical aspects such as internet access, and the lack of time or difficulties to read the paper version of the guidelines. In fact, these constrains were related with the organization of the workshop itself and not with difficulties related with the bioinformatics-based activities performed. However, the internet connection was fixed even during the workshop and the digital version of the guidelines was sent by email to the participants. In this regard, we can assume that the logistic constrains were solved and the workshop work-flow was not affected. Two out of 18 participants (11.11%) revealed to have difficulties in interpreting "*aspects associated with gene sequences/nucleotides*" and to "*understand the steps to follow*". In contrast with these results, 38.89% (7 out of 18) reported no difficulties and one teacher did not answer this question.

Figure 1. Answers given by participants according to a Likert Scale (Range 1 to 5). Grey bars represent the mean value and the error bars refer to the standard deviation.



Finally, suggestions for workshop improvement were asked to the participants (Q15). 44.44% of the participants did not answer this question. 33.33% of the participants listed suggestions for improvement. Essentially participants claim for: "*More exercises*"; "*I would like to attend a training course (longer) in this area, once 3 hours are not sufficient to understand all the information discussed*"; and "*to increase the font size of the text in the guidelines – paper version*". 22.22% highlighted that "*do not think that the workshop needs to be changed*".

CONCLUSION

Teachers revealed to be interested in bioinformatics and recognized its importance for scientific advances, which is in frame with the expected teachers' perceptions about bioinformatics as a scientific discipline. Teachers were open and motivated to integrate bioinformatics in their teaching practices. Regardless their will, teachers believe that key constrains have to be overcome, emphasizing the need of suitable training through dedicated courses. Thus, the main take-home message from this workshop is the urgent need of training courses for teachers in order to fuel the integration of bioinformatics in the curriculum and education daily practices. Adding to this, it is important to better understand the reasons why teachers admitted that their schools have the necessary conditions to implement bioinformatics-based approaches, but contradictorily they indicated as the main constrains to this implementation: poor internet connection and lack of computers. A reedition of the workshop occurred in July 2019 with 40 participant teachers. In this workshop, new data were collected in order to increase the robustness of this study. Adding to this, a website is under construction and will be soon available for teachers, with bioinformatics-based exercises in Portuguese in order to meet the participants request of having more available resources in their native language.

We believe that the current study is a wakeup call for educational stakeholders to boost bioinformatics educational integration aiming to meet the challenges of a society capable to understand the scientific advances and take informed decisions.

ACKNOWLEDGEMENT

The authors are grateful to all participants of this study and to Casa das Ciências (https://www.casadasciencias.org/) for the invitation to present a workshop and for creating the opportunity to perform this research. Ana Sofia Martins is supported by a fellowship from Fundação para a Ciência e Tecnologia – FCT (SFRH/BD/112038/2015).

REFERENCES

Attwood, T. K., Blackford, S., Brazas, M. D., Davies, A., & Schneider, M. V. (2017). A global perspective on evolving bioinformatics and data science training needs. *Briefings in Bioinformatics*. https://doi.org/10.1093/bib/bbx100

Casa das Ciências. (2018). V Encontro Internacional da Casa das Ciências - Ciência, Comunicação, Imagem e Tecnologia. Retrieved January 8, 2020, from https://www.casadasciencias.org/5encontrointernacional/

Cebesoy, U., & Oztekin, C. (2018). Genetics Literacy: Insights From Science Teachers' Knowledge, Attitude, and Teaching Perceptions. *International Journal of Science and Mathematics Education*, *16*(7), 1247–1268. https://doi.org/10.1007/s10763-017-9840-4

Chiovitti, A., Thorpe, F., Gorman, C., Cuxson, J., Robevska, G., Szwed, C., Sumner, J. (2019). A citizen science model for implementing statewide educational DNA barcoding. *PLOS ONE*, *14*(1), e0208604. https://doi.org/10.1371/journal.pone.0208604

Council, N. R. (2013). *Next Generation Science Standards*. Washington, D.C.: National Academies Press. https://doi.org/10.17226/18290

Eklund, J., Rogat, A., Alozie, N., & Krajcik, J. (2007). *Promoting Student Scientific Literacy of Molecular Genetics and Genomics*. Retrieved from http://www.umich.edu/~hiceweb/presentations/documents/Genetics_NARST_07.pdf

European Comission. (2013). Survey of Schools: ICT in Education - Benchmarking Access, Use and Attitudes to Technology in Europe's Schools. Publications Office of the European Union.

Foster, M., & Sharp, R. (2007). Share and share alike: deciding how to distribute the scientific and social benefits of genomic data. *Nature Reviews Genetics*, *8*(8), 633–639. https://doi.org/10.1038/nrg2124

Gelbart, H., & Yarden, A. (2006). Learning genetics through an authentic research simulation in bioinformatics. *Journal of Biological Education*, *40*(3), 107–112. https://doi.org/10.1080/00219266.2006.9656026

Kirkpatrick, G., Orvis, K., & Pittendrigh, B. (2002). A teaching model for biotechnology and genomics education. *Journal of Biological Education*, *37*(1), 31–35. https://doi.org/10.1080/00219266.2002.9655843

Koehler, M., & Mishra, P. (2009). What is technological pedagogical content knowledge? *Contemporary Issues in Technology and Teacher Education*, *9*(1), 60–70.

Kolarova, T. (2011). Modern biotechnology from the point of view of 15-19-year-old high school students. *Biotechnology and Biotechnological Equipment*, *25*(3), 2538–2546. https://doi.org/10.5504/bbeq.2011.0069

Kovarik, D., Patterson, D., Cohen, C., Sanders, E., Peterson, K., Porter, S., & Chowning, J. (2013). Bioinformatics Education in High School: Implications for Promoting Science, Technology, Engineering, and Mathematics Careers. *CBE—Life Sciences Education*, *12*(3), 441–459. https://doi.org/10.1187/cbe.12-11-0193

Lock, R. (1996). Biotechnology and genetic engineering: Student knowledge and attitudes: Implications for teaching controversial issues and the public understanding of science. In G. Welford Osborne, J. , Scott, P. (Ed.), *Research in Science Education in Europe* (pp. 229–242). London: The Falmer Press.

Luscombe, N., Greenbaum, D., & Gerstein, M. (2001). What is bioinformatics? A proposed definition and overview of the field. *Methods of Information in Medicine*. https://doi.org/10.1053/j.ro.2009.03.010

Machluf, Y., Gelbart, H., Ben-Dor, S., & Yarden, A. (2017). Making authentic science accessible—the benefits and challenges of integrating bioinformatics into a high-school science curriculum. *Briefings in Bioinformatics*, *18*(1), 145–159. https://doi.org/10.1093/bib/bbv113

Machluf, Y., Gelbart, H., & Yarden, A. (2012). *High-School Teachers' Appropriation of an Innovative Curriculum in Bioinformatics*. (D. Kruger & M. Ekborg, Eds.), *The 9th Conference of European Researchers in Didactics of Biology (ERIDOB)*. Berlin.

Machluf, Y., & Yarden, A. (2013). Integrating bioinformatics into senior high school: design principles and implications. *Briefings in Bioinformatics*, *14*(5), 648–660. https://doi.org/10.1093/bib/bbt030

Mariano, D., Martins, P., Santos, L., & Minardi, R. (2019). Introducing Programming Skills for Life Science Students. *Biochemistry and Molecular Biology Education*, *47*(3), 288–295. https://doi.org/10.1002/bmb.21230

Marques, I., Almeida, P., Alves, R., Dias, M., Godinho, A., & Pereira-Leal, J. (2014). Bioinformatics Projects Supporting Life-Sciences Learning in High Schools. *PLoS Computational Biology*, *10*(1), e1003404. https://doi.org/10.1371/journal.pcbi.1003404

Martins, A., Fonseca, M., & Tavares, F. (2018). Mining the Genome: Using Bioinformatics Tools in the Classroom to Support Student Discovery of Genes. *The American Biology Teacher*, *80*(8), 619–624. https://doi.org/10.1525/abt.2018.80.8.619

Martins, A., Lencastre, L., & Tavares, F. (2017). Adequacy of bioinformatics tools to elementary and secondary school curricula: a training course for teachers. In *Congresso Internacional - O Tempo dos Professores*. Porto: FPCEUP. Retrieved from https://sigarra.up.pt/fpceup/pt/pub_geral.pub_view?pi_pub_base_id=262743&pi_pub_r1_id=

Martins, A., Lencastre, L., & Tavares, F. (2018). Integrating bioinformatics in elementary and secondary education: Teacher's perceptions. In *3rd International Conference on Teacher Education (INCTE)*. Bragança: Instituto Politécnico de Bragança.

Martins, A., & Tavares, F. (2018). Genomics Education: Update Core Concepts in High School. In M. Costa, B. Dorrío, & J. Fernandez-Novell (Eds.), *Hands-on Science. Advancing Science. Improving Education.* (pp. 145–150). Barcelona: Hands-on Science Network.

Mumtaz, S. (2000). Factors affecting teachers' use of information and communications technology: a review of the literature. *Journal of Information Technology for Teacher Education*, *9*(3), 319–342. https://doi.org/10.1080/14759390000200096

Nunes, R., Júnior, E., Menezes, I., & Malafaia, G. (2015). Learning nucleic acids solving by bioinformatics problems. *Biochemistry and Molecular Biology Education*, *43*(5), 377–383. https://doi.org/10.1002/bmb.20886

Oliver, J., Slashinski, M., Wang, T., Kelly, P., Hilsenbeck, S., & McGuire, A. (2012). Balancing the Risks and Benefits of Genomic Data Sharing: Genome Research Participants' Perspectives. *Public Health Genomics*, *15*(2), 106–114. https://doi.org/10.1159/000334718

Punch, K. F. (2009). *Introduction to Research Methods in Education.* Sage Publications.

Roberts, C. (2015). Content Analysis. In *International Encyclopedia of the Social & Behavioral Sciences: Second Edition* (pp. 769–773). Elsevier Inc. https://doi.org/10.1016/B978-0-08-097086-8.44010-9

Sadek, H. (2004). *Bioinformatics : principles, basic internet applications*. Trafford.

Sayres, M., Hauser, C., Sierk, M., Robic, S., Rosenwald, A., Smith, T., Pauley, M. (2018). Bioinformatics core competencies for undergraduate life sciences education. *PLOS ONE*, *13*(6), e0196878. https://doi.org/10.1371/journal.pone.0196878

Schuster, C., & Weber, R. (2006). Basic Content Analysis. *Journal of Marketing Research*, *23*(3), 310. https://doi.org/10.2307/3151496

Shuster, M., Claussen, K., Locke, M., & Glazewski, K. (2016). Bioinformatics in the K-8 Classroom: Designing Innovative Activites for Teacher Implementation. *International Journal of Designs for Learning*, *7*(1), 60–70. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/27429860

Tarver, T. (2010). Genomics: A New Challenge in Consumer Health Information Literacy. *Journal of Hospital Librarianship*, *10*(1), 23–32. https://doi.org/10.1080/15323260903470910

Wood, L., & Gebhardt, P. (2013). Bioinformatics Goes to School—New Avenues for Teaching Contemporary Biology. *PLoS Computational Biology*, *9*(6), e1003089. https://doi.org/10.1371/journal.pcbi.1003089

PROFESSIONAL DEVELOPMENT FOR ICT-BASED TEACHING

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Using information and communications technologies (ICT) in the classroom requires new skills on the part of educators. We have elicited current best practices for professional development of educators from the participants in this workshop, what knowledge teachers need and how it is best imparted. We found that even given their different starting points, teachers in different regions are often feeling unsure about how to use ICT in a pedagogical context, and there is no clear consensus on how to best train teachers in this use, but that the digitalisation of schools will require a long-term commitment from school management and political leadership.

Keywords: Teacher Professional Development, ICT Enhanced Teaching and Learning, Technology in Education and Training

INTRODUCTION

The increased use of information and communications technologies (ICT) in the classroom to support students' learning places new demands on teachers at all levels, from pre-school to graduate school. This in turn increases the expectations on the teachers' abilities to develop their own proficiency of using this technology: internationally, such proficiency is commonly referred to as *digital literacy*, while within the Scandinavian educational context the term *digital competence* is more common (Hanell, 2018; Ilomäki et al., 2016; Krumsvik, 2008). Digital competence refers here to a holistic perspective incorporating proficiency with pedagogical judgement and with the focus on pedagogy and subject matter. In other words, digital competence is knowledge about how digital tools affect our everyday life, and how to use digital tools to support critical thinking, creativity, and innovation.

Teachers are now required to have a working understanding of:

- hardware, in the various forms of computers, mobile phones, and electronic tablets, but possibly also peripherals such as network routers, digital projectors, and printers;
- software, from word processors and drawing programs to specialised educational software, and learning management systems;
- the limitations of computer systems, being able to critically evaluate claims of current and future functionality, the impact of social media on rumors, social unrest, and political events.

For most teachers, having these skills is not a goal in itself, but a prerequisite for developing new learning situations. Many are uncertain of how to best use digital systems for best effect on students' learning or may even be uncertain whether they are helped at all by digital systems. In many cases, there might also be a considerable learning effort required simply to start using a digital tool, and often enough, the actual use requires some skill and effort. These issues may make such tools less suitable for use in the educational situation by students, but also divert time from the actual teaching effort. The use of technology is also limited by personal factors such as teaching vision and understanding of the technology's influence on teaching (Hylén, 2013). Still, the digital competence of teachers is required and we need to find ways to develop digital skills in teacher education and in-service training to meet the goals regarding digitalisation in the curriculum. These ways should be based on the priorities of teachers, we thus need to elicit information on what knowledge teachers feel they lack and how they would prefer to address this.

Despite governmental expectations of increased digital competence among teachers, there is still much to do to assist teachers with accessing knowledge on what might enhance their practice. The purpose of this workshop was therefore to address teachers' professional development by encouraging the sharing of knowledge among teachers (Ertmer et al., 2012) and to address both local and global settings (Albion et al., 2015).

BACKGROUND AND PREVIOUS RESEARCH

Previous studies show that digital tools, defined as word processors, spreadsheet programs, drawing programs, programming environments, etc., develop creativity, problem solving and critical thinking (Albion et al., 2015). Various aspects of digitization and digital tools have therefore been integrated into the school curriculum in most countries in the Western world. According to the curriculum in for example Sweden, students are to develop an understanding of how digitalisation affects individuals and society, develop the ability to use and understand digital systems and services, relate to media and information in a critical and responsible way, and solve problems and translate ideas into action in a creative way (Skolverket, 2017). Digital tools are already used to varying degrees in primary school education, and there is a great deal of research on learning and digital tools that shows both the educational potential of digital tools (Newhouse, 2017), as well as the new challenges that teachers face when tools are to be integrated into practical teaching situations (European Schoolnet, 2017; Skolverket, 2019). In the STEM subjects, ICT has been reported to enhance engagement, motivation, and learning by stimulating inquiry-based learning, and enhance communication between students and teachers (Newhouse, 2017). In addition, it has been demonstrated that ICT lets students investigate subjects relevant to their lives and control their own learning (European Schoolnet, 2017).

In line with the previous studies, the Erasmus+ project Functional Information and Communication Technology Instruction On the Net (FICTION) investigates how science teachers in primary and secondary schools currently use digital tools in their teaching practice, how they can be supported in their choice of digital tools within their teaching practice, as well as what additional professional training they need in order to be able to use these tools. Further, the project aims to develop guidelines for what type of tools that are most useful within the teaching practice of STEM education and how to best acquire the requisite skills in using these tools. The FICTION project partners come from three countries: Södertörn University and the Ronna school from Sweden, Limerick Institute of Technology and Coláiste Mhuire Co-Ed from

Ireland, and the University of Genoa, Liceo statale Niccolò Machiavelli Firenze, and Pixel from Italy.

Initial results by the Swedish partners have shown that schools have invested in infrastructure and equipment to support ICT and the use of digital tools for teaching. However, there are still obstacles of administrative character such as scheduling, lack of time, insufficient competence development, and lack of choice on what platforms and systems to work with (Josefsson et al., 2019). Swedish public school teachers are required to use digital tools in their teaching, however there is a lack of knowledge among teachers on how to use digital tools that needs to be taken into account when promoting the use of digital tools in teaching (Josefsson et al., 2019). In line with these findings and based on previous research on digitization and digital competence (Albion et al., 2015; Ertmer et al., 2012; Hanell, 2018; Ilomäki et al., 2016; Krumsvik, 2008) the purpose of this workshop was to address teachers' professional development by encouraging the sharing of knowledge among teachers (Ertmer et al., 2012), and to address settings other than the ones involved in the FICTION project. To interpret the participants' statements and reasoning during the workshop we mainly draw on the previous research presented and the initial findings from the FICTION project.

DESIGN OF THE WORKSHOP

The workshop started with a ten-minute presentation of the organisers and the FICTION project by the moderator. The introduction was followed by an outline of the questions to be addressed during the workshop and why these were of interest to discuss.

The participants were divided into three groups and were asked to discuss the following issues during the workshop:

- What is the current approach to teaching digital competence in your region? What are the driving forces?
- What are your personal experiences of using digital tools in schools? What works, what does not?
- What do teachers feel they need in order to perform well?

There was in total seventeen participants, mainly teachers and researchers at university level. As such, the participants were not necessarily directly involved in teaching at a primary or secondary school level, but had an interest in the questions that the workshop concerned. The workshop participants were associated with universities in Australia, Finland, Germany, Japan, South Africa, Spain, and Sweden.

The discussion lasted for one hour and during that time the two attending organisers circulated among the groups and took part and notes in the discussions. Any errors in our notes are fully our responsibility.

RESULTS OF THE WORKSHOP

Our assumption, as noted in the introduction, that there is a strong need for additional training, in particular for in-service teachers, was confirmed by the participants. Not only was training in the technology itself perceived as important, but also time to practice using it and working out how to best fit it into everyday teaching practices. The benefits for the students have to be the primary focus. Working out all this requires contact with other teachers for exchanging experiences on best practice. The time required to do this should not be underestimated, as it encompasses multiple stages: learning practical ICT skills, understanding the purpose of ICT in teaching and finally changing teaching styles and examination methods to make effective use of ICT. There are large individual variations in attitudes among teachers—it was noted that pre-service teachers tend to be more open to the use of ICT for teaching and might eventually work as catalysts for the introduction of ICT at their respective schools. An important point is that since technology is in constant flux, periodic retraining is necessary. The necessary resources for training and reflection require the long-term commitment of school management and school politicians. It must be understood that digitalisation is a tool for improving teaching, and should not be used as an excuse for cutting down on resources for schools—teachers are still necessary. Indeed, a suggestion was made that future teaching teams may need to be interdisciplinary, with both technology and pedagogy experts.

The discussion made clear that there is a wide variation in access to technology in different regions. Almost all schools in Australia and Sweden were reported to have Internet access, and digital competence written into the national curricula. In contrast, Internet access and resources varies a lot among schools in South Africa depending on socio-economic differences: from well-equipped schools to those with hardly any digital technology. An estimated 60% of South African schools have Internet access. A complication is that while the technology may be present, it is not always available for use: in one school, for example, the computers were locked up in a special room to which most of the teachers did not have access. The result was that the computers were unused and eventually not up to date.

Teacher skills vary from those who are competent in computer use to those "who do not know how to switch on the computer". A comment was made that many in-service teachers might not even be interested in using computers, not from lack of exposure to them, but from the attitude that computers will not contribute to teaching, something which has been noted in previous research as well (Blackwell et al., 2013; Drossel et al., 2017; Prestridge, 2012; Young, 2016).

In Spain, the main use of digital tools by in-service teachers is indicated to be the use of interactive smartboards for presentations, which does not necessarily imply changing or improving existing teaching practice. Rather, it was reported that many teachers use their smartboards simply as projectors. Making use of the full potential of the smartboard requires designing the learning situation accordingly (Simó et al., 2018). In order to help teachers understand how to organise their teaching around ICT tools, our Spanish participant's team had formulated guidelines for in-service teachers to increase the use of digital tools, with an emphasis on a deeper understanding of production tools. Summer courses have also been provided to in-service teachers to enhance their digital competence.

The situation in Germany is described as lacking a systematic approach: schools have received money to invest and buy technology, but no instructions for teachers on how to use potential tools. Specifically schools in Southern Germany were described as passive, waiting for others to take the lead and supply ready recipes for digitalisation. There is a feeling that Germany has fallen behind and lacks infrastructure, maybe only 50% of schools have Internet access. Teachers are uncertain and sometimes fearful of technology. In order to alleviate those fears there have been local efforts at staging ”impulse” workshops for teachers (Institut für Qualitätsentwicklung an Schulen Schleswig-Holstein, 2020), showing what can be done with digital tools in the classroom. As the technology becomes more familiar, teachers develop pedagogical creativity.

One of the participants reflected on why some teachers change their teaching practices and integrate ICT, while some do not, and summed up their thoughts on whether it is the teachers' views or the access to technology that drives the change. In the beginning, they stated, “I was thinking exposure was the problem.”—if teachers were only given the opportunity to try different ICT tools, they would see new opportunities and integrate the new tools into their teaching. However, today they have changed their mind on the issue and emphasize the importance of teachers' attitudes towards technology. That said, they still do not deny the importance of exposure to ICT tools.

CONCLUSION

The consensus was that (strategic investments in) professional development were considered important in enhancing teachers' digital skills. The workshop participants agreed that this will continue to be important as these technologies will be constantly changing, hence teachers will have to constantly develop their teaching practice to respond to these changes. The participants also agreed that one of the big benefits with this investment was that digitalisation has the potential to empower students to work more effectively, giving them more control over how to learn a subject. This said, it should be taken into account that both Internet access and resources vary a lot among schools. The same applies to the teachers' knowledge and attitudes towards technology integration and the support from school management and school politicians. All these are important components if we aim to use ICT in classrooms to its full potential.

ACKNOWLEDGEMENTS

We thank all workshop participants for their input, in particular Helena Lennholm of the Royal Institute of Technology, Carme Grimalt Álvaro of the Autonomous University of Barcelona and Silke Rönnebeck of the IBN Leibniz Institut for supplying additional information after the event. We also thank the Department of Media Technology at Södertörn University for financing our attendance at ESERA. FICTION is Erasmus+ project number 2018-1-SE01-KA201-039098.

REFERENCES

Albion, P. R., Tondeur, J., Forkosh-Baruch, A., & Peeraer, J. (2015). Teachers' professional development for ICT integration: Towards a reciprocal relationship between research and practice. *Education and Information Technologies*, *20*(4), 655–673. https://doi.org/10.1007/s10639-015-9401-9

Blackwell, C. K., Lauricella, A. R., Wartella, E., Robb, M., & Schomburg, R. (2013). Adoption and use of technology in early education: The interplay of extrinsic barriers and teacher attitudes. *Computers & Education*, *69*, 310–319. https://doi.org/10.1016/j.compedu.2013.07.024

Drossel, K., Eickelmann, B., & Gerick, J. (2017). Predictors of teachers' use of ICT in school – the relevance of school characteristics, teachers' attitudes and teacher collaboration. *Education and Information Technologies*, *22*(2), 551–573. https://doi.org/10.1007/s10639-016-9476-y

Ertmer, P. A., Ottenbreit-Leftwich, A. T., Sadik, O., Sendurur, E., & Sendurur, P. (2012). Teacher beliefs and technology integration practices: A critical relationship. *Computers & Education*, *59*(2), 423–435. https://doi.org/10.1016/j.compedu.2012.02.001

European Schoolnet. (2017). *ICT in STEM Education—Impacts and Challenges: On Teachers. A STEM Alliance Literature Review* http://www.stemalliance.eu/documents/99712/104016/STEM_Alliance_ict-paper-3-on-teachers.pdf/ac115d43-4d17-43f1-8bc6-15fbc0acaccb

Hanell, F. (2018). What is the 'problem' that digital competence in Swedish teacher education is meant to solve? *Nordic Journal of Digital Literacy*, *13*(03), 137–151. https://doi.org/10.18261/issn.1891-943x-2018-03-02

Hylén, J. (2013). *Digitalisering i skolan – en kunskapsöversikt* (2013:1; Ifous rapportserie). Ifous och FoU Skola/Kommunförbundet Skåne. https://docplayer.se/12043471-Digitalisering-i-skolan-en-kunskapsoversikt-jan-hylen.html

Ilomäki, L., Paavola, S., Lakkala, M., & Kantosalo, A. (2016). Digital competence – an emergent boundary concept for policy and educational research. *Education and Information Technologies*, *21*(3), 655–679. https://doi.org/10.1007/s10639-014-9346-4

Institut für Qualitätsentwicklung an Schulen Schleswig-Holstein. (2020). *Startseite—Digitalstrategie*. https://digitalstrategie.lernnetz.de/

Josefsson, P., Jää-Aro, K.-M., Lundmark, S., & Mutvei Berrez, A. (2019). The implementation of digital tools in teaching: A qualitative case study at a Swedish primary school. *11th International Conference on Education and New Learning Technologies*, 2382–2387. https://doi.org/10.21125/edulearn.2019.0643

Krumsvik, R. J. (2008). Situated learning and teachers' digital competence. *Education and Information Technologies*, *13*(4), 279–290. https://doi.org/10.1007/s10639-008-9069-5

Newhouse, C. P. (2017). STEM the boredom: Engage students in the Australian curriculum using ICT with problem-based learning and assessment. *Journal of Science Education and Technology*, *26*(1), 44–57. https://doi.org/10.1007/s10956-016-9650-4

Prestridge, S. (2012). The beliefs behind the teacher that influences their ICT practices. *Computers & Education*, *58*(1), 449–458. https://doi.org/10.1016/j.compedu.2011.08.028

Simó, V. L., Grimalt-Álvaro, C., & Lagarón, D. C. (2018). ¿Cómo ayuda la Pizarra Digital Interactiva (PDI) a la hora de promover prácticas de indagación y modelización en el aula de ciencias? *Revista Eureka sobre Enseñanza y Divulgación de las Ciencias*, 3302–3302. https://doi.org/10.25267/Rev_Eureka_ensen_divulg_cienc.2018.v15.i3.3302

Skolverket. (2017). *Få syn på digitaliseringen i vuxenutbildningen. Ett kommentarmaterial för komvux och särvux.* Skolverket. https://www.skolverket.se/publikationer?id=3873

Skolverket. (2019). *Digital kompetens i förskola, skola och vuxenutbildning* (text No. 476). Skolverket. https://www.skolverket.se/publikationer?id=4041

Young, K. (2016). Teachers' Attitudes to using iPads or Tablet Computers; Implications for Developing New Skills, Pedagogies and School-Provided Support. *TechTrends*, *60*(2), 183–189. https://doi.org/10.1007/s11528-016-0024-9

IN-SERVICE TEACHER MENTORING FOR THE IMPLEMENTATION OF MODULES ON CUTTING-EDGE RESEARCH TOPICS

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The negotiation of cutting-edge research topics in science courses may contribute to the scientific literacy of students. However, incorporating such an approach into teaching practice requires appropriate preparation and support, for teachers to meet the challenges of such a venture. In this context, this study examines the support provided by mentor-teachers to other in-service teachers who are called to implement in their classrooms modules on cutting-edge scientific subjects with social implications. In total 5 mentors and 32 in-service teachers participated in the study. The mentoring meetings were recorded and the discussions were analyzed in terms of content and mentoring roles assumed by mentors. Data indicate that mentors focused their support on science-specific instructional knowledge and tended to do so using mostly directive skills, but also trying to adapt their role according to mentees' needs.

Keywords: Mentoring in Teacher Education, In-service Teacher Training, Teaching Innovations

INTRODUCTION

One of the long-established aims of research on science education is the improvement of educational practice through the operationalization and dissemination of the research results. Yet, spreading innovations in a wide range of educational contexts requires an ongoing supportive training procedure that would guide teachers throughout the whole implementation period, as they often have to change their attitudes and beliefs, to expand their professional knowledge and repertoire of teaching practices while addressing the restrictions imposed by the school context (van Driel et al., 1998). In order for teachers to meet the demands of educational innovations and to be able to effectively integrate them in their teaching, they should receive appropriate training and support.

Subjects related to cutting-edge research usually define an area of science that is uncertain and incorporates issues around which the scientific community has not yet come to commonly accepted conclusions (Levinson, 2006). Integrating such topics in science classes familiarizes students with the process of scientific research and provides them with the opportunity to experience scientific knowledge as an ongoing procedure and to elaborate on its social implications (Wong et al., 2008). However contemporary scientific research topics have not yet been broadly incorporated in school science curricula and teaching practice. Therefore, there is a need to disseminate the implementation of such innovations to more school contexts and also to train teachers on these issues in order to overpass the entailed difficulties.

Certainly the task of applying modules associated with cutting-edge research topics entails a series of difficulties on behalf of the teachers, which are mainly focused on their content knowledge scarcity and on the lack of specific teaching strategies to approach such topics (Peers et al., 2003).

One of the methods that have shown encouraging results as a means of teacher professional development is *mentoring in collaborative settings* (Feiman-Nemser, 2012). Through mentoring conversations, teachers grow professionally by collaboratively inquiring and reflecting on their everyday practice, exchanging ideas and paving the way for change (Bradbury & Koballa, 2007). Therefore, the content of these conversations as well as the mentor's style (directive or not) determine to a great extent the effect of this interaction.

Even though research on science teacher mentoring is growing, it is mostly related to pre-service or early career teachers and the studies that employ mentoring as a means for in-service science teacher training are still few (e.g. Appleton, 2008). Based on this approach, the aim of the present study is to give an insight on the support mentor-teachers provide to other in-service teachers in order to implement modules on cutting-edge research topics. The specific research question is:

How do mentor-teachers support in-service mentee-teachers in order to implement modules on cutting-edge research topics in their classrooms?

and it is examined through the following sub-questions:

(i) *What topics do mentoring conversations focus on?*

(ii) *What roles do mentor-teachers assume during their mentoring conversations with the mentee-teachers?*

METHOD

Research design

The study was carried out in the framework of the EU IRRESISTIBLE project (www.irresistible-project.eu) which aimed to develop and implement teaching material on contemporary scientific research topics and their social implications.

According to the design of the project, 5 highly skilled teachers (one primary education teacher and 4 secondary education physics and chemistry teachers) developed and piloted a teaching module on Nanotechnology, with the support of nanotechnology experts and science education researchers. Afterwards, these 5 teachers (hereinafter referred to as "mentors") acted as multipliers and trained 32 mentee-teachers serving in primary and secondary schools in implementing a module on a cutting edge research topic.

The 3 modules that the mentees were trained on and applied were: *Nanotechnology Applications* , *Microplastics in the ocean* and *Carbohydrates of baby formulas*. As all three modules were developed within the IRRESISTIBLE project, they dealt with contemporary scientific research subjects and their social implications and used an inquiry-based approach for learning.

The mentoring process lasted for about 9 months (during which each group held about 8 mentoring meetings) and was divided in three successive phases.

- In the *orientation* phase, mentors and mentees elaborated on (i) the scientific content of each module, (ii) the involved social implications and (iii) aspects of inquiry-based learning.
- In the *redesign* phase, mentees thoroughly examined the modules and then re-designed them in order to adapt them to each school context.
- The *implementation* phase concerned the enactment of the modules in real class conditions and the mentees' reflection on the mentoring experience.

During each phase, mentors supported their mentees by 2-5 group mentoring meetings and with personalized support.

Data collection and analysis

In an effort to investigate the mentoring interactions, our main data source was the audio-recordings of all the group mentoring meetings.

Due to the explorative nature of the research, qualitative methods of content analysis were used.

First, all recorded mentoring conversations were transcribed verbatim. As regards the topic of mentoring conversations, we used as categories the knowledge bases of teacher professional knowledge (Gess-Newsome, 2015) that were addressed, namely: subject-matter knowledge, general pedagogical knowledge, instructional knowledge, knowledge of students and curricular knowledge. Issues that referred to organizational and administrative aspects of the mentoring process formed a sixth category entitled organizational issues (Table 1). Then, we calculated the percentage of mentoring discussions' extent that was dedicated to each topic.

Table 1: Categories of analysis regarding the topic of mentoring conversations

Categories	Description
Subject-matter knowledge	Discussion on the scientific subject of each module & social aspects
General Pedagogical Knowledge	Discussion on classroom management & learning theories
Instructional knowledge	Discussion about inquiry-based learning, negotiation of social aspects and ways to explore students' ideas Assistance in lesson redesign Demonstration of experiments and activities Providing feedback on teaching
Knowledge of students	Discussion of students' cognitive abilities, common alternative ideas and skills
Curricular knowledge	Discussion on the modules' objectives
Organizational Issues	Organizing visits, Sharing materials, Meetings arrangement

For the characterization of mentors' roles in these conversations, we based our analysis on the

MERID model (Crasborn et al., 2011; Figure 1), which identifies the mentor's use of directive skills and his/her initiative in introducing the topics as two behavioral dimensions that, vertically arranged, define 4 complementary mentoring roles: initiator (introduces topics & uses non-directive skills), imperator (introduces topics & uses directive skills), advisor (responds to issues introduced by mentees & uses directive skills) and encourager (responds to issues introduced by mentees & uses non-directive skills).

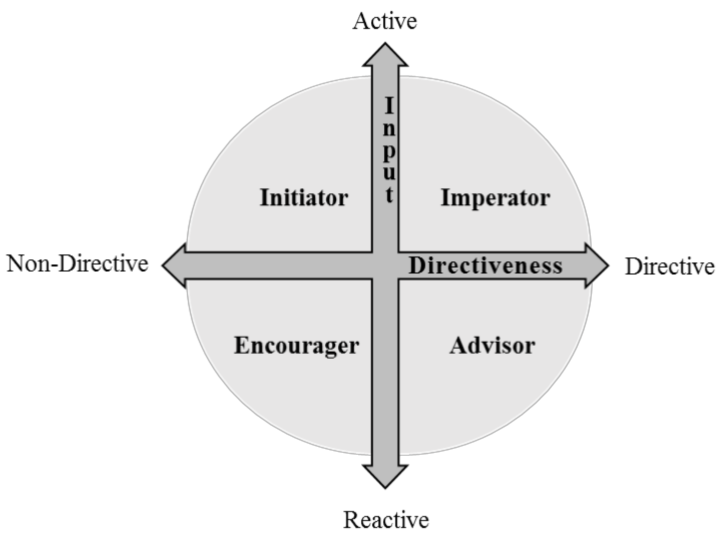

Figure 1: Representation of the MERID model (Crasborn et al., 2011)

In that way we constructed two coding keys, one addressing mentors' degree of directiveness and one addressing their degree of input (see Table 2). Analysis continued by recording the percentage of mentors' extent of speech that belonged to each category. Combining these two dimensions, we were able to define the percentages of the resulting mentoring roles.

Table 2: Categories of analysis regarding mentoring roles

Categories		Description
Directiveness	Directive	The mentor provides directions, confirms / rejects , evaluates, expresses opinion , gives advice, demonstrates activities, gives information
	Non-directive	The mentor asks questions, enhances reflection .
Input	Active	The mentor introduces the topic for discussion
	Reactive	The mentor responds to issues introduced by mentees

RESULTS

The results regarding the content of mentoring conversations (Figure 2) show that the most discussed topics were related to the negotiation of instructional knowledge (teaching strategies, negotiation of social implications and lesson design) and organizational issues. Issues regarding scientific knowledge have been discussed to a limited extent, as well as students' pre-existing knowledge, ideas and interests. Equally limited was the negotiation of issues of general pedagogical knowledge, fact that is mainly attributed to the increased teaching experience of the in-service mentee-teachers. On the other hand, mentors dedicated a significant extent of their conversations to the explanation and clarification of the innovative elements of the modules.

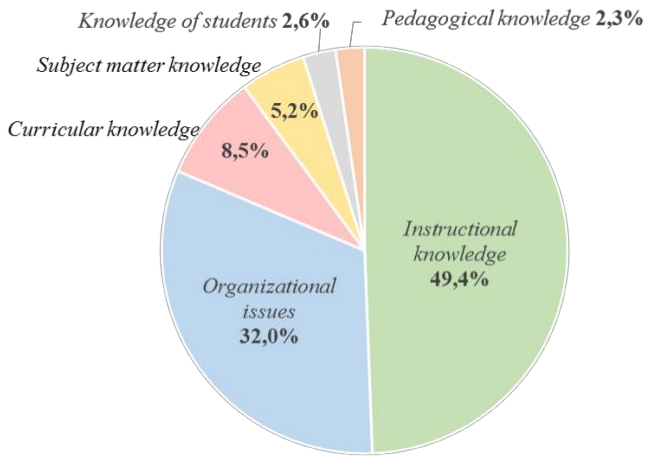

Figure 2 : Percentage of mentoring discussions dedicated to different areas of professional knowledge

Regarding the roles adopted by the mentors (see Table 3), we should first point out that the mentors participated in the mentoring discussions with all four different roles, with a tendency to use more frequently directive skills and to introduce discussion topics, adopting the imperator role. The second more frequent role was the advisor, according to which mentors shared their opinion on issues raised by the mentees. Finally, mentors assumed the initiator and encourager role, only during a small extent of the conversations.

Table 3: Percentages of mentoring roles assumed by each mentor

	Mentoring Roles			
	Initiator	Imperator	Advisor	Encourager
Mentor-A	9,8%	59,3%	26,5%	4,4%
Mentor-B	14,9%	51,5%	26,1%	7,5%
Mentor-C	10,1%	48,5%	34,3%	7,1%
Mentor-D	9,0%	35,2%	44,4%	11,4%
Mentor-E	8,3%	43,4%	40,6%	7,7%

Moreover, mentors tended to adapt their practices to the mentees' needs, and particularly to limit their directional practices when mentees had the necessary background knowledge on a subject that allowed them to participate more actively in the discussion. Specifically, as shown in Figure 3, when mentors discussed about the innovative scientific content of the modules, they tended to utilize almost exclusively directional practices. Therefore, in these cases they only adopted the imperator and advisor role.

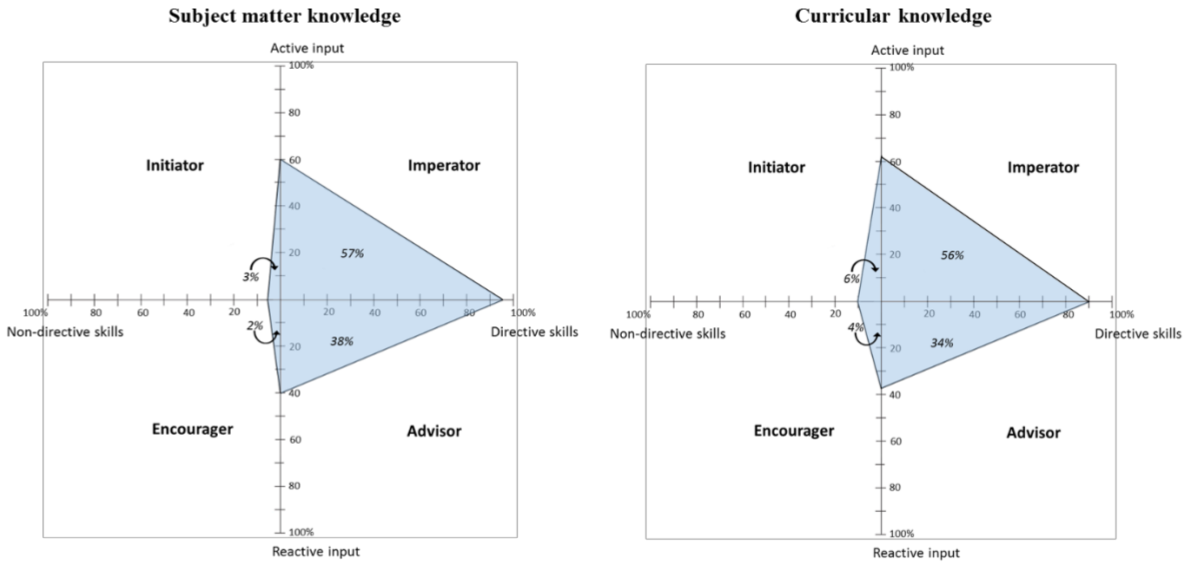

Figure 3: Pictorial representation of mentoring roles during the negotiation of issues related with subject matter knowledge and curricular knowledge

On the other hand, their use of directional practices was significantly limited when discussing topics on which mentees had profound background knowledge, like general pedagogical issues or students' ideas and interests. In these cases mentors adopted more dominantly the encourager role (Figure 4).

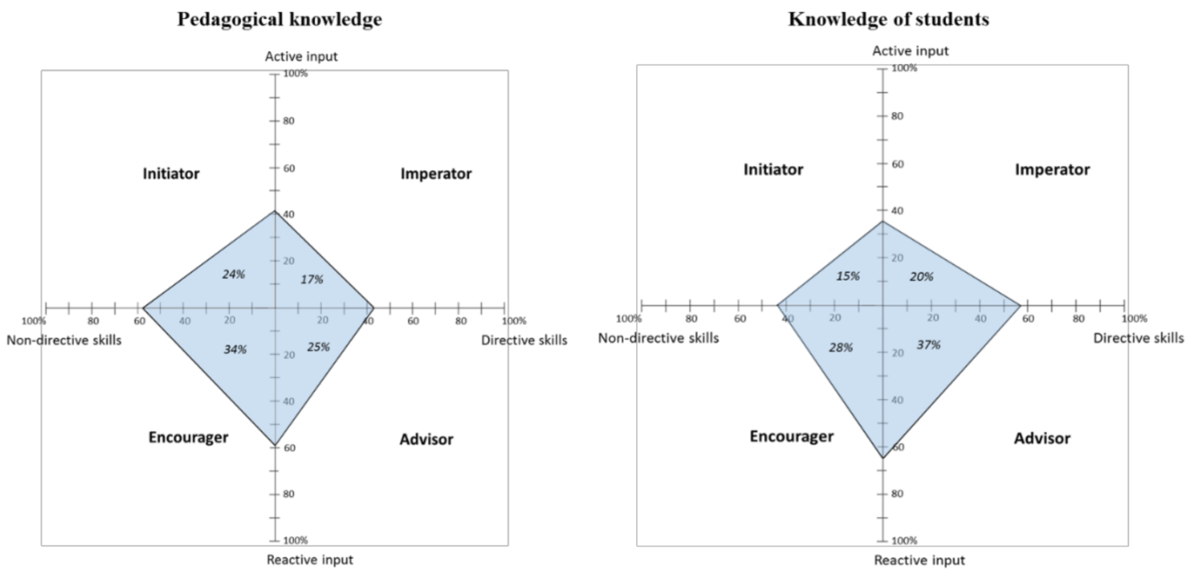

Figure 4: Pictorial representation of mentoring roles during the negotiation of issues related with general pedagogical knowledge and knowledge of students

DISCUSSION AND CONCLUSIONS

The results regarding the content of the mentoring discussions initially showed a strong tendency of mentors to discuss issues that were oriented towards different aspects of science teaching strategies, such as inquiry-based learning, lesson planning etc. Adding to the above, the long discussion of issues related to the teaching objectives of the modules, the students' ideas and the scientific content, the results show a strong orientation of the mentors' discourse on science-specific topics. Although these findings contradict those of related studies that reveal a mentoring focus on general teaching skills or general pedagogical knowledge (Bradbury & Koballa 2007; Bang & Luft 2014; Barnett & Friedrichsen 2015), this divergence can be attributed to the fact that in our study mentees were not novice but experienced teachers and to the very clear and specific targeting of the mentoring relation, which was the provision of suitable support to mentees in order to implement innovative modules in their classes.

Concerning mentoring roles, the participating mentors more frequently adopted directive practices to support the mentees, often resorting to advice giving and demonstrating. Moreover, the majority of mentors provided active input to the discussions, leading to the overall adoption of an imperator role. These results are in line with findings from other studies that highlight the predominance of imperator role among mentors (Hennissen et al., 2008; Crasborn et al., 2011; Mena et al., 2017). In fact, Hennissen et al. (2008) argue that this tendency is even more overt among untrained mentors, as in the case of the participants in the present study.

However, even if mentors adopted mostly the imperator role, they also managed to adapt themselves to the evolving needs of the mentees and to their degree of expertize on each subject. The dynamic shift of the roles is particularly interesting, taking into account that one of the most important and influential factors determining the success of a mentoring process is the extent to which the mentoring approach is flexibly adaptive to the learning needs of the trainee (Hobson et al., 2009).

From the above we can deduce that the mentoring process unfolded on the background of the implementation of modules on contemporary scientific research, was a dynamic process which provided mentee-teachers with professional development opportunities and concentrated features of an effective science teacher education effort. Therefore, mentoring could be used for the professional growth of experienced science teachers, beyond the limited scope of the induction phase, as a means of disseminating educational innovations, provided that teacher-mentors have previously received training on the novel practices.

ACKNOWLEDGEMENT

This study has been supported by the IRRESISTIBLE (http://www.irresistible-project.eu), European project, in the context of the European Union's Seventh Framework Program for research, technological development and demonstration under grant agreement no 612367.

Financial support to this work by the Greek State Scholarships Foundation through the program "Enhancement of human scientific resources though implementation of PhD research" with resources of the European program "Development of human resources, Education and lifelong learning", 2014-2020, co-funded by the European Social Fund and the Greek State, is gratefully acknowledged.

REFERENCES

Appleton, K. (2008). Developing science pedagogical content knowledge through mentoring elementary teachers. *Journal of Science Teacher Education*, 19(6), 523-545.

Bang, E., & Luft, J. A. (2014). Exploring the written dialogues of two first-year secondary science teachers in an online mentoring program. *Journal of Science Teacher Education*, 25(1), 25-51.

Barnett, E., & Friedrichsen, P. J. (2015). Educative mentoring: How a mentor supported a preservice biology teacher's pedagogical content knowledge development. *Journal of Science Teacher Education,* 26(7), 647-668.

Bradbury, L., & Koballa Jr, T. R. (2007). Mentor advice giving in an alternative certification program for secondary science teaching: Opportunities and roadblocks in developing a knowledge base for teaching. *Journal of Science Teacher Education*, 18(6), 817-840.

Crasborn, F., Hennissen, P., Brouwer, N., Korthagen, F., & Bergen, T. (2011). Exploring a two-dimensional model of mentor teacher roles in mentoring dialogues. *Teaching and Teacher education*, 27(2), 320-331.

Feiman-Nemser, S. (2012). Beyond solo teaching. *Educational Leadership*, 69, 10–16.

Gess-Newsome, J. (2015). A model of teacher professional knowledge and skill including PCK: Results of the thinking from the PCK summit. In A. Berry, P. Friedrichsen, & J. Loughran (Eds.), *Re-examining pedagogical content knowledge in science education* (pp. 28–42). London: Routledge Press.

Hennissen, P., Crasborn, F., Brouwer, N., Korthagen, F., & Bergen, T. (2008). Mapping mentor teachers' roles in mentoring dialogues. *Educational research review*, 3(2), 168-186.

Hobson, A. J., Ashby, P., Malderez, A., & Tomlinson, P. D. (2009). Mentoring beginning teachers: What we know and what we don't. *Teaching and teacher education*, 25(1), 207-216.

Levinson R., (2006). Towards a theoretical framework for teaching controversial socio-scientific issues, *International Journal of Science Education*, 28(10), 1201- 1224.

Mena, J., Hennissen, P., & Loughran, J. (2017). Developing pre-service teachers' professional knowledge of teaching: The influence of mentoring. *Teaching and Teacher Education*, 66, 47-59.

Peers, C., Diezmann, C., & Watters, J. (2003). Supports and concerns for teacher professional growth during the implementation of a science curriculum innovation. *Research in Science Education*, 33(1), 89-110.

van Driel, J. H., Verloop, N., & de Vos, W. (1998). Developing science teachers' pedagogical content knowledge. *Journal of Research in Science Teaching*, 35(6), 673–695.

Wong, S. L., Hodson, D., Kwan, J., & Yung, B. H. W. (2008). Turning Crisis into Opportunity: Enhancing student-teachers' understanding of nature of science and scientific inquiry through a case study of the scientific research in severe acute respiratory syndrome. *International Journal of Science Education*, 30(11), 1417-1439.

RELATIONSHIP OF EMOTIONS WITH ASSOCIATED VARIABLES TO THE SCIENCE TEACHING ON IN-SERVICE TEACHERS

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A research has been carried out with 339 Chilean in-service teachers (early childhood, primary and secondary education) of science teaching. In relation with the emotions of teachers, highlighting the influence of variables associated with election to be teachers, such as intrinsic career and working with student's value, and self-efficacy as teachers, such as in instructional strategies, classroom management and student engagement.

Keywords: emotions, in-service teachers, science teaching.

INTRODUCTION

Although there is a remarkable amount of research dedicated to the quality of teaching or the classroom environment generated by teachers, attention has hardly been paid to teachers as human beings who have their own motives, goals and emotional experiences (Frenzel, 2014). An exception is research on burnout, associated with the high risk that teachers present.

Although all workers experience emotions during their work (Weiss and Brief 2001), teaching can be especially emotional work (Frenzel 2014; Hargreaves 1998; Saunders 2013; Schutz 2014; Schutz and Zembylas 2009; Uitto, Jokikokko, et al. 2015). According to Schutz and Lanehart (2002), emotions are intimately involved in virtually all aspects of the teaching and learning process and, therefore, an understanding of the nature of emotions within the school context is essential. Teachers' emotional ties with students are often at the centre of their work (Day and Leitch, 2001), and teachers often experience enjoyment, anxiety and anger as they teach (Frenzel, Becker-Kurz, et al. 2015; Frenzel, Goetz, et al. 2009a, Taxer and Frenzel, 2015). In addition, teachers 'emotional experiences during class can directly affect their behaviour (Day and Leitch, 2001; Kunter, Tsai, et al. 2008), students' emotional experiences (Becker, Goetz, et al. 2014) and learning outcomes (Frenzel, Goetz, et al. 2009b). It follows that the emotional experiences of teachers could influence the configuration of their interactions and the implementation of what they learn in professional development. Emotions are to some extent dispositions, although they are also very context sensitive (Schutz, 2014, Schutz, Aultman, et al. 2009). On the other hand, teachers' emotions are related to a variety of important outcomes related to teaching, including teacher effectiveness in the classroom (Sutton, 2005), their well-being and health (Chang, 2013; Taxer and Frenzel 2015), and the emotions and motivation of the students (Becker, Goetz, et al. 2014; van Doorn, van Kleef, et al. 2014).

The research confirm that teachers' emotions are related to the effectiveness of instruction in terms of cognitive and motivational stimulation, classroom management and social support (Pekrun, Muis, et al. 2018). The enjoyment of teaching by teachers is positively related to appraisals of monitoring, development, understanding, support for autonomy, enthusiasm and support of students. On the contrary, negative relationships have been found between the anger and anxiety of teachers and the perceptions of students about the instructional behaviour of teachers, including the elaboration, understanding, support for autonomy, enthusiasm of students, and teachers support after failure (Frenzel, Goetz, et al. 2009a, 2009b; Frenzel, Pekrun, et al. 2016). However, negative emotions can sometimes have beneficial effects. Thus, Stough and Emmer (1998) discovered that beginning teachers, whose students showed hostile reactions to their comments, experienced negative emotions such as frustration and anger. As a result, some of them altered their classroom management strategies by modifying their comments to better control student interactions.

Importantly, teachers often exercise some level of control over their emotions through emotional regulation (Sutton 2004; Taxer and Frenzel 2015). As with other types of self-control, emotions are regulated to achieve goals, and different strategies can be used to achieve those goals. Existing research on how teachers modify their emotions has focused predominantly on teachers' use of deep-acting emotional work strategies, such as the act of internalizing the desired emotion so that the expressed emotion matches the emotion felt (Grandey 2000). Also, superficial action such as the act of expressing an emotion not felt (Grandey 2000; Hülsheger, Lang, et al. 2010; Näring, Briët, et al. 2006; Näring, Vlerick, et al. 2011; Philipp and Schüpbach 2010; Yin, 2015).

The three basic emotions that have been found to be the most notable and most frequent among teachers (Frenzel 2014; Hagenauer, Hascher, et al. Volet 2015; Sutton and Wheatley 2003) are enjoyment (pleasant, related to activity and results), anxiety (unpleasant, related to the result) and anger (unpleasant, activity and related to the result). Using two daily studies, Frenzel, Becker-Kurz, et al. (2015) analysed the frequency of each teacher's emotions by calculating the proportion of class periods in which each of the emotions was present. On average, teachers reported that they experienced enjoyment in 97%, anger in 44% and anxiety in 25% of their classes.

In summary, the well-being of the teachers and students, and the good functioning of the classrooms are related to the emotions of the teachers. The participation of teachers in cognitive and motivational stimulation, in classroom management and in social support, in turn, affects the cognitive growth, motivation, social and emotional behaviour of students in class and relationships with the teacher. Consequently, the behaviours of students and teachers in class can be seen as a cause and an effect of the emotional experiences of teachers during teaching.

Therefore, given the relative shortage of available research on teachers' emotions, the main objectives are to know the emotions of teachers, and how they can be affected, as well as affect other dimensions of classroom processes in a group of in-service Chilean teachers.

METHODOLOGY

The research has been carried out with 339 in-service teachers of Early Childhood (90), Primary (166) and Secondary (77) during science teaching training course. Age is between 23 and 65 years old (mean = 39,5), with a predominance of women (270) in relation to men (69).

It has been used to research emotions the Teacher Emotions Scales (TES), and various constructs to know attitudes and beliefs in relation to the teaching of science: Factors Influencing Teacher Choice (FIT-Choice), Dimensions of Attitude Toward Science Instrument (DAS), Ohio State Teacher Efficacy Scale (OSTES), Science Teaching Efficacy Belief Instrument (STEBI-A).

In the analysis and interpretation of the results, an analysis were carried out with the SPSS 24 program of calculation of bivariate correlations between emotions and the remaining dimensions to show significant correlations.

RESULTS

1) There are numerous significant correlations (See Table 1) between the three dimensions of emotions studied and the factors that influence career choice, and beliefs associated with the teaching of science in the group of in-service teachers. In general, the correlations are positive in relation to enjoyment, while they are negative with the other emotions studied (anger and anxiety). The difficulty in teaching science and the perception of social status correlates negatively with enjoyment but also with anxiety.

Table 1. Significant bivariate correlations of emotions with other dimensions, positive in brown and negative in green (r> | .111|* p <.05) N = 339).

Pearson correlations	JOY	ANGER	ANXIETY
INTRINSIC CAREER VALUE	0,562	-0,373	-0,363
WORK WITH CHILDREN	0,373	-0,150	-0,338
PRIOR TEACHING LEARNING	0,365	-0,110	-0,227
SOCIAL STATUS	0,207	0,084	0,136
SATISFACTION CHOICE	0,464	-0,105	-0,222
RELEVANCE TEACHING SCIENCE	0,472	-0,088	-0,209
DIFFICULTY TEACHING SCIENCE	-0,157	0,052	-0,139
INSTRUCCIONAL STRATEGIES	0,393	-0,315	-0,524
CLASSROOM MANAGEMENT	0,463	-0,262	-0,486
STUDENTS ENGAGEMENT	0,567	-0,148	-0,414
OUTCOME EXPECTANCY	-0,004	0,045	0,020

DISCUSSION AND CONCLUSIONS

In relation to teachers' emotions, highlight the influence of variables associated with control, such as in instructional strategies, in the management of classes and in the engagement of students; and the influence of valuation variables, such as intrinsic value of the career or the value of working with students; and the influence of dimensions associated with achievements, such as satisfaction with the choice of career, relevance or difficulty of teaching science.

As previously noted (Frenzel, 2014), teachers 'emotions are related to the effectiveness of instruction in terms of teachers' cognitive and motivational stimulation, classroom management and social support. As Baird, Gunstone, Penna, Fensham and White (2007) conclude, a balance between affection and cognition is important for effective teaching.

Measures should be taken to improve emotions in practicing teachers, starting them already in the initial training. In this sense, they should take actions that clearly protect against negative emotions and/ or enhance positive ones such as promoting the intrinsic value of the career of being a teacher, the valuation of work with students, self-efficacy in instructional strategies, classroom management and in student engagement.

As previously indicated (Frenzel, 2014), teachers' emotions are related to the effectiveness of instruction in terms of cognitive and motivational stimulation of teachers, classroom management and social support. As Baird, Gunstone, Penna, Fensham and White (2007) conclude, a balance between affect and cognition is important for effective teaching.

ACKNOWLEDGEMENT

For its collaboration, of the course of intermediate specialization in scientific inquiry taught by the University of Arica, within the framework of the Scientific Inquiry for Science Program ICEC of the Chilean government.

REFERENCES

Baird, J. R., Gunstone, R. F., Penna, C., Fensham, P. J., & White, R. T. (2007). Researching balance between cognition and affect in science teaching and learning. *Research in Science Education, 20,* 11–20.

Becker, E.S., Goetz, T., Morger, V., & Ranellucci, J. (2014). The importance of teachers' emotions and instructional behavior for their students' emotions e an experience sampling analysis. *Teaching and Teacher Education, 43,* 15–26. https://doi.org/10.1016/j.tate.2014.05.002.

Chang, M.-L. (2013). Toward a theoretical model to understand teacher emotions and teacher burnout in the context of student misbehavior: Appraisal, regulation and coping. *Motivation and Emotion 37,* 799-817. https://doi.org/10.1007/s11031-012-9335-0.

Chiang, W., & Liu, C. (2014). Scale of academic emotions in science education: Development and evaluation. *International Journal of Science Education*, *36*, 908–928

Day, C., & Leitch, R. (2001). Teachers' and teacher educators' lives: the role of emotion. *Teaching and Teacher Education 17,* 403–415.

Frenzel, A. C. (2014). Teacher emotions. In *International handbook of emotions in education,* Pekrun, R. & Linnembrink-Garcia, L. (Ed) 415–436. New York: Routledge.

Frenzel, A. C. (2014). Teachers emotions. In R. Pekrun & L. Linnembrink-Garcia (Eds.), *International handbook of emotions in education* (pp. 415–436). New York: Routledge.

Frenzel, A. C., Becker-Kurz, B., Pekrun, R. & Goetz, T. (2015). Teaching this class drives me nuts! - examining the person and context specificity of teacher emotions. *PLoS One 1,* 1-15. https://doi.org/10.1371/journal.pone.0129630.

Frenzel, A. C., Goetz, T., Lüdtke, O., Pekrun, R. & Sutton, R. E. (2009a). Emotional transmission in the classroom: Exploring the relationship between teacher and student enjoyment. *Journal of Educational Psychology 101,* 705-716. https://doi.org/10.1037/a0014695.

Frenzel, A. C., Goetz, T., Stephens, E. J., & Jacob, B. (2009b). Antecedents and effects of teachers' emotional experiences: An integrated perspective and empirical test. In *Advances in teacher emotion research: The impact on teachers' lives,* Schutz, P.A. & Zembylas, M. (ed) 129–152. New York: Springer.

Frenzel, A. C., Pekrun, R., Goetz, T., Daniels, L. M., Durksen, T. L., Becker-Kurz, B., & Klassen, R. M. (2016). Measuring teachers' enjoyment, anger, and anxiety: The Teacher Emotions Scales (TES). *Contemporary Educational Psychology, 46,* 148–163.

Frenzel, A. C., Pekrun, R., Goetz, T., Daniels, L. M., Durksen, T. L., Becker-Kurz, B. & Klassen, R. (2016). Measuring enjoyment, anger, and anxiety during teaching:

The Teacher Emotions Scales (TES). *Contemporary Educational Psychology 46*, 148–163.
Grandey, A. A. (2000). Emotion regulation in the workplace: a new way to conceptualize emotional labor. *Journal of Occupational Health Psychology* 5: 95–110. http://dx.doi.org/10.1037//1076-8998.5.1.95.
Hagenauer, G., Hascher, T. & Volet, S. (2015). Teacher emotions in the classroom: Associations with students' engagement, classroom discipline and the interpersonal teacher-student relationship. *European Journal of Psychology of Education 3,* 385–403. https://doi.org/10.1007/s10212-015-0250-0.
Hargreaves, A. (1998). The emotional practice of teaching. *Teaching and Teacher Education* 14: 835-854.
Hülsheger, U. R., Lang, J.W.B & Maier, G. W. (2010). Emotional labor, strain, and performance: testing reciprocal relationships in a longitudinal panel study. *Journal of Occupational Health Psychology* 15, no. 4: 505–521. http://dx.doi.org/10.1037/a0021003.
Kunter, M., Tsai, Y.-M., Klusmann, U., Brunner, M., Krauss, S. & Baumert, J. (2008). Students' and mathematics teachers' perceptions of teacher enthusiasm and instruction. *Learning and Instruction 18*, 468–482. https://doi.org/10.1016/j.learninstruc.2008.06.008.
Näring, G., Briët, M. & Brouwers, A. (2006). Beyond demand control: emotional labour and symptoms of burnout in teachers. *Work and Stress* 20: 303–315. http://dx.doi.org/10.1080/02678370601065182
Näring, G., Briët, M. & Brouwers, A. (2011). Emotion work and emotional exhaustion in teachers: the job and individual perspective. *Educational Studies* 38: 63–72. http://dx.doi.org/10.1080/03055698.2011.567026.
Pekrun, R., & Perry, R. (2014). Control-value theory of achievement emotions. In R. Pekrun & L. Linnembrink-Garcia (Eds.), *International handbook of emotions in education* (pp. 120–141). New York: Routledge
Pekrun, R., Muis, K.R., Frenzel, A. C. & Goetz, T. (2018). *Emotions at school*. New York: Routledge.
Philipp, A. & Schüpbach, H (2010). Longitudinal effects of emotional labor on emotional exhaustion and dedication of teachers. *Journal of Occupational Health Psychology* 15: 494–504. https://doi.org/10.1037/a0021046.
Saunders, R. (2013). The role of teacher emotions in change: Experiences, patterns and implications for professional development. *Journal of Educational Change 14,* 303-333.
Schutz, P. A. (2014). Inquiry on Teachers' Emotion. *Educational Psychology 49,* 1–12. doi: 10.1080/00461520.2013.864955
Schutz, P. A., & Lanehart, S. L. (2002). Introduction: Emotions in education. *Educational Psychologist 37,* 67–68.
Schutz, P. A., & Zembylas, M. (2009). *Advances in teacher emotion research. The impact on teachers' lives*. Dordrecht, Netherlands: Springer.
Schutz, P. A., Aultman, L. P. & Williams-Johnson, M. R. (2009). Educational psychology perspectives on teachers' emotions. In *Advances in teacher emotion research: The impact on teachers' lives*, Schutz, P. & Zembylas, M. (ed) 195-215. New York, NY: Springer.
Stough, L. M., & Emmer, E. T. (1998). Teacher emotions and test feedback. *International Journal of Qualitative Studies in Education 11*, 341–362.
Sutton, R. E. (2004). Emotional regulation goals and strategies of teachers. *Social Psychology of Education* 7: 379–398. http://dx.doi.org/10.1007/s11218-004- 4229-y.

Sutton, R. E., & Wheatley, K. F. (2003). Teachers' emotions and teaching: A review of the literature and directions for future research. *Educational Psychology Review 15,* 327–358. https://doi.org/10.1023/A:1026131715856.
Taxer, J. L., & Frenzel, A. C. (2015). Facets of teachers' emotional lives: A quantitative investigation of teachers' genuine, faked, and hidden emotions. *Teaching and Teacher Education 49*, 78–88.
Uitto, M., Jokikokko, K. & Estola; E. (2015). Virtual special issue on teachers and emotions in Teaching and Teacher Education (TATE) in 1985-2014. *Teaching and Teacher Education*, *50,* 124–135.
Van Doorn, E. A., Kleef, G. A. & van der Pligt, J. (2014). How instructors' emotional expressions shape students' learning performance: The roles of anger, happiness, and regulatory focus. *Journal of Experimental Psychology: General 143,* 980–984. https://doi.org/10.1037/a0035226.
Weiss, H. M., & Brief, A. P. (2001). Affect at work: A historical perspective. In *Emotions at work: Theory, research and applications for management*, Payne, R. & Cooper, C. (ed) 133-171. New York: John Wiley & Sons.
Yin, H. (2015). The effect of teachers' emotional labour on teaching satisfaction: Moderation of emotional intelligence. Teachers and Teaching: Theory and Practice 21: 789–810. https://doi.org/10.1080/13540602.2014.995482.

RESULTS OF IMPROVED PROGRAM TO DEVELOP TEACHERS' ABILITIES TO CONSTRUCT AND EVALUATE ARGUMENTS

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A teacher who introduces argumentation into his or her classes must have the ability to construct his or her own arguments, as well as the ability to properly evaluate the arguments of his or her students. However, even though some Japanese teacher training programs include constructing and scoring arguments, it has been reported that teachers' confidence in teaching argumentation has not improved enough (Yamamoto & Kamiyama, 2018). In this research, we developed an improved program for training teachers that includes a proposal for teachers to introduce argumentation into their own classes. We then demonstrated the effectiveness of the program in developing teachers' abilities to construct and evaluate arguments, as well as improving teacher confidence in teaching argumentation. In addition to the lectures and exercises included in the program prior to improving it, we also added sessions on "proposal to introduce argumentation into classes (30 min.)" and "exchanging proposals (40 min.)." The program was implemented for 35 teachers working in primary schools, middle schools, and high schools during 2017 and 2018. Surveys conducted on teachers' abilities to construct and evaluate arguments as well as on teacher self-efficacy before and after the program showed improvement in teachers' abilities to construct and evaluate arguments as well as in teacher self-efficacy ($p<.01$ for all results). These results indicate that this program is effective at having teachers properly construct and evaluate arguments. The results also indicate that the program is beneficial in improving teachers' confidence in teaching. However, roughly one-third of the teachers provided a negative response with regard to confidence; thus, confidence has not been improved enough. The program will therefore need to be further developed with practical activities, in which teachers will further introduce argumentation into their actual classes and then reflect on the results.

Keywords: argument, teachers' abilities, confidence

INTRODUCTION

When introducing argumentation into science classes, importance is placed on the teacher's own understanding of argumentation and on his or her ability to construct arguments (Zohar, 2008). A teacher who introduces argumentation into his or her classes must also have the ability to properly evaluate the arguments of his or her students. For example, Osborn, Erduran, and Simon (2004) have incorporated activities into a teacher training program where teachers themselves construct and evaluate arguments. Iordanou and Constantino (2014) report that putting into practice activities in which evidence is used to engage in argument over pairs of contrasting opinions and constructing arguments using more evidence than in a standard curriculum had the result of increasing the meta-level awareness of teachers.

Similar activities have been put into practice even in East Asia. In Japan, Yamamoto and Kamiyama (2018) have implemented a teacher training program that incorporates explaining, constructing, and grading arguments. However, this program is composed only of lectures and drills on provided material. Teachers do not engage in practical activities to incorporate argumentation into their own classes, and thus teachers were not able to build enough confidence to teach argumentation in their classes. Previous research indicates that confidence to teach argumentation is a factor contributing toward teachers introducing argumentation, and that it is also affected by the teacher's experience teaching argumentation and his or her level of knowledge on his or her students (McNeill, Katsh-Singer, González-Howard, & Loper, 2016). Therefore, teachers can expect to not only improve their abilities to construct and evaluate arguments, but also to gain confidence in introducing argumentation into their teaching, by gaining experience in imagining the students in their own classes, and in proposing arguments to be constructed by their students and the situations in which these arguments are introduced.

In this research, we develop an improved program for training teachers based on the program implemented by Yamamoto and Kamiyama (2018), in which we have also included a proposal for teachers to introduce argumentation into their own classes. We then shed light on the results of this program. Our research questions are as follows:

· Was the improved program effective at developing teachers' abilities to construct and evaluate arguments?

· Did the improved program increase teachers' confidence in teaching argumentation?

METHOD

Subjects

The subjects for this research included 35 teachers currently working in Japan (18 elementary school teachers, 8 middle school teachers, and 9 high school teachers). The program was conducted for 12 teachers (6 elementary school teachers, 4 middle school teachers, and 2 high school teachers) from April through May 2017 and then again for the remaining 23 teachers from April through May 2018.

Program

The program comprised three sessions. The first session was a "lecture on what argumentation means and its significance (20 min.)," while the second session included a "lecture on grading exercises and the current state of students' abilities to construct arguments (20 min.)," "exercises to gain first-hand experience in teaching and evaluating argumentation (40 min.)," and a "briefing on actual class conditions (10 min.)." Although the first two sessions were the same as the program implemented by Yamamoto and Kamiyama (2018), a third session was added covering "proposal to introduce argumentation into classes (30 min.)" and "exchanging proposals (40 min.)" as a means for teachers to consider arguments to introduce into their own classes. Figure 1 shows one of the arguments for a teacher to introduce into his class.

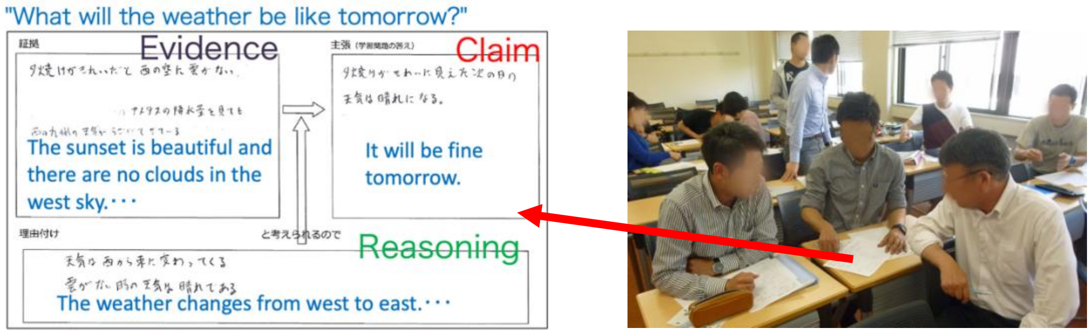


Figure 1. One of the arguments for a teacher to introduce into his class.

Test and survey

The 35 teachers participating in the program were provided with questions on constructing and evaluating arguments, both before and after the program was conducted. Each took around 10 minutes. A survey was also conducted on teachers' confidence in teaching argumentation (teacher self-efficacy) in order to gauge their beliefs on argumentation.

Figure 2 shows the argument construction question, and Figure 3 shows the desirable answer. The question was taken from Sakamoto et al. (2012). Teachers were asked to provide an explanation in their own words of a question in which a circuit in a hidden area was to be selected from two choices. Teachers were assigned a score out of two points in three areas (for a total of six points), based on a rubric evaluating "whether an answer was given (presence/absence of component)" and "whether the answer was scientifically correct (correctness of contents)." The three areas were the following: their "claim" as an answer to the question, their "evidence" mentioning the brightness of miniature light bulbs in each circuit (the fact of the matter), and their "reasoning" mentioning the size of each current (voltage/power) connected in parallel. These answers were judged by two independent judges with a concordance rate of 98.1%.

The circuit of ① and ② has the part of the cell hidden.

In the circuit of ①, the brightness of the light bulb was brighter than that of one cell. In the circuit of ②, the brightness of the light bulb was the same as that of one cell.

Which of the following A and B applies to how to connect the cells of each of the circuits 1 and 2? And why did you think so?

Explain these things scientifically. Write an explanation.

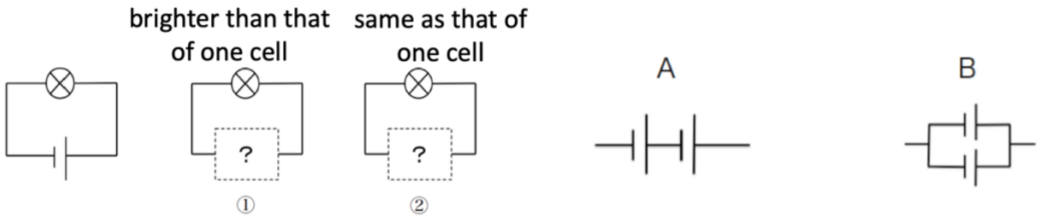


Figure 2. Argument construction question.

Claim: ① is A, ② is B.

Evidence: In the circuit of ①, the brightness of the light bulb was brighter than that of one cell. In the circuit of ②, the brightness of the light bulb was the same as that of one cell.

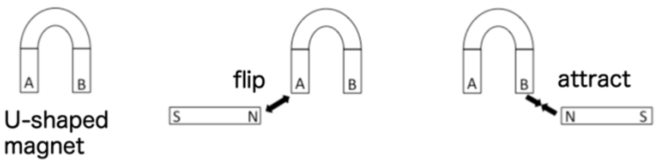
Reasoning: If you increase the number of cells to two in series connection and turn on the light bulb, the current (or any of voltage, power and electricity) will increase compared to when connected to one cell.

Even if you increase the number of cells to two and connect the light bulb with parallel connection, the current (or any of voltage, power, and electric quantity) does not change compared to the time when one cell is connected.

Figure 3. Desirable answer in the argument construction question.

Figure 4 shows the argument evaluation question. For the question on evaluating arguments, teachers were asked to evaluate answers from child X, Y, and Z (cases X, Y, and Z hereafter), who were presented with a U-shaped magnet of unknown polarity and told to determine the polarity by bringing the north pole of a bar magnet into contact with the U-shaped magnet. In judging these answers, teachers were asked to focus on students' "claim" as answers they gave for each pole, their "evidence" mentioning how the bar magnet reacted in the way it did (the facts of the matter), and their "reasoning" indicating that magnets of the same polarity are repulsed while magnets of opposite polarity are attracted. Teachers were then assigned a score of either zero or one point based on their "judgment" that all cases X, Y, and Z were found insufficient and then their "reason" mentioning why they were insufficient as arguments. These answers were judged by two independent judges with a concordance rate of 99.5%.

What are the poles of A and B of the U-shaped magnet? And why did you think so? Explain these things scientifically.



If you can judge that the children's descriptions X, Y and Z are sufficient for scientific explanation, enter ○ in the "judgment" column. If you judge that it is not enough, enter △. And briefly state in the "reason" column why you have judged that.

【Child X】 judgment [ ] reason [ ]

A is N pole and B is S pole.

When the N pole was brought close to A, the magnets was flipped, and when the N pole was brought close to B, the magnets attracted each other.

【Child Y】 judgment [ ] reason [ ]

When the N pole was brought close to A, the magnets was flipped, and when the N pole was brought close to B, the magnets attracted each other.

The magnets have the same poles are flipped and the other poles attract each other.

【Child Z】 judgment [ ] reason [ ]

A is N pole and B is S pole.

The magnets have the same poles are flipped and the other poles attract each other.

Figure 4. Argument evaluation question.

Teachers were also asked before and after the program how they felt about the seven belief categories from Katsh-Singer, McNeill, and Lope (2016), and were instructed to rate each category as "strongly believe so" (four points), "believe so" (three points), "do not believe so" (two points), or "strongly do not believe so" (one point). Of these categories, we provide a report on teacher self-efficacy in this research.

RESULTS

Argument construction question

Table 1 shows the score distribution for the argument construction question. The results of a Wilcoxon signed-rank test revealed component elements with significant improvements to score distribution between the pre- and post-tests. These are indicated in bold. For "claim," teachers mostly received full scores for both "presence/absence of component" and "correctness of contents" during both the pre- and post-tests. For "evidence," a significant improvement was observed for both "presence/absence of component" and "correctness of contents" (p<.01). For "reasoning," although teachers mostly received full scores for "presence/absence of component" during the pre- and post-tests, only 20 teachers received full scores for "correctness of contents" during the tests.

Argument evaluation question

Table 2 shows the score distribution for the argument evaluation question. Nearly all teachers received full scores during the post-test for both their "judgment" and "reason" for case X (in which the student's reasoning was lacking) and case Y (in which the student's claim was lacking). For case Z (in which the student's evidence was lacking), the number of teachers who received full scores increased from the pre-test to the post-test (p<.01).

Survey on beliefs on argumentation

Figure 5 presents "teacher self-efficacy" before and after the program. A Wilcoxon signed-rank test showed a significant improvement between the pre- and post-tests (p<.01).

Table 1. Score distribution for the argument construction.

		pre-test			post-test			
	score	2	1	0	2	1	0	
presence/absence of component	claim	32	1	2	35	0	0	
	evidence	13	0	22	**26**	**3**	**6**	**
	reasoning	27	3	5	32	1	2	
correctness of contents	claim	30	1	4	33	0	2	
	evidence	14	0	21	**26**	**2**	**7**	**
	reasoning	19	3	13	20	1	14	

Note: Components that showed significant improvement in the score distribution between pre-test and post-test are shown in bold.

Table 2. Score distribution for the argument evaluation.

		pre-test		post-test		
	score	1	0	1	0	
judgment	case X	32	3	35	0	
	case Y	32	3	35	0	
	case Z	**16**	**19**	**28**	**7**	**
reason	case X	28	7	34	1	
	case Y	30	5	34	1	
	case Z	**11**	**24**	**26**	**9**	**

Note: Components that showed significant improvement in the score distribution between pre-test and post-test are shown in bold.

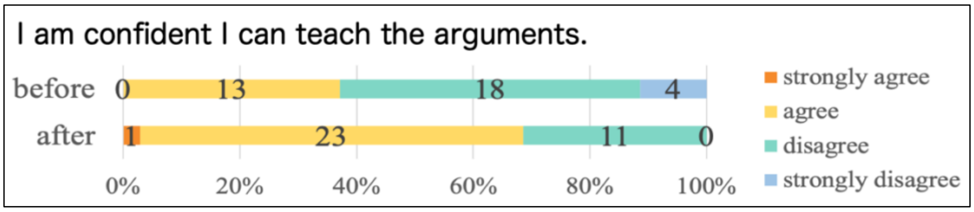


Figure 5. Confidence in teaching arguments.

DISCUSSION AND CONCLUSIONS

As a result of implementing this program, teachers were able to obtain overall good scores during their post-tests for the argument construction question and argument evaluation question. Teachers maintained an awareness of component elements when writing their arguments, and were able to check these component elements when evaluating arguments. This is likely a direct result of their activities during the program, in which they constructed arguments and scored the arguments of students. The teachers were able to properly construct and evaluate arguments even when the content changed.

Furthermore, the survey conducted on beliefs on argumentation showed that scores increased for "teaching confidence" after the program, so it can be inferred that the program had the effect of improving teachers' confidence in teaching. However, roughly one-third (11) of the teachers responded negatively ("do not believe so") during the post-test, suggesting that confidence was not sufficiently improved. In order for teachers to improve their confidence in teaching argumentation, a program accompanied by activities that are more practical will be required, in which teachers introduce argumentation into their actual classes and then reflect on the results.

ACKNOWLEDGEMENT

This research was supported by JSPS KAKENHI Grant Number 18K02936.

REFERENCES

Iordanou, K., & Constantinou, C.P. (2014). Developing pre-service teachers' evidence-based argumentation skills on socio-scientific issues. *Learning and Instruction, 34*, 42-57.

Katsh-Singer, R., McNeill, K.L., & Loper, S. (2016). Scientific argumentation for all?: Comparing teacher beliefs about argumentation in high, mid, and low socioeconomic status schools. *Science Education, 100*(3), 410-436.

McNeill, K.L., Katsh-Singer, R., González-Howard, M., & Loper, S. (2016). Factors impacting teachers' argumentation instruction in their science classrooms. *International Journal of Science Education, 38* (12), 2026-2046.

Osborn, J., Erduran, S., & Simon, S. (2004). *Ideas, evidence and argument in science.* London, U.K.: King`s College, London.

Sakamoto, M., Yamamoto, T., Yamaguchi, E., Nishigaki, J., Muratsu, K., & Inagaki, S. (2012). Argument skill acquisition among grade 5 and grade 6 elementary school students. *Journal of science education in Japan, 36*(3), 252-261.

Yamamoto, T., & Kamiyama, S. (2018). Teacher beliefs about argumentation in Japanese in-service teachers. In Finlayson, O., McLoughlin, E., Erduran, S., & Childs, P. (Eds.), *Electronic Proceedings of the ESERA 2017 Conference.* Dublin, Ireland: Dublin City University, 952-959.

Zohar, A. (2008). Science teacher education and professional development in argumentation. In S. Erduran, & M. P. Jiménez-Alexandre (Eds.), *Argumentation in science education: Perspectives from classroom-based research* (pp.245-268). Netherlands: Springer.

AN EMPIRICAL PILOT IN ASSESSING STUDENT TEACHERS' BIOGRAPHY AND INSTRUCTIONAL BELIEFS

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Switzerland is undergoing a curricular change. Curriculum 21 has been ratified by all 21 German-speaking and is currently being implemented. With this innovation, German-speaking Switzerland will move toward a more technology-oriented education. What has been Manual Training or Wood/ Metalwork Classes is now replaced by composite subjects such as Nature and Technology. These subjects now structurally anchor technology-oriented content at the compulsory school level (Stuber, Heitzmann, & Käser, 2013) and are supposed to be implemented in the sense of the Anglo-Saxon concept of Science – Technology – Society – Environment (Labudde, 2012, p. 86). The technology orientation includes an instructional orientation toward a technical understanding or understanding technology, which, eo ipso, needs to be part of teacher education programs (Keller, 2017). To put things bluntly: Who else than technology/ technics-oriented teachers should teach technology and technics? Yet, technics or technology is not explicitly part of their initial studies, perhaps because in "the mandatory school, i.e. K-12, there is no specific subject 'Technology', but there is a subject called 'Textile and Technical Design'" (Kruse & Labudde, 2016, p. 62). Therefore, student teachers may at the most specialize in textile and technical design or in information technology/ computer science and teach technics and technology in an integrated way. But what are factors they would consider to impede tech instruction? In other words: What are factors that hinder high quality technology instruction by means of teacher beliefs? In this presentation we will give insights to a quantitative exploratory study.

Keywords: Science & technology education, pre-service teacher education, technology instruction

INTRODUCTION

Currently, Switzerland is moving toward a more technology/ engineering-oriented education. What has been *Manual Training* or *Wood/ Metalwork Classes* is replaced by composite subjects such as *Nature, Man, Society*, *Nature and Technology* or T*extile and Technical Design*. These subjects now structurally anchor technology at the compulsory school level (Stuber et al., 2013) and are supposed to be implemented in the sense of *Science – Technology – Society – Environment* (Labudde, 2012, p. 86). Also the subject area of media & information technology education touches the general technology branch, especially when informatics is extended to computer programming, digitalization of work routines and robotics. All this includes an instructional orientation toward a *technical understanding* or *understanding technology* (National Research Council, 2002), which, eo ipso, needs to be part of teacher education programs (Keller, 2017). Current cohorts of student teachers at the Swiss universities of teacher education are supposed to be educated toward these contents. But in praxis, who else than technology-affine teachers should teach technology? Technology was not explicitly part of their initial studies, and even current students do not receive a uniform technology-oriented education. Perhaps because in "the mandatory school, i.e. K-9, there is no specific subject

‘Technology’, but there is a subject called ‘Textile and Technical Design’” (Kruse & Labudde, 2016, p. 62). Also, *Textile Design* is not pure technology and technology is not solely design-oriented. The same is true for media and information technology, digital technology, engineering or any other area.

At the moment, student teachers may – at the most – specialize in textile and technical design or in information technology/ computer science, and consequently teach technology in an integrated way. From the fact that there is no systematic technology education in the course of their university studies, the question arises under which circumstances student teachers individually integrate technology-oriented instruction into their teaching. Thus, we need to know about predictors of technology-oriented instruction. Our question is: What are preconditions that support student teachers pursue technology-oriented instruction in compulsory K-9 school, i.e. primary and lower-secondary school?

THEORETICAL BACKGROUND

It is generally difficult to draw a comprehensive picture of instructional integration processes, especially in terms of a rather opaque field of “technology” education. Thus, in first part of the theoretical section, we want to clarify our conception of technology. In the second theoretical part – because we ask the question “What are preconditions that support student teachers pursue technology-oriented instruction in compulsory K-9 school, i.e. primary and lower-secondary school?” – we want to focus on holistic theories of behavior prediction and integrate them into a framework of technology education.

The term technology

The most debatable term in this study is *technology*. Looking at a large body of research in technology integration in instruction, we see that the term *technology* is mainly used to refer to computer-like systems, digital devices or applications that are programed to substitute analog antecedents. For example the use of computers in classrooms, the implementation of tablets or apps, or having online examinations (e.g. Lumpe et al., 1998; Palak & Walls, 2009; Ottenbreit-Leftwich et al., 2010; Ertmer et al., 2012; Kim et al., 2013; Hutchison & Woodward, 2014; Beschorner et al., 2018). In sum, most studies find teacher beliefs, values, pedagogical self-concept, reflected, goal-oriented intentions, and value for learning outcomes as main factors for technology implementation.

Yet, the term technology not solely refers to digitalization. Although there may be various understandings around the world and particularly within European countries, and also differences between US and Europe, we want to employ a definition that, to our knowledge, addresses most conceptions: “Technology comprises the entire system of people and organizations, knowledge, processes, and devices that go into creating and operating technological artifacts, as well as the artifacts themselves.” (National Research Council, 2002, p. 3). Thus, *technology* and *technics* are defined as a construct of informatics & digital literacy as well as technical & engineering knowledge and any innovative combination of any of these fields. Within this broad conception of technology one needs to consider engineering school education, too. Yet, this has been hardly explored. Van Haneghan et al. (2015) find that teachers' experience with engineering is of advantage when it comes to teaching engineering topics. Also, the value teachers see in teaching engineering has an effect on the implementation of engineering topics (Park et al., 2016). Similarly to technology integration, engineering instruction is also related to how well prepared (content-wise and pedagogically) the teachers feel themselves (Wang et al., 2011; Rich et al., 2017)

Pedagogical knowledge, beliefs, socialization, and motivation as instructional predictors

Teachers work within a context of not-well-structured problems and infinite variability of outcomes. By definition, "well-structured problems are constrained problems with convergent solutions that engage the application of a limited number of rules and principles within well-defined parameters. Ill-structured problems possess multiple solutions, solution paths, fewer parameters which are less manipulable, and contain uncertainty about which concepts, rules, and principles are necessary for the solution or how they are organized and which solution is best" (Jonassen, 1997, p. 65). To solve ill-structured problems teachers need a broad spectrum of reactions, competence, and experience. Jonassen (1997) argues that ill-structured problems are solved best if one can a) articulate the problem space and contextual constraints, b) identify and clarify alternative opinions, c) assess the viability of alternative solutions by argumentation and beliefs, and d) apply, monitor and adapt the solution. Taking into account that this whole process is situational, the most relevant predictors of solving an ill-structured interaction may be the teachers' mindset and their ability to consider the contextual/ interactional constraints (i.e. pedagogical knowledge). A prominent model of teacher resources for instructional practice has been proposed by Kunter et al. (2013). It integrates professional cognitive competences (e.g. pedagogical content knowledge), beliefs and motivational variables as the most valuable predictors of instruction:

a) *Pedagogical (content) knowledge* represents what the teacher knows about teaching content matter to students in a particular stage of development. Thus, pedagogical content knowledge includes knowledge about the content area, knowledge about instructional methods, and knowledge about the developmental stage of the students.
b) *Teacher beliefs* of instruction can be seen an interactive process guided by individual norms, one needs to understand the beliefs of the involved individuals (Raymond, 1997; Pane, 2010). Beliefs are often formed by prior teaching experiences, e.g. how they were taught to teach in their teacher education program or even how they were taught themselves during their schooling. Especially the latter reaches out into the wide field of socialization and biographical backgrounds.
c) Hurrelmann (1986, 2002) draws on socialized cognition, knowledge, biography and social contexts in order to explain purposeful behavior and decision-making. General, but also family and school socialization develops motivation and interest in any domain, also in technology (Deci & Ryan, 2000; Renn et al., 2009; Ardies et al., 2015; Adenstedt, 2016).

Therefore, we want to emphasize home, school and hobby/ interest as major predictors of technology socialization.

d) *Motivation* can be defined as the result of situation-belief interaction (J. Heckhausen & Heckhausen, 2018). Motivation results in action. In the motivational process intention plays a central role: The Rubicon model of action phases (H. Heckhausen & Gollwitzer, 1987; Gollwitzer & Oettingen, 2001; Achtziger & Gollwitzer, 2007) – a sequential, psychological model – predicts a person's behavior. In the model, the intention-building is central as it activates planned behavior. Based on van Hooft, Born, Taris, van der Flier, and Blonk (2005), who articulate that planning is essential and can be assessed in a questionnaire. This methodological idea is in line with Fishbein and Ajzen (2010) who argue that asking a person is a good proxy for the person's true intentions.

Based on the above mentioned, we developed a research framework that includes the major dimensions of instruction and their relevance in general educational contexts. In our case we focus teacher prerequisites related to their instruction in compulsory school (see Figure 7).

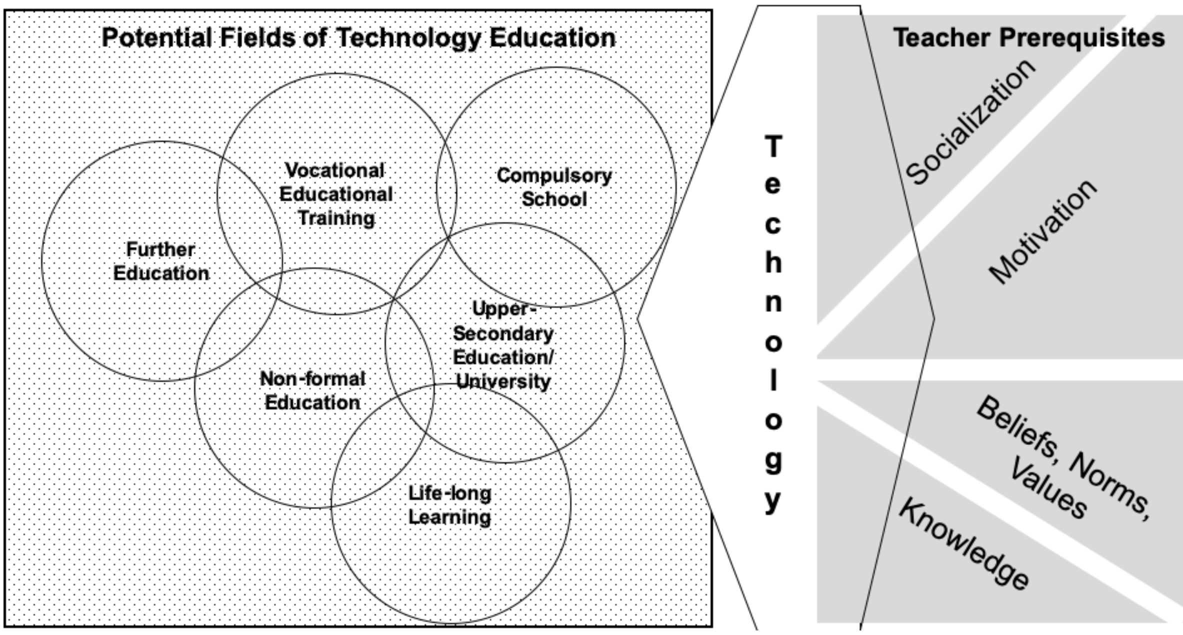

Figure 7: Framework of teacher prerequisites and implementation fields for technology education

In Figure 7 the major variables for successful technology implementation are teacher socialization, motivation, beliefs, and knowledge. These variables combine self-attribution as well as objective evaluation.

METHOD

Instruments

We used a questionnaire to assess the biographical background (socialization) and the intention to implement technology instruction and self-confidence in technology instruction. All items were rated on a 5-point Likert scale (do not agree --- fully agree). The instruction included clarification of the term, i.e. it means digital technology as well as engineering.

Technology socialization was newly developed, has 4 items (e.g. Technology played a role in my family during my childhood"), showed uni-dimensionality in principal component analysis and reliability was α=.78; The intention to implement technology instruction was adapted from van Hooft et al. (2005), included 4 items (e.g. "I know exactly how to implement technology in my instruction"), showed uni-dimensionality in principal component analysis and reliability was α=.78.

In addition to the two theoretical variables above, we assessed a lack professional and instructional self-confidence as hindering elements to implement technology instruction. These single item indicators were "I think my content knowledge is insufficient." and "I think my pedagogical competence does not suffice."

Sample and context of data acquisition

In autumn 2016 we deployed questionnaires to 69 student teachers (66% kindergarten & primary level, 34% lower-secondary level; 2 courses in primary level – 4-4.5% male students; one course in lower-secondary – 64% male students). All participants were enrolled in a class on "quantitative research methods". As the class was compulsory in the education program the backgrounds of the students were manly randomized, i.e. they were neither biased in terms of interest, nor preferred subjects. 77% of the students were female, kindergarten and primary level are dominated by female students (Phi=.66, p.000). On average, they were in their second year of study. Data were analyzed with SPSS 24. Two-tailed Spearman-correlations were computed and Kruskal-Wallis test/ separate Mann-Whitney U tests were used for comparisons between the three groups. Because of the small sample and the exploratory purpose of the study, we give exact p-values that need to be interpreted carefully, but also with tolerance.

RESULTS

The implementation intention correlation was .24, p=.066, the correlation between the single item indicators was .46, p=.000. The pedagogical confidence was not associated to the socialization (r=.20, p=.118), but the confidence in content knowledge was (r=-.27, p=.035). With reference to the implementation intention, both pedagogical confidence (r=-.35, p=.006) and confidence in content knowledge (r=-.50, p=000) showed statistical significance. The the Kruskal-Wallis test for overall comparison resulted in two-sided p-values for technology socialization (p=.006) and the other variables in a range of p=[.366;.515]. Mann-Whitney U tests with corrected alpha level of p=.05/3 tests=.017 showed that the group of lower secondary students scored higher on technology socialization than any of the primary teacher groups (p=.010; p=.004), the two primary teacher groups did not differ (p.=872).

DISCUSSION

This study framed the term "technology" in a content area of informatics & digital literacy as well as technical & engineering knowledge and any innovative combination of any of these fields. We also picked up the issue of technology instruction without a subject named "technology" in Switzerland and investigated the relation of a technology-oriented socialization and the implementation of technology instruction. Furthermore, we explored the association of pedagogical and professional self-confidence with respect to socialization and implementation. The results seem promising and showed that a stronger self-reported technology orientation during childhood is associated with how technology education enters instruction. Confidence in pedagogical and professional knowledge share a stronger association with the implementation than socialization does, but it seems that socialization can play an important role. As this is a pilot study with a small sample size we still need to be careful in interpretation. But if the effect holds true in a large sample we have evidence that school sets itself into a vicious cycle of technology education and its mandate to educate kids toward a good fit into society. The reason is that technology at school is part of the socialization, and if it is left out we will not have teachers with sufficient technology socialization that trust themselves to teach technology. A second exploratory finding is that lower-secondary teacher students rate their technology socialization higher than the primary school peers, but they are not more confident in their abilities. Thus, a "women underrate their abilities" explanation in which the female-dominated primary teachers do not trust their abilities as much as the male students, does not apply. We speculate that this effect may rather appear because students perceive subjects in different way: in lower-secondary education they have separate subjects, in primary/ kindergarten they teach holistically. We hope for more research on this assumption, especially because it is just out of an exploratory approach in a small sample pilot study.

ACKNOWLEDGEMENT

Thanks and credit is given to the research team "Erfolgsfaktoren für die allgemeine technische Bildung" (2015-2017) School of Engineering & School of Education at the University of Applied Sciences and Arts Northwestern Switzerland.

REFERENCES

Achtziger, A., & Gollwitzer, P. M. (2007). Rubicon Model of Action Phases. In R. F. Baumeister & K. D. Vohs (Eds.), *Encyclopedia of social psychology* (Vol. 2, pp. 769–770).

Adenstedt, V. (2016). Erhebung des technischen Selbstkonzepts von Grundschulkindern. *Journal of Technical Education (JOTED)*, *4*(2), 64–86.

Ardies, J., De Maeyer, S., Gijbels, D., & van Keulen, H. (2015). Students attitudes towards technology. *International Journal of Technology and Design Education*, *25*(1), 43–65.

Beschorner, B., Colwell, J., Hutchison, A., & Woodward, L. (2018). Using the Technology Integration Planning Cycle to Prepare Pre-service Teachers for Multimodal Instruction. In E. Ortlieb, E. H. Jr. Cheek, & P. Semingson (Eds.), *Best Practices in Teaching Digital Literacies* (Vol. 9, pp. 13–27). Emerald Publishing Limited. https://doi.org/10.1108/S2048-045820180000009002

Deci, E. L., & Ryan, R. M. (2000). The "What" and "Why" of Goal Pursuits: Human Needs and the Self-Determination of Behavior. *Psychological Enquiry*, *11*(4), 227–268.

Ertmer, P. A., Ottenbreit-Leftwich, A. T., Sadik, O., Sendurur, E., & Sendurur, P. (2012). Teacher beliefs and technology integration practices: A critical relationship. *Computers & Education*, *59*(2), 423–435. https://doi.org/10.1016/j.compedu.2012.02.001

Fishbein, M., & Ajzen, I. (2010). *Predicting and changing behavior: The reasoned action approach*. Psychology Press.

Gollwitzer, P. M., & Oettingen, G. (2001). Psychology of Motivation and Actions. In N. J. Smelser & P. B. Baltes (Eds.), *International Encyclopedia of the Social & Behavioral Sciences* (pp. 10105–10109). Pergamon.

Heckhausen, H., & Gollwitzer, P. M. (1987). Thought Contents and Cognitive-Functioning in Motivational Versus Volitional States of Mind. *Motivation and Emotion*, *11*(2), 101–120.

Heckhausen, J., & Heckhausen, H. (2018). Motivation and Action: Introduction and Overview. In J. Heckhausen & H. Heckhausen (Eds.), *Motivation and Action* (3rd ed., pp. 1–14). Springer.

Hurrelmann, K. (1986). *Einführung in die Sozialisationstheorie: Über den Zusammenhang von Sozialstruktur und Persönlichkeit.* Beltz.

Hurrelmann, K. (2002). Selbstsozialisation oder Selbstorganisation? Ein sympathisierender, aber kritischer Kommentar. [Self-socialization or self-organization? A sympathetic but critical comment.]. *Zeitschrift Für Soziologie Der Erziehung Und Sozialisation*, *22*(2), 155–166.

Hutchison, A., & Woodward, L. (2014). A planning cycle for integrating digital technology into literacy instruction. *The Reading Teacher*, *67*(6), 455–464.

Jonassen, D. H. (1997). Instructional design models for well-structured and III-structured problem-solving learning outcomes. *Educational Technology Research and Development*, *45*(1), 65–94. https://doi.org/10.1007/BF02299613

Keller, H.-J. (2017). Die Zukunft der Lehrpersonenbildung in der Schweiz. *Beiträge Zur Lehrerinnen- Und Lehrerbildung, SGL Jubiläumsnummer*, *35*(0), 113–122.

Kim, C., Kim, M. K., Lee, C., Spector, J. M., & DeMeester, K. (2013). Teacher beliefs and technology integration. *Teaching and Teacher Education*, *29*, 76–85. https://doi.org/10.1016/j.tate.2012.08.005

Kruse, S., & Labudde, P. (2016). Technology Education in Switzerland. In M. J. de Vries, S. Fletcher, S. Kruse, P. Labudde, M. Lang, I. Mammes, C. Max, D. Münk, B. Nicholl, J. Strobel, & M. Winterbottom (Eds.), *Technology Education Today: International Perspectives.* (pp. 59–74). Waxmann.

Kunter, M., Klusmann, U., Baumert, J., Richter, D., Voss, T., & Hachfeld, A. (2013). Professional Competence of Teachers: Effects on Instructional Quality and Student Development. *Journal of Educational Psychology*, *105*(3), 805–820.

Labudde, P. (2012). Aus- und Weiterbildung von Lehrpersonen für die MINT-Fächer: Desiderata. In D. Ambühl, N. Birbaumer, A. Gürtler, M. Iseli, & D. Quadri (Eds.), *Zukunft Bildung Schweiz—Förderung der MINT-Kompetenzen zur Stärkung des Bildungs-, Wirtschafts- und Wissenschaftsstandorts Schweiz. Akten der Veranstaltung vom 23. Und 24. Oktober 2012.* (pp. 83–89). Akademien der Wissenschaften Schweiz.

Lumpe, A. T., Haney, J. J., & Czerniak, C. M. (1998). Science teacher beliefs and intentions to implement science-technology-society (STS) in the classroom. *Journal of Science Teacher Education*, *9*(1), 1–24.

National Research Council. (2002). *Technically Speaking: Why All Americans Need to Know More About Technology*. The National Academies Press. https://doi.org/10.17226/10250

Ottenbreit-Leftwich, A. T., Glazewski, K. D., Newby, T. J., & Ertmer, P. A. (2010). Teacher value beliefs associated with using technology: Addressing professional and student needs. *Computers & Education*, *55*(3), 1321–1335. https://doi.org/10.1016/j.compedu.2010.06.002

Palak, D., & Walls, R. T. (2009). Teachers' Beliefs and Technology Practices. *Journal of Research on Technology in Education*, *41*(4), 417–441. https://doi.org/10.1080/15391523.2009.10782537

Pane, D. M. (2010). Viewing classroom discipline as negotiable social interaction: A communities of practice perspective. *Anthropological Perspectives on Learning and Teaching: Legitimate Peripheral Participation Revisited*, *26*(1), 87–97. https://doi.org/10.1016/j.tate.2009.05.002

Park, M.-H., Dimitrov, D. M., Patterson, L. G., & Park, D.-Y. (2016). Early childhood teachers' beliefs about readiness for teaching science, technology, engineering, and mathematics. *Journal of Early Childhood Research*, *15*(3), 275–291. https://doi.org/10.1177/1476718X15614040

Raymond, A. M. (1997). Inconsistency between a Beginning Elementary School Teacher's Mathematics Beliefs and Teaching Practice. *Journal for Research in Mathematics Education*, *28*(5), 550–576. https://doi.org/10.2307/749691

Renn, O., Pfenning, U., Brennecke, V., Lohel, V., Brachatzek, N., & Steinert, T. (2009). *Nachwuchsbarometer Technikwissenschaften*. acatech & VDI.

Rich, P. J., Jones, B. L., Belikov, O., Yoshikawa, E., & Perkins, M. (2017). Computing and Engineering in Elementary School: The Effect of Yearlong Training on Elementary Teacher Self-Efficacy and Beliefs about Teaching Computing and Engineering. *International Journal of Computer Science Education in Schools*, *1*(1).

Stuber, T., Heitzmann, A., & Käser, A. (2013). Technik- und Naturwissenschaftsunterricht an Schweizer Schulen. In W. Bienhaus & W. Schlagenhauf (Eds.), *Technische Bildung im Verhältnis zur naturwissenschaftlichen Bildung: Methoden des Technikunterrichts.* (pp. 101–131). Deutsche Gesellschaft für Technische Bildung e.V.

Van Haneghan, J. P., Pruet, S. A., Neal-Waltman, R., & Harlan, J. M. (2015). Teacher beliefs about motivating and teaching students to carry out engineering design challenges: Some initial data. *Journal of Pre-College Engineering Education Research (J-PEER)*, *5*(2), 1–9.

van Hooft, E. A. J., Born, M. P., Taris, T. W., van der Flier, H., & Blonk, R. W. B. (2005). Bridging the gap between intentions and behavior: Implementation intentions, action control, and procrastination. *Journal of Vocational Behavior*, *66*(2), 238–256.

Wang, H.-H., Moore, T. J., Roehrig, G. H., & Park, M. S. (2011). STEM integration: Teacher perceptions and practice. *Journal of Pre-College Engineering Education Research (J-PEER)*, *1*(2), 1–13.

EVALUATING SCIENCE TEACHERS' TEACHING PRACTICES: STRENGTHS AND WEAKNESSES

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Teacher's evaluation is considered critical for teachers' professional development. Evaluation systems with different characteristics are used worldwide. According to the literature, the most common practice to collect data for the evaluation of teachers is classroom observation. Despite students' perspectives being considered as a viable and reliable source of teachers' evaluation, students' insights have not been used for teachers' evaluation. Within this context, the aim of the present study was to highlight the strong and weak aspects of science teachers' teaching practices. For this purpose, we designed and implemented an evaluation system for secondary education science teachers. Our data were collected with classroom observations and with questionnaires for exploring students' perceptions. Thirty-two (32) science teachers serving in secondary education were evaluated and 1154 students completed the questionnaire. The results indicated that teachers' strengths are related to the subject matter knowledge, the use of representations, questioning, the instructional objectives, classroom management, and the knowledge of students' difficulties. Their weaknesses concern some of the instructional strategies and methods, students' alternative conceptions, and assessment. These findings provide an overview of teachers' everyday practices and indicate the aspects of teaching in which teachers need support as well as potential areas that future professional development programs could focus on.

Keywords: Evaluation, Teacher Professional Development, Science Education Policy

INTRODUCTION

There is a strong correlation between the quality of education and the quality of practices in teaching. The quality of teachers' classroom practices constitutes a central issue for those who are concerned with teachers' professional development (Kallery & Psillos, 2001, p.166). Teachers' knowledge, teachers' practices, and teachers' professional development have been the subject of studies by many scholars (e.g., Van Driel & Berry, 2012).

In modern education, evaluation is seen as a meaningful and essential process for teachers' professional development. To highlight the strengths and weaknesses of teachers' practices, different evaluation systems have been applied worldwide. The most common method to collect data for teachers' evaluation is classroom observation with the use of a scoring rubric. (Isoré, 2009). However, scholars highlight that "classroom observation, no matter how well-focused, can only capture certain aspects of what a teacher has planned and indeed is undertaking in the classroom" (Shinkfield & Stufflebeam, 1995, p. 228).

On the other hand, students spend most of their school life behind a desk or participating in activities designed by the teachers. In turn, they can provide a more holistic look at teachers' teaching practices. Despite students' opinions perceived as a reliable and viable source of data (e.g., Peterson, Wahlquist, & Bone, 2000, Aleamoni, 1999), they are not systematically used as a source for teacher's evaluation (Isoré, 2009, Santiago, 2009).

Based on the above, we designed and applied an evaluation system specifically for science teachers using both a student questionnaire and an observation tool (scoring rubric), and we formed evaluation criteria (see Table 1), based on aspects of Pedagogical Content Knowledge (PCK). The present study aims to evaluate science teachers serving in secondary education and to highlight the weaknesses and strengths of their everyday practice. Based on this closer examination of individual teacher's needs, we provide a foundation upon which the future development of professional upgrading programs could be based.

METHOD

Evaluation criteria and levels of achievement

The evaluation system uses 21 criteria (see Table 1) in which teachers' practices are evaluated. The criteria are divided into four categories based on the PCK analysis of Jang (2011): Subject Matter Knowledge, Instructional Representations and Strategies, Instructional Objective and Context, and Knowledge of Students Understanding. In each criterion, the evaluation is based either on results from classroom observations or on students' opinions or both.

Tools of the evaluation system and data collection

Classroom observations were recorded using a scoring rubric designed by the authors and evaluated by experienced educational advisors. Students' opinions about teachers' performance were collected with the use of a questionnaire originally designed by Jang (2011) and adapted to the context of our study. Both tools use a five-point Likert scale. For each teacher, the observer performed direct first-hand observations of two one-hour lessons and scored the teachers' performance for every aspect of teaching. Students of two different classes answered the questionnaire. The science teachers were evaluated during the lesson of their major subject (e.g., Physicist – Physics).

Data were collected from both observation and students' questionnaires to collect data for the quality of the practices that teachers use in everyday teaching and the frequency that these practices are used, respectively. Furthermore, students' perceptions of the usefulness of some methods that their teacher use is essential for the evaluation of the teacher in some aspects of teaching.

Sample

The study was conducted in Central Northern Greece. Thirty-two (32) science teachers from Gymnasium and Lyceums participated in the study. Seventeen (17) of the teachers with major in Physics, twelve (12) with major in Chemistry, and three (2) with major in Biology. The sample was representative. The questionnaires were completed by 1154 students (579 male and 571 female), 484 Gymnasium students (12-15 years old) and 571 Lyceum students (16-18 years old).

Table 3: Evaluation criteria and the aspects of teaching recorded (R for scoring rubric and Q for students' questionnaire

Domain 3:Instructional Objectives and Context	
Criteria	**Aspects included in each criterion**
Instructional objectives and goals	*Instructional objectives and goals (communication and understanding) (R)* *Understanding of the lesson goal (Q)*
Interactive atmosphere	*Teaching Adjustment based on students' reaction (Q and R)* *Discussion on students' questions (Q)*
Students participation	*Students participation (R)*
Motivation for learning	*Motivation for learning (Q)*
Additional teaching material	*Additional teaching material (Q)*
Classroom management and mutual respect among students	*Classroom management (Q and R)* *Mutual Respect (R)*

Domain 4: Knowledge of Students Understanding	
Criteria	**Aspects included in each criterion**
Alternative conceptions investigation	*Teachers' Questions before introducing a new topic (Q)* *Alternative conceptions investigation (R)* *Strategies to handl students' alternative conceptions (R)*
Knowledge of students' difficulties	*Knowledge of students' difficulties (Q and R)*
Assessment during the lesson	*Use of different ways to access understanding (Q)* *Formative Assessment during lesson (R)* *Variety of assement methods and adjustment related to students' diversity (R)*
Summative assessment (test, etc.)	*Summative Assesment (tests, etc) (Q)*

Domain 1: Subject Matter Knowledge	
Criteria	**Aspects included in each criterion**
Knowledge of the content	*Knowledge of the content (Q)* *Adequete presentation of the topic (Q)* *Adequately answering of students' questions (Q)*
Quality of the language used during the lesson	*Quality of the language used during the lesson (R)* *Didactic tranformation (Q)*
Connection between the teaching notion or phenomenon and everyday life	*Connection between the teaching notion or phenomenon and everyday life (Q and R)*

Domain 2 : Instructional Representation and Strategies	
Criteria	**Aspects included in each criterion**
Instuctional Strategies	*Instructional Strategies (Variety and appropriateness) (R)* *Strategies maintaining students' interest (Q and R)*
Students' attentiveness related reactions during instruction	*Students' attentiveness related reactions during instruction (Q and R)*
Instructional representations	*Use of examples, analogies, graphs, everyday objects (Q)* *Appropriateness and usefulness of instructional respresentations (R)*
Use of ICTs	*Use of ICTs (Q)*
Use of experiments	*Demonstration of Experiments (Q)* *Students' experiments*
Inquiry	*Type of Inquiry (R)*
Scientific skills promoted by the teacher	*Scientific skills promoted by the teacher (R)*
Questioning	*Conceptual Level of teaching questions (R)* *Students' participation in questioning (R)*

Data analysis

The data from the questionnaire were statistically analyzed for each teacher and the mean of students' responses was calculated. The results from the scoring rubric and the means were inserted in a Sheet of Personal Evaluation. The evaluator compared and synthesized the results for each aspect of teaching recorded and made decisions about teachers' level of achievement on every criterion based on the following scale: Exceptional (Q:4.00-5.00, R:4 & 5), Adequate (Q:3.00-3.99, R:3), Weak (Q:2.00-2.99, R: 2) and Inadequate (Q:1.00-2.99, R:1). After the individual evaluation of teachers, a descriptive statistical analysis was performed to describe the strengths and the weakness among the science teachers of the total sample.

RESULTS & DISCUSSION

Subject Matter Knowledge

The results showed that the teachers were rated as exceptional or adequate in the criteria included in Subject Matter Knowledge (see Table 2). Teachers have good knowledge of their subjects. The quality of the language used during the lesson was exceptional for the majority of the teachers (Table 2, *Quality of language use during the lesson: Exceptional*) while the minority of them use some inappropriate expressions (mirror mistakes in verbs or expressions that seem to represent animistic views) but theu use does not seem to affect learning (Table 2, *Quality of language use during the lesson: Adequate)*. The connection of the topic to everyday life seems to be a common practice for a large percentage of the teachers (Table 2).

Table 4: Evaluation results' statistics for criteria included in the SMK domain

Level of achievement	Knowledge of the content		Quality of language use during the lesson		Connection to everyday life	
	Frequency	Percent	Frequency	Percent	Frequency	Percent
Exceptional	32	100	24	75	14	43.8
Adequate	0	0	8	25	14	43.8
Weak	0	0	0	0	3	9.4
Inadequate	0	0	0	0	1	3.1

Instructional Representations and Strategies

Teachers use a variety of teaching methods and techniques in which students are engaged and maintain students' interest in the lesson (Table 2: *Instructional Strategies*). Most of the teachers give students the opportunities to express their opinions (Table 2: *Opportunities for students to express their opinions*).

Moreover, teachers make proper use of instructional representations that seem to have a positive effect on the learning process. However, weaknesses are found in ICT-based teaching and the use of experiments during instruction. The vast majority of the teachers either use experiments rarely or never in their practice (Table 4: *Use of experiments, Weak and Adequate*) while another large percentage of them avoid using Information and Computer Technologies in their everyday practice (Table 3: *Use of ICT, Weak and Adequate*).

Table 5: Evaluation results' statistics for criteria included in the IRS domain

Level of achievement	Instructional Strategies		Opportunities for students to express their opinions		Instructional representations		Use of ICTs	
	Frequency	Percent	Frequency	Percent	Frequency	Percent	Frequency	Percent
Exceptional	18	56.3	14	43.8	24	75	6	18.8
Adequate	7	21.9	12	37.5	4	12.5	8	25
Weak	7	21.9	6	18.8	4	12.5	7	21.9
Inadequate	0	0	0	0	0	0	11	34.4

Teachers use mainly structured inquiry to promote basic skills (Table 4: *Types of Inquiry and Scientific Skills promoted by teacher*). Most of the teachers were rated as adequate or excellent in questioning. Teachers escalate the conceptual level of their questions (from basic to high level) in order to guide students to understand and explain the ideas or phenomena of the taught topic.

Table 6: Evaluation results' statistics for criteria included in the domain IRS

Level of achievement	Use of experiments		Types of Inquiry		Scientific skills promoted by the teacher		Conceptual level of teachers questions	
	Frequency	Percent	Frequency	Percent	Frequency	Percent	Frequency	Percent
Exceptional	7	21.9	4	12.5	4	12.5	9	28.1
Adequate	6	18.8	13	40.6	13	40.6	15	46.9
Weak	14	43.8	7	21.9	11	34.4	0	0.0
Inadequate	5	15.6	8	25	4	12.5	8	25.0

Instructional Objectives and Context

Teachers are also positively evaluated in the criteria included in the domain of Instructional Objectives and Context. Most of the teachers communicate the instructional objectives in multiple ways and achieve an understanding of them for most of the students (Table 5: *Instructional Objectives)*.

Table 7: Evaluation results' statistics for criteria included in the domain IOC

Level of achievement	Instructional objectives and goals		Interactive atmospheres		Students participation	
	Frequency	Percent	Frequency	Percent	Frequency	Percent
Exceptional	22	68.8	11	34.4	16	50
Adequate	10	31.3	11	34.4	15	46.9
Weak	0	0	10	31.3	1	3.1
Inadequate	0	0	0	0	0	0

Most of the teachers are successful in creating an interactive atmosphere in the classroom for the students to participate in the lesson, a not so palatable percentage of them is found weak in creating an interactive atmosphere. Also, as we can see in Table 6 (*Additional Teaching Material*) almost half of the teachers rarely or never provide additional teaching material.

Table 8: Evaluation results' statistics for criteria included in the domain IOC

Level of achievement	Motivation for learning		Additional teaching material		Classroom management and mutual respect among students	
	Frequency	Percent	Frequency	Percent	Frequency	Percent
Exceptional	4	12.5	7	21.9	20	62.5
Adequate	20	62.5	12	37.5	11	34.4
Weak	8	25	6	18.8	1	3.1
Inadequate	0	0	7	21.9	0	0

Knowledge of Students Understanding

In the domain of Knowledge of Students Understanding, the results highlight the most significant weaknesses of teachers' everyday practice. The majority of the teachers don't investigate and therefore do not handle students' alternative conceptions. Also they rarely assess students during the lesson and when they do it is for the students' compliance (Table 7: *Assessment during the lesson: Weak)*.

Table 9: Evaluation results' statistics for criteria included in the domain KSU

Level of achievement	Students alternative conceptions		Knowledge of students difficulties		Assessment during the lesson		Summative assessment	
	Frequency	Percent	Frequency	Percent	Frequency	Percent	Frequency	Percent
Exceptional	7	21.9	21	65.6	9	28.1	9	28.1
Adequate	4	12.5	9	28.1	10	31.3	17	53.1
Weak	5	15.6	2	6.3	13	40.6	6	18.8
Inadequate	16	50	0	0	0	0	0	0

However, teachers seem to have a good knowledge of the difficulties of the students in the topic they teach, and they focus on these in order to address them properly (Table 7: *Knowledge of Students' Difficulties)*.

Regarding students' summative assessment most of the teachers are evaluated as adequate (Table 7). However, because the findings of this specific criterion are based only on students' responses, students seem to question the usefulness of the type of assessment that teachers employ.

CONCLUSIONS

The findings of the present study provide an overview of the Greek science teachers' weaknesses and strengths regarding their everyday practices. This closer examination of the individual teacher's needs indicates potential areas that future professional development programs could focus on.

Even though this study focuses on the strengths and the weaknesses of teachers' practices, if we take into account the theoretical background of the Greek teachers and the lack of pre- and in-service teacher education in the country, we believe that we could describe some potential reasons for science teachers' strengths and weaknesses. On the one hand, the weaknesses observed and described above may be connected to a lack of teachers' knowledge related to *General Pedagogy* (e.g., Shulman, 1986)*, Knowledge of students* and *Knowledge of Assessment* (Magnusson, Krajcik, & Borko, 1999), and students beliefs about learning and the aim of teaching science (Van Driel, Beijaard, & Verloop, 2001). On the other hand, the strengths of the teachers are related to aspects of teaching that could be developed through their experience (Clermont, Borko, & Krajcik, 1994) as a kind of *craft knowledge of teachers* (Van Driel et al., 2001).

From the methodological point of view, the combination of the students' views with observations using a tool (scoring rubric) designed in collaboration with experienced educational advisors who have a good knowledge of the educational system in which teachers act in their every-day work, seems to be fruitful as it produces a holistic view of the practices that take place in the real everyday classroom (Shinkfield & Stufflebeam, 1995, p. 228).

ACKNOWLEDGEMENT

This research is co-financed by Greece and the European Union (European Social Fund- ESF) through the Operational Programme «Human Resources Development, Education and Lifelong Learning» in the context of the project "Strengthening Human Resources Research Potential via Doctorate Research" (MIS-5000432), implemented by the State Scholarships Foundation (IKY).

REFERENCES

Aleamoni, L. M. (1999). Student Rating Myths Versus Research Facts from 1924 to 1998. *Journal of Personnel Evaluation in Education*, 13(2), 153–166.

Clermont, C. P., Borko, H., & Krajcik, J. S. (1994). Comparative study of the pedagogical content knowledge of experienced and novice chemical demonstrators. *Journal of Research in Science Teaching*, *31*(4), 419–441. https://doi.org/10.1002/tea.3660310409

Magnusson, S., Krajcik, J., & Borko, H. (1999). Nature , Sources , and Development of Pedagogical Content Knowledge for Science Teaching. *Examining Pedagogical Content Knowledge: The Construct and Its Implications for Science Education*, 95–132. https://doi.org/10.1007/0-306-47217-1_4

Clermont, C. P., Borko, H., & Krajcik, J. S. (1994). Comparative study of the pedagogical content knowledge of experienced and novice chemical demonstrators. *Journal of Research in Science Teaching*, *31*(4), 419–441. https://doi.org/10.1002/tea.3660310409

Isoré, M. (2009). Teacher Evaluation : Current Practices in OECD Countries and a Literature Review, (23), 1–49. https://doi.org/10.1787/223283631428

Jang, S.-J. (2011). Assessing college students' perceptions of a case teacher's pedagogical content knowledge using a newly developed instrument. *Higher Education*, *61*(6), 663–678. https://doi.org/10.1007/s10734-010-9355-1

Magnusson, S., Krajcik, J., & Borko, H. (1999). Nature , Sources , and Development of Pedagogical Content Knowledge for Science Teaching. *Examining Pedagogical Content Knowledge: The Construct and Its Implications for Science Education*, 95–132. https://doi.org/10.1007/0-306-47217-1_4

Peterson, K. D., Wahlquist, C., & Bone, K. (2000). Student Surveys for School Teacher Evaluation. *Space Science Reviews*, *96*(MAY 2000), 317–330. https://doi.org/10.1023/A

Shinkfield, A. J., & Stufflebeam, D. L. (1995). Models for Teacher Evaluation. In *Teacher Evaluation* (pp. 173–376). Dordrecht: Springer Netherlands. https://doi.org/10.1007/978-94-009-1796-5_4

Shulman, L. S. (1986). Those Who Understand: Knowledge Growth in Teaching. *American Education Research Association*, *15*(2), 4–14. https://doi.org/10.1017/CBO9781107415324.004

Van Driel, J. H., Beijaard, D., & Verloop, N. (2001). Professional development and reform in science education: The role of teachers' practical knowledge. *Journal of Research in Science Teaching*, *38*(2), 137–158. https://doi.org/10.1002/1098-2736(200102)38:2<137::AID-TEA1001>3.0.CO;2-U

Van Driel, J. H., & Berry, A. (2012). Teacher Professional Development Focusing on Pedagogical Content Knowledge. *Educational Researcher*, *41*(1), 26–28. https://doi.org/10.3102/0013189X11431010

INTERDISCIPLINARY REFLECTIVE TOOL ON SCHOOL SCIENCE AND MATHEMATICS

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In this paper, we focus on the importance of interdisciplinary communication between the teachers' didactical interaction with textbooks of school science and mathematics. We adopt an interdisciplinary approach to argue that the scientific learning needs to be realised through making explicit the use of mathematical symbolism, as well as the mutual conceptual compatibilities or incompatibilities between science and mathematics. We argue that the students may face concrete learning obstacles for each discipline due to the lack of appropriate didactic communication between science and mathematics teachers. Drawing upon this perspective, we focus on the mathematical signs that co-appear in school science and mathematics, with the purpose to identify the divergences and the convergences between the associated meanings and intentionalities for each course. For this purpose, we introduce an interdisciplinary reflective tool that we developed, in order to create a communicational space between the teachers of science and mathematics.

Keywords: Interdisciplinarity, Reflection, Teacher Thinking

INTRODUCTION

The interdisciplinary approach presented in this study highlights the need for reflection on the common signs that appears in textbooks. We consider the epistemological framework of interdisciplinarity as a dynamic process of integrating the distinction and the connection of disciplines, recognising and highlighting the different methodological and conceptual approaches, as well as their common formal language and symbolism. Interdisciplinarity in education aims to link departmental pedagogical approaches in a convergent teaching framework (Nikitina & Mansilla, 2003).

We adopt a systemic approach to didactic situations, which allows us to focus on the interactions between official documents, research results and school practices to facilitate the emergence of the implicit teaching-learning processes in science and in mathematics which are explicitly linked to common symbolisms and, thus, to study its reverse effects on the construction of academic knowledge in each area. In this paper, we discuss a reflective tool that focuses on the importance of linking the teaching of science and mathematics.

We present the reflective tool that we have developed to emphasize the importance of linking science and mathematics education by managing the variety of alternative or complementary points of view that is compressed in the apparent commonality of terminologies or expressions. The first results of its application with teachers of the two disciplines seem to support our design, as it helped in creating a common space for communication and didactic collaboration.

THEORETICAL FRAMEWORK

In the school reality of a class, the students receive distinct, though invisibly interactive, messages from teachers of different disciplines. The interactions of the messages and their decoding are not explicitly considered during the teaching process. The artificial fragmentation of the scientific knowledge as realised through the (we argue misconceived) separation of disciplines is reflected on the compartmentalisation of the respective school courses, which creates invisible obstacles to the understanding of scientific concepts. Consequently, the students may construct alternative ideas generated from arbitrary interconnections between the meanings that are extracted from the discrete teachings of different courses. In our work, we adopt the systemic approach of the school unit (Davis & Simmt, 2003), which allows the exploration of the teaching-learning processes in the school Mathematics and Physics through their common signs.

In addition, we adopt an interdisciplinary approach of teaching that highlights the need for reflection on the common signs of school textbooks. The aim of this approach is the interconnection of teaching practices of different disciplines in an integrated teaching programme (Nikitina & Mansilla, 2003). We assume that interdisciplinary teaching and communication (Watzlawick, Beavin & Jackson, 1967) amongst the teachers of a school unit are essential for the learning of scientific concepts. We posit that the mathematical and scientific signs that appear in the school science and mathematics textbooks may be utilised to create a communication space within which the teachers of different disciplines may start sharing the meanings that they assign to each sign and their reflections about these meanings.

Our theoretical perspective focuses on the phenomenology of signs in an interdisciplinary teaching-learning approach (Moutsios-Rentzos, Kritikos & Kalavasis, 2017), based on theories that have been developed especially for mathematics education (Radford, 2006; Steinbring, 2005). In line with these ideas, we introduce a communicational semiotic system, which consists of a basic communicational triad “epistemic object – interpreter – sign” (Moutsios-Rentzos, Kritikos & Kalavasis, 2019; Moutsios-Rentzos, Pinnika, Kritikos & Kalavasis, in press) as shown in Figure 1.

A *sign* includes all the means of signification that may be employed within a communication and activates the communicative triad. For example, it could be a symbol, an image, a natural language word, as well as their combination as a complex whole constituting a phrase, an equation etc.

Interpreters are the participants in the communication processes. In the case of a school class, they usually are teachers or/and students. In our present study, we focus on the teachers-interpreters. Figure 1c represents the case in which the same teacher acts in a different way when teaching different disciplines. For example, in Greece, primary school teachers teach both Science and Mathematics. In addition, the same student may behave in different ways when attending different courses, because of the different teaching framework that activates specific representations from the corresponding representational registry (Duval, 2006).

Objects are the epistemic objects, fields, or courses, whilst the *meaning* includes the entirety that emerges from the communication interactions. Our conceptualisation allows for an important identification that occurs in everyday classroom teaching. The students are constantly asked to assume different roles, to be different interpreters in different courses, as for the same sign they have to assign meanings appropriate for the specific course. For example, the concept of “area” functions in ways that do not necessarily converge in Science and Mathematics. Consequently, in the proposed approach, we explicitly acknowledge and build upon the fact that the students do encounter the same mathematical symbolism in different disciplines, positing that the communication between the teachers of different courses is crucial for the students to give to their experiences of the phenomena distinct, yet connected, uni-disciplinary and inter-disciplinary meanings.

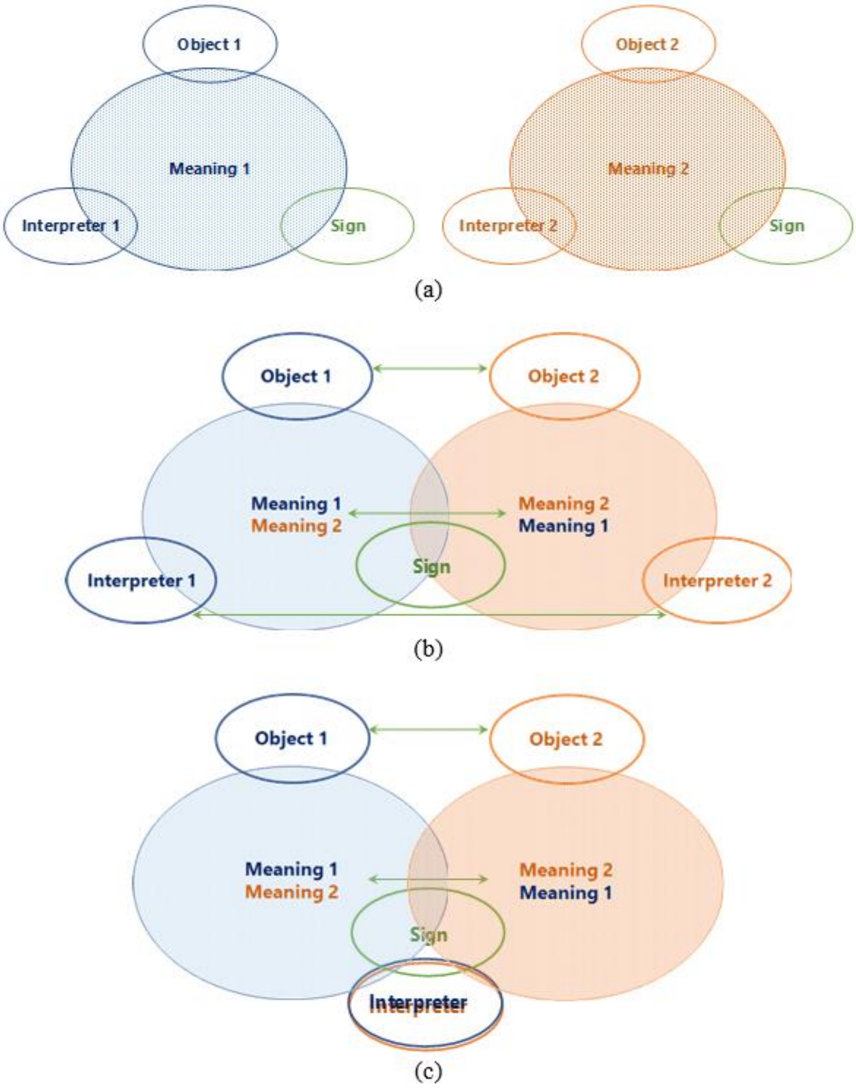

Figure 1. The proposed perspective of communicational space (adopted from Moutsios-Rentzos, Kritikos & Kalavasis, in press).

RESEARCH

The construction of the Interdisciplinary Reflective Tool (IRT) was based on a series of pilot studies that we had designed, focusing on the importance of the interconnection between Mathematics teaching and Physics teaching. In this paper, we present one of these pilot studies that is based on the case of the capacitor's capacitance. Our sample consisted of 28 teachers [6 Kindergarten teachers, 10 Primary teachers, 8 Mathematics teachers (Mathematicians), 3 Physics teachers (Physicists), and 1 Chemistry teacher (Chemist)] who attended the postgraduate programme "Didactics of Mathematics, Science and Information and Communication Technologies in Education: Interdisciplinary Approach" of the University of the Aegean, Greece. Moreover, we in included in our study the Greek school textbooks of Physics and Mathematics of the respective school grades.

The main research question was "Does the lack of interconnection between Mathematics teaching and Physics teaching affect the construction of Concepts in Physics?". We chose as example the concept of capacitor's capacitance, because we knew that this concept is taught only for a few lectures in high school Physics, without any explicit linking with Mathematics teaching, whilst the conceptually linked hyperbola equation y=a/x had been taught in depth in Mathematics. Therefore, our hypothesis was that the participants may incorrectly link the capacitance's formula C=Q/V to the hyperbola equation y=a/x, due to the apparent commonalities of the *form* of the employed signs.

In such situation, as shown in Figure 2, the same students receive messages from Mathematics and Physics courses, with seemingly similar signs, usually without appropriate links between the distinct Mathematics and Physics teachings. As a result, the students may incorrectly think that the calculating formula C=Q/V for the capacitance is conceptually similar to the hyperbola equation y=a/x. Besides, research from science education suggests that one of the common alternative conceptions that the students hold about the capacitance C is that C is proportional to the capacitor's charge Q (Kritikos & Dimitracopoulou, 2017).

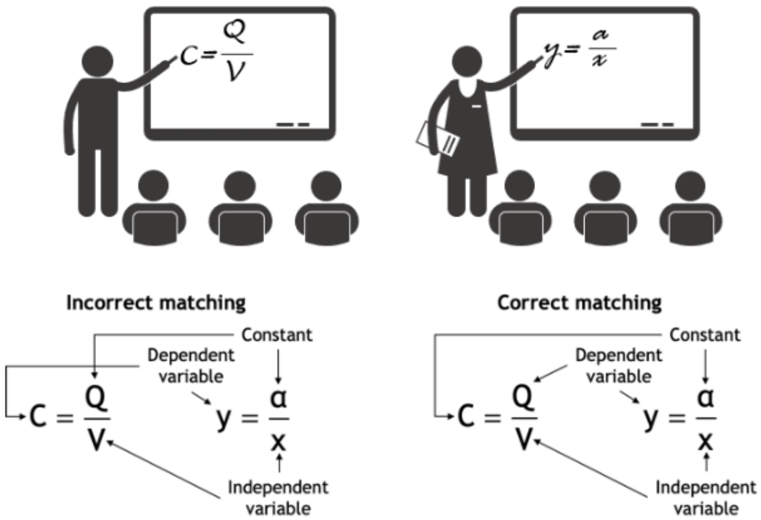

Figure 2: Interacting meanings in non-communicating discrete Mathematics and Physics teachings.

Methodology

Considering that most of the participants did not have any knowledge of the capacitor and its capacitance, we illustrated a short superficial instruction. In particular, we mentioned that the capacitor is an electrical element that has the capability to store charge when connected to a voltage source. In addition, the calculating formula C=Q/V for the capacitance was given, explaining the symbols C, Q and V. Notice that that we deliberately did not mention that the capacitance was not affected by either the load or the voltage, since it was a demand of the workshop activity (Figure 3) that the participants were involved with.

A capacitor is charged by a battery of voltage V. Thus, it stores charge Q. The capacitance C of the capacitor can be calculated by the formula:

$$C = \frac{Q}{V}$$

If we replace the battery (V) with another of double voltage (2V), then the capacitance C will be:

a) doubled. b) halved. c) the same.

Choose the correct answer by marking X in the corresponding cell in the table below. For each incorrect answer, write in the corresponding cell the grade (maximum of 10) that you would give to a student who had chosen it.

a	b	c

Figure 3. Workshop activity: Capacitor's capacitance.

The purpose of this activity was to investigate whether the semiotics of the formula y= a/x and the school mathematical knowledge "when the denominator of a fraction changes, then the fraction changes inversely" affect the learning of a concept in Physics. This mathematical knowledge is incomplete, as the numerator is not declared –though considered to be– as a constant. As a result, this could constitute an interdisciplinary learning obstacle in the students' paths towards constructing appropriate scientific meanings about the capacitor's capacitance.

In this pilot study, we focused on identifying the diversity of sources that appear to be related to students' alternative conceptions. For this reason, we reviewed and studied the sections about capacitor's capacitance in the Physics school textbooks, as well as the sections about the proportional quantities and the straight-line equation y=ax in the Mathematics school textbooks.

RESULTS

Findings from the workshop activity

The results from the workshop activity showed that only Science teachers (4 out of 28) responded correctly (answer c; see Figure 3). Among the 24 incorrect answers, 21 were that when the voltage gets doubled, the capacitance gets halved (answer b), whilst 3 thought it would get doubled (answer a; see Figure 3). For the 24 non-Science teachers, the question had not any conceptual content compatible with the physical meaning of the capacitance, as their knowledge was superficial from their school years. However, they spontaneously answered, relying mainly on their mathematical knowledge. Therefore, the conceptual content that they activated was based on Mathematics rather than Physics. Those who chose "b" as the correct answer were particularly strict in evaluating the students who would choose answer "c", whilst they were lenient about those who would choose "a". One of the participants justified his evaluation with the following explanation: *"…The student who chose (c) did not realize that changing V would result a change on the fraction, whilst the one who chose (a) at least saw that something would change…*". We argue that in this phrase, it is evident the crucial interdisciplinary effect of the mathematical knowledge "when the denominator of a fraction changes, then the fraction changes inversely" (implying that the numerator remains constant), which is also related to the hyperbola equation. Note that in Greece the same students that have been taught the hyperbola equation y=a/x, have been also taught the calculating formula C=Q/V for the capacitance; nevertheless, they have been taught in different courses, by different teachers, in different learning contexts. The apparent commonality of the empoloyed signs between the two writings may be incorrectly matched by the students, as shown above in Figure 2. As a result, the symbol C in the left-hand member of the relation is assigned to the independent variable y, which is also in the left-hand member. The symbol Q is assigned to the constant a, as fraction numerators. The only correct match is between the symbol V and the independent variable x. As indicated by the participants' responses, semiotic form (in this case mathematics) matching (even incorrectly) prevailed over the conceptual content (in this case physics), as no one sought to investigate the physical meaning, nor the relationship between Q and V magnitudes.

Findings from school textbooks

An additional issue arises from a phrase in a Physics school textbook (Alexakis et al., 2013), related to the quotient and the role of equality: "*Capacitance C of a capacitor is called the scalar physical magnitude that is equal to the quotient of the capacitor's electrical charge Q by the capacitor's voltage V. C=Q/V*" (p. 32). Mathematics education researchers (Jones & Pratt, 2012; Knuth et al., 2008) identify two main functions of the equality sign: relational and operational. Relational equality refers to the equivalence relationships (y is equal to x), whilst operational refers to the result of an operation. The quotient refers to operational equality, so that capacitance is considered to be the result of an operation, in this case the operation of division. However, the value of the symbol C does not depend on the Q/V operation, since the capacitor's capacitance exists even if there is no voltage or charge at its terminals. Instead of the term "quotient", a more legitimated term would be the "ratio", which refers to relational equality and imposes a proportional correlation of the numerator with the denominator. Of course, the problem of indeterminate form 0/0 arises when the voltage and charge are 0. To avoid this teaching barrier, but also the confusion caused by incorrect matching, we consider the mathematical form Q=CV to be more appropriate. Thus, the equation y=ax is recalled from Mathematics. In a Mathematics school textbook (Vlamos, Droutsas, Presvis & Rekoumis 2013), a paragraph is entitled "*The function y=ax*" and begins with the subparagraph "*Proportional quantities – The function y=ax*". The same paragraph refers to a ratio rather than a quotient: "*We see that in the straight-line y=ax the ratio y/x is always constant and equal to a, that is: y/x=a, for x ≠ 0*" (p. 68). Drawing on their mathematics knowledge of the equation y=ax students can move on to the relation Q=CV, where the common signs is compatible with the correct matching, as shown in Figure 4.

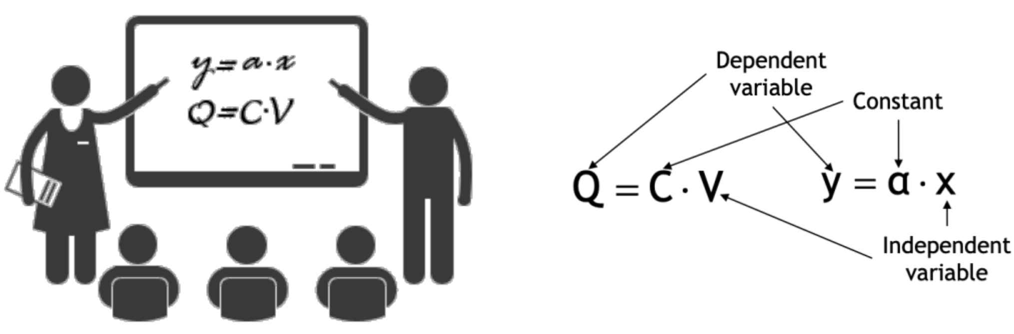

Figure 4: Interacting meanings in communicating Mathematics and Physics (co)teachings.

This is in line with our finding that teachers, who did not activate any physical meaning, they activated a mathematical meaning. Therefore, it is important the spontaneous mathematical meaning, which is activated anyway, to assist in the construction of the intended physical meaning. In an interdisciplinary (co)teaching environment, the role of the independent variable x may be emphasized in combination with the voltage V of the battery, the value of which is independent of the capacitance. Furthermore, the analogy between dependent-independent values and results-cause could be shown up as follows. The value of the dependent variable y is determined by the value of the independent variable x, such as the value of the charge Q is the result of the cause V. Thus, an additional matching arises that concerns not only the magnitudes but also the relationships between them. In addition, in the formula Q=CV the pair of values V=0, Q=0, is allowed regardless of the value of C.

At this point, we have to make clear that the use of the formula Q=CV instead of C=Q/V does not promise the correct physical meaning, but at least it avoids the creation of incorrect meaning through incorrect matching.

DISCUSSION – TOWARDS THE INTERDISCIPLINARY REFLECTIVE TOOL

The artificially imposed compartmentalisation of disciplines creates barriers to the communication of teachers of different disciplines. However, students make links between meanings with similar semiotics. We posit that when these links are scientifically incompatible, learning barriers emerge, which are often not attributed to the incorrect linking between the different disciplines, since the search for the didactical causes within a discipline is made with reference to the didactics of that particular discipline exclusively. For example, if a student expresses the alternative idea that the capacitor's capacitance is proportional to its charge, often the search for the factors of the student's holding this conception is limited to the didactics of Physics. Even in the case that mathematical causes are sought, they will rarely be found in the didactics of Mathematics. With our proposed interdisciplinary approach of (co)teaching in Mathematics and Physics, we look for the causes of learning barriers, through both didactics of Mathematics and Physics (Moutsios-Rentzos et al., 2017; Moutsios-Rentzos et al., 2019; Moutsios-Rentzos et al., in press). This search requires the collaboration of teachers from both disciplines, where each one contributes from its own perspective. Therefore, we do not refer to the unification of teaching disciplines, but to the convergence of teaching practices when common signs appear, which if not presented in a converge way (either by parallel teaching or by coteaching), can lead to learning obstacles in both of the two cognitive disciplines.

In order to assist teachers of different disciplines to communicate their teachings, we designed the Interdisciplinary Reflective Tool (IRT), which aims to highlight the importance of linking Science and Mathematics teaching. According to the protocol of the tool, the participants initially work individually, answering questions in a questionnaire. Questions refer to selected pieces from science and mathematics school textbooks. Subsequently, the participants work in groups of the same discipline, answering group questionnaires, based on the same pieces of the textbooks. In this way, we aim at interdisciplinary reflection amongst teachers of the same discipline. Then, we ask the participants to choose the two most important problems that converge both for the teaching of science and mathematics. Finally, we ask all the groups of different disciplines to reflect interdisciplinary, presenting in the plenary session the two most important problems that they had chosen before as a group. The final step includes a discussion on the solutions of the problems, using the resources of each lesson, but also between them, as the boundaries between the disciplines have been permeable. Below, we cite a sample of questions of the protocol, based on the concept of "area".

- Based on your experience as a teacher, think about the uses and meanings of the concept of "area" in Physics and Mathematics.

- Do you think that the meaning of concept of “area” is different in Physics than in Mathematics?
- Do you consider that the uses of the concept of “area” are different in Physics than in Mathematics?
- Study the following examples on the meaning of the concept of “area” from the school Physics and Mathematics textbooks. Concentrate on the impressions of the concept of “area”, its uses and its meanings.

1. Could you identify any representations of area and signs of measurement units that may cause problems in the students’ understanding of Mathematics ideas? In specific:

   In the representations you identified, according to your opinion, which problems about learning Mathematics derive from inappropriate already taught/learnt Mathematics knowledge?

   In the representations you identified, according to your opinion, which problems about learning Mathematics derive from inappropriate already taught/learnt Physics knowledge?

2. Could you identify any representations of area and signs of measurement units that may cause problems in the students’ understanding of Physics ideas? In specific:

   In the representations you identified, according to your opinion, which problems about learning Physics derive from inappropriate already taught/learnt Physics knowledge?

   In the representations you identified, according to your opinion, which problems about learning Physics derive from inappropriate already taught/learnt Mathematics knowledge?

3. What would you advise:

   a fellow Mathematics teacher, in order to help her/him to avoid the aforementioned potential problems that the students may face?

   a fellow Physics teacher, in order to help her/him to avoid the aforementioned potential problems that the students may face?

   the textbooks authors?

   the curriculum designers?

Concluding, the IRT supports teachers of different disciplines to communicate and reflect in various ways of interdisciplinary reflection. One way is self-reflection, when separately each member of a group studies the given examples. Another way is group (collective) reflection when the members of a group express their opinion about the obstacles in learning. In the framework of a single-discipline group, the reflection is one-perspective, whilst in the plenary session, the reflection is cross-perspectives. Finally, we plan to design a web-supported IRT platform, in which teachers may communicate either asynchronously or in real time and reflect in any of the aforementioned ways.

ACKNOWLEDGEMENT

This research is co-financed by Greece and the European Union (European Social Fund-ESF) through the Operational Programme “Human Resources Development, Education and

Lifelong Learning 2014-2020" in the context of the project "The didactical linking between mathematics and physics during the transition from primary school to high school: a systemic approach to the manifoldness of the concept of equality" (MIS 5004240).

REFERENCES

Alexakis, N., Ampatzis, S., Gkougkousis, G., Kountouris, B., Moschovitis, N., Ovadias, S., & Petroxeilos, K. (2013). *Fysiki B Genikou Lykiou [Physics B Lyceum General]*. Athens: ITYE Diophantos.

Davis, B., & Simmt, E. (2003). Understanding learning systems: Mathematics education and complexity science. *Journal for Research in Mathematics Education*, *34*(2), 137–167.

Duval, R. (2006). A cognitive analysis of problems of comprehension in a learning of mathematics. *Educational Studies in Mathematics*, *61*, 103–131.

Jones, I., & Pratt, D. (2012). A Substituting Meaning for the Equals Sign in Arithmetic Notating Tasks. *Journal for Research in Mathematics Education*, *43*(1), 2–33.

Knuth, E.J., Alibali, M.W., Hattikudur, S., McNeil, N.M, & Stephens, A.C. (2008). The Importance of Equal Sign Understanding in the Middle Grades. *Mathematics Teaching in the Middle School*, *13*(9), 514–519.

Kritikos, G., & Dimitracopoulou, A. (2017). Secondary Students' Analogical Reflections on Unfamiliar Scientific Concepts. *The International Journal of Technologies in Learning*, *24*(2), 25–36.

Moutsios-Rentzos, A., Kritikos, G., & Kalavasis, F. (2017). Functions of operations and operands in school mathematics and physics: a complex interdisciplinary (de)mathematised phenomenology. *Quaderni di Ricerca in Didattica (Mathematics), 27*(2), 297–299.

Moutsios-Rentzos, A., Kritikos, G., & Kalavasis, F. (2019). Co-constructing teaching and learning spaces in and between mathematics and physics at school. *Quaderni di Ricerca in Didattica (Mathematics), 2*(3), 215–220.

Moutsios-Rentzos, A., Pinnika, V., Kritikos, G., & Kalavasis, F. (in press). Appearances of the equals sign in primary school mathematics and natural sciences: an interdisciplinary, systemic approach. *Quaderni di Ricerca in Didattica (Mathematics)*.

Nikitina, S., & Mansilla, V. B. (2003). *Three strategies for interdisciplinary math and science teaching: A case of the Illinois Mathematics and Science Academy*. Cambridge, MA: Project Zero, Harvard University.

Radford, L. (2006). The anthropology of meaning. *Educational Studies in Mathematics, 61*(1-2), 39–65.

Steinbring, H. (2005). *The construction of new mathematical knowledge. An epistemological perspective*. Dordrecht: Springer.

Vlamos, P., Droutsas, P., Presvis, G., & Rekoumis, K. (2013). *Mathimatika B Gymnasiou [Mathematics B Gygmanium]*. Athens: ITYE Diophantos.

Watzlawick, P., Beavin, J., & Jackson, D. D. (1967). *Pragmatics of Human Communication. A study of interactional patterns, pathologies, and paradoxes*. New York: Norton.

EVALUATION CONCEPTIONS AND SCIENCE TEACHING CHALLENGES IN THE CONTEXT OF TEACHING PLANNING

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This work discusses the relevance and the planning of the learning evaluation by four secondary chemistry teachers from the Joinville city (Brazil) starting from twenty-two questions formulated weekly in a continuing formation course and the use of Topological Model of Teaching. The questions were analyzed by inductive coding and classified into two categories: (1) Evaluation Conceptions and (2) Science Teaching Challenges. The problem of the study was focused on the conceptions and models of teachers´ learning evaluation from the questions elaborated in a context of continuous formation, and how the planning of didactic sequences by socio-scientific issues and the use of a teaching model allowed them to develop and qualify the evaluation in its planning.

Keywords: Evaluation, models in science, teacher preparation.

THE RELEVANCE OF TEACHING PLANNING AND THE EVALUATION MODELS

The planning and use of evaluative models has been emphasized in the literature as a possibility of structuring and orienting important processes to scientific education, as well as promoting teaching contexts based on interactivity and on the production of knowledge about human learning. The quality of the evaluation developed by the teacher depends, to a large extent, on the socio-scientific themes, concepts and activities chosen and the use of models that allow teachers to create authentic and original curricula and teaching proposals, and they must be meaningful in the situated context in terms of the different educational contingencies of educational systems (Giordan, 2008; Maceno, Lara & Giordan, 2018).

It is an important part of investigations the attention to the models in order to characterize and explain the nature of the evaluation planning and how teachers drive the evaluation processes during the teaching (Bell & Cowie, 2001). One of the essential aspects of understanding an evaluation model is to analyze the relationships between planning, conceptions and teaching purposes, since models and theories guide the teaching activity in the classroom (Giordan, 2008; Bell & Cowie, 2001). Equally relevant is to study the dilemmas (Bell & Cowie, 2001) and the challenges in the planning of learning evaluation (Grob, Holmeier & Labudde, 2018) that can be analyzed by the questions addressed by science teachers as socioscientific problems and reflection on diverse teaching situations. Thus, the main purpose of learning evaluation is to contribute to improving education and schooling in various aspects, elements and factors.

The evaluation also requires the analysis of processes and the judgment of the evidence, productions and quality standards. In this sense, the guidance and use of teaching and evaluation models allow teachers to interpret and understand human development. The models, with characteristics, comparative traces and functions, produce conceptions and meanings to the phenomena and processes of the classroom, besides the accompaniment, justification and strategies for the improvement of the learning environments (Giordan, 2008).

When used a teaching model, reference standards are established by the teacher, which allows understanding the related phenomena and guiding action by a paradigm of understanding about educational processes. Through support and guidance according to a model, the teacher uses theory, be it learning, language or philosophical, and creates explanatory modes for classroom phenomena. A model is meant the more it is used by the teacher so that it has use value to conduct daily teaching activities. By analogy, a teaching model can become an evaluation model, given the intrinsic relationship between them. It is expected that a teacher, by valuing a teaching model used to guide his action and for his own purposes, also establish new explanatory ways for the evaluation of learning. Thus, reflecting about teaching oriented by one model is a first step in reframing pedagogical practice, and it is also necessary to create new ways of understanding and conducting the evaluation.

The Topological Model of Teaching and the teachers' questions as data source

The scientific literature has several teaching models that guide the concepts and the knowledge of evaluation by science teachers. Among them, the Topological Model of Teaching (TMT) is a socio-cultural approach based to the theory of mediated action, which assumes that a classroom is endowed with its own culture, organization and characteristics (Giordan, 2008). It is configured as a model of teaching organization for the planning of activities, lessons and didactic sequences from the articulation of socio-scientific issues with a problem that is developed and solved along the sequence. The main objectives of the TMT highlighted in this work are to make use of questions to encourage and accompany the learning, to analyze in the conceptual dimension the rules and reasoning used, to contextualize the challenges of the classroom, to foment the questioning and debate of central issues to scientific education (ibidem).

When discussing a teaching model in a continuing formation course, teachers ask questions that, in addition to various topics, can be a source of information about their professional needs and the daily dilemmas they face in the classroom. Considerable part of the discursive interactions in a continuing formation course stem from teachers' questions. The use of questions helps in the elaboration of meanings, mastery and appropriation of other cultural tools by teachers as well as the understanding of educational processes. The question is crucial for the triggering of teaching action, being used with various functions. For Wertsch (1998), the question is considered a specific type of statement and is succeeded by its partner - the answer - as it is expected to occur. Questions are a discursive marker in different types of interaction, as well as being a link in interactional sequencing and can be used for initiation, development or termination of dialog units. When asked by teachers, questions can provide information about self-satisfaction with work, school climate, doubts and professional needs.

In this sense, the study problem was:

1. What are the conceptions and models of learning evaluation of the teachers from the questions elaborated in a context of continuing formation?

2. How did the planning of didactic sequences for socio-scientific problems and the use of the teaching model allowed them to develop and qualify the evaluation in their planning?

The problem of this study was to analyze the themes, contingencies and challenges that science teachers pointed out about the classroom through the analysis of questions elaborated during a continuing formation course. The questions were elaborated in a context of discussion of teaching plans based on the TMT and explored curriculum, discursive interactions, evaluation and other issues related to teaching.

METHODS

The study was conducted in one semester with four science teachers from the city of Joinville (Brazil) who worked in public high school. During one semester, a continuing formation course based on the TMT was developed, in which the teachers weekly produced questions about the texts read. Twenty-two questions were elaborated, analyzed and classified in two categories: (a) *Evaluation conceptions* and (b) *Science Teaching Challenges*. For the first category, one has considered four subcategories proposed by Hargreaves, Earl & Schmidt (2002) and to the second, the subcategories were emergent and inspired by the study of Grob, Holmeier & Labudde (2018).

According to Hargreaves, Earl & Schmidt (2002), there are four evaluation conceptions: the *technological*, focused on the organization, strategies, uses of techniques and methodologies to evaluate; *cultural*, focused on the interpretation of evaluations and their integration with the social and cultural context of schools under a socioscientific problem; *political*, focused on the incorporation and dynamics of power and control between administrators and schools for accountability; and *postmodern*, focused on experiences, multiculturalism, and questions about the impact of complexity, diversity, and uncertainty on evaluation.

In the study by Grob, Holmeier & Labudde (2018) it was investigated how peer evaluation affects student learning in science education. In the study, the researchers analyzed the teaching plans, individual interviews and focus groups of 17 swiss elementary and high school teachers and identified eight evaluation challenges from the perspective of the interlocutors. Based on the study by Grob, Holmeier & Labudde (2018), the second category of this work was proposed to identify the main challenges pointed out by teachers in science education.

The questions was analysed by Nvivo 12® software with the tecniches of word frequence, automatic analisy of *themes* and *sentiments*. Automatic coding by *themes* groups coded references and indicates possible nodes for analysis. Automatic *sentiment* coding indicates the overall tone of the content as positive or negative by coding entire sentences, paragraphs, or documents (Qualitative analysis software international, 2016).

DISCUSSION

For the twenty-two questions asked in the course of continuing formation, eleven explored the relation between teaching and evaluation (1, 2, 3, 5, 6, 7, 8, 9, 12, 15, 17), five encompassed exclusively evaluation (4, 11, 13, 14, 20) and six were not categorized because they were doubts about specific terminologies of texts read (10, 16, 18, 19, 21, 22).

Among the conceptions of evaluation (Table 1), the teachers indicated mainly the *cultural* one, with questions about curricular planning and development, how to explore real problems in the classroom, how to promote learning and interaction in social and cultural contexts facing the particularities of schools, how to contextualize topics, how to select concepts, the language forms, strategies and approaches to be used by the teacher to benefit students' curricular and cultural development, as well as the analysis of their productions and results achieved. In few questions, the *political* conception of evaluation was explored, with mentions to the dilemmas and challenges of discourse control, relationships and roles of teachers and students in the process of elaborating answers to the questions that aim to understand the learning situated in the classroom. Questions about structuring activities, teaching planning and the impacts of student diversity and information and communication technologies on culture and society were rare, but were asked by teachers.

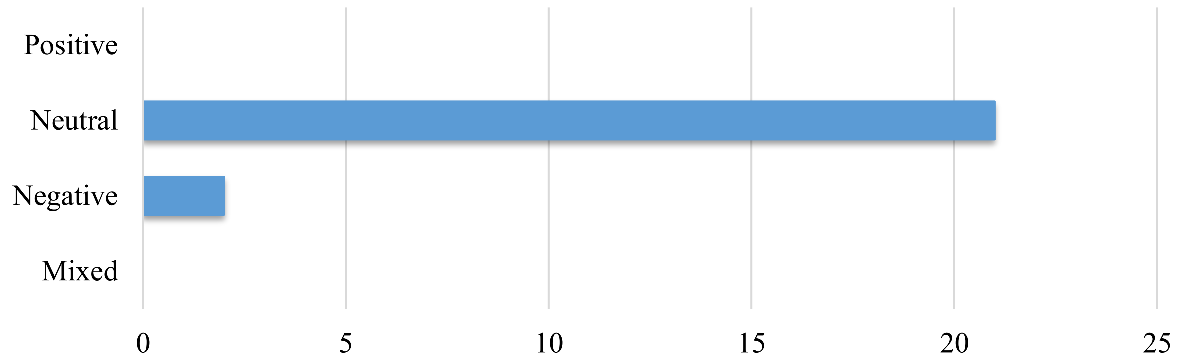
Subcategories	Description	Question
Technological	Structuring and development of measurement techniques	7, 20
Cultural	Interpretation and meaning of ideas, reflections, problematizations and judgments in school socialcultural contexts	1, 3, 4, 5, 6, 8, 11, 12, 15, 17
Political	Result of negotiation and dynamics of power and control in human interactions and by institutional requirements	2, 9, 13
Postmodern	Complexity, uncertainty and questioning in the culture and society caused by information and communication technologies and by the students´s diversity	14

Table 1. Evaluation conceptions of chemistry teachers. Source: the authors using the manual coding using Nvivo 12® software.

Complementing Table 1, when proceeding with word frequency analysis and automatic analisy of *themes* using the Nvivo 12® software, it was observed that the teachers presented questions about the following themes: problematization, environment, meanings, learning difficulties, contextualization, discursive interactions, evaluation, language, diversity, concepts and mediation. Such themes mainly evoke the conceptions of evaluation of *cultural*, *political* and *postmodern*. Complementing the ideia, the word cloud is show in the Figure 1 using the word frequency tool.

Figure 1. Frequency of words in chemistry teachers´ questions. Source: the authors using the word frequency tool using Nvivo 12® software.

The Graphic 1 show the automatic coding by *sentiments* of paragraphs indicated that the overall tone of the 22 questions was eminently neutral and in rare cases negative. The software identified 23 coding references in the document with all questions.



Graphic 1. Automatic coding by sentiments of 22 questions elaborated by teachers. Source: the authors using the automatic coding by sentiments using Nvivo 12® software.

Comparing the conceptions of teacher evaluation highlighted in this study with the results found in the literature, the differences are noticeable, since in most studies teachers evoke a *technological* perspective (Hargreaves, Earl & Schmidt, 2002; Celik & Walpuski, 2018; Freire & Fernandez, 2018) rather than *cultural*, *political* or *postmodern*.

Considering that the teachers in this study indicated more questions about the *cultural* perspective of evaluation under a predominantly neutral, it is possible to understand that their main concerns are about how to interpret learning in school contexts and how to integrate these contexts into scientific culture. According to Hargreaves, Earl & Schmidt (2002), from a *cultural* perspective, the challenge to evaluation is to rethink its nature and purposes in the classroom and how to integrate teachers 'collective judgment with their students' learning potentials. From this perspective, teachers seek to assess under a common understanding through dialogue to detect students' representations and ideas when seeking to solve authentic problems, which demands equally authentic evaluations (ibidem).

Among the challenges facing teaching science (Table 2), teachers mentioned the difficulties in contextualizing current issues while at the same time observing national curricular guidelines and the time available for teaching (challenge 1), which should also consider students´ diversity (challenge 2) and the language used by the teacher in the classroom (challenge 3).

In this way, the evaluation can be qualified from the creation of strategies and approaches by the teacher to overcome the students' lack of participation in the classroom dialogues and the incompleteness or limitation of the short answers expressed by them (challenge 4), also benefiting the relationship inside the classroom (challenge 5) and the understanding of making meaning, the analysis of student performance (challenge 6), the production of authentic answers to the questions addressed (challenge 7), and the constructive reflection on mistakes, problems and failures identified in the teaching of planning and the evaluation process (challenge 8).

Challenge	Description	Question	Total
1	Contextualization of current themes, national curricular guidelines and teaching time	1, 5, 6, 12	4
2	Teaching for diversity	2, 14	2
3	Forms of language used by the teacher	3, 8	2
4	Lack of participation in class discussions and incomplete / short answers of the students	4, 7	2
5	Relationship and roles of teacher and students	9, 17	2
6	Elaboration of meanings and analysis of students´ performance	11, 15	2
7	Elaboration of authentic answers by students	13	1
8	Identification and reflection on errors, failures and planning problems	20	1

Table 2. Science Teaching Challenges of chemistry teachers. Source: the authors using the manual coding using Nvivo 12® software.

In part, the results of this study are close to those obtained by Grob, Holmeier & Labudde (2018) regarding teachers' challenges in judging and making decisions about student performance and how to create plans for evaluation activities. As in this study, the need for progress at different levels of learning from evaluation and teacher-student relationships were also two challenges identified in the research by Nielsen, Dolin, Brunn & Jensen (2018).

CONCLUSION

In a context of professional development and planning of original proposals on socio-scientific issues from a teaching model, the questions addressed by the teachers explored the evaluation mainly as a cultural conception, that is, they were centered on the creation of pertinent curricula to the school and that could be at the same time, feasible, problematizing and propitiate the collective discussion about the selected issue, the elaboration of meanings and the learning. Nevertheless, concerns were raised about how to conduct the dynamics of negotiations and about the control and power of teachers and students in a shared way, such as considering the cultural diversity and current social demands for the classroom, the influence of technologies and how to organize activities and concepts in teaching planning.

One of the concerns in teaching planning is also the evaluation organization. In general, the study reported different challenges about evaluation: related to teaching (contextualization of planned subjects, available time, student diversity, teacher language, student performance analysis techniques), questions and answers, the answer authenticity, elaboration of meanings, errors, problems´ learning) and to the interactional dynamics (rules, participation, interpersonal relationships). Similarly, studies by Grob, Holmeier & Labudde (2018), Hargreaves, Earl & Schmidt (2002) and Bell & Cowie (2001) point out teachers' dilemmas in making evaluation a learning opportunity, requiring new teaching strategies as the classroom challenges emerge, it expands and qualifies the planning of teaching initially developed, providing a continuous and reflective creation of the teaching plan.

Although there are limitations on the information obtained by teachers' questions and their conceptions and models of evaluation, it can be said that they evoke a *cultural* perspective, which is congruent with TMT's purposes and indicates teachers' attention to social conventions, language and how to plan teaching proposals that enable the elaboration of meanings considering diversity and contextualization. The planning of didactic sequences for socio-scientific problems using TMT as a teaching model also allowed teachers to develop and qualify the evaluation in their planning by reflections on performance, the use of socio-scientific problems, the language in science teaching, the interactions discursive and think about mediation. By considering these aspects, teachers were able to introduce thematic of their interests in the continuing formation course and to reflect on how studies from the sociocultural perspective can contribute to science teaching.

REFERENCES

Bell, B. & Cowie, B. (2001). The characteristics of formative assessment in science education. *Science Education*, p.536-553.

Celik, A.N. & Walpuski, M. (2018). Development and validation of learning progressions on Chemical concepts. E-Book Proceedings of the ESERA 2017 Conference*: Research, Practice and Collaboration in Science Education*. Strand 11 (pp.1423-1432).

Freire, L.I.F. & Fernandez, C. (2018). Teaching to teach: indications of formative chemistry teacher training practice of its undergraduates. E-Book Proceedings of the ESERA 2017 Conference*: Research, Practice and Collaboration in Science Education*. Strand 11 (pp.1669-1680).

Giordan, M. (2008). Computadores e Linguagens nas Aulas de Ciências: uma perspectiva sociocultural para compreender a construção de significados. Ijuí: Editora Unijuí.

Grob, R., Holmeier, M. & Labudde. P. (2018). A Teacher Perspective on Benefits and Challenges of Peer-Assessment. E-Book Proceedings of the ESERA 2017 Conference*: Research, Practice and Collaboration in Science Education*. Strand 11 (pp.1416-1422).

Hargreaves, A., Earl, L. & Schmidt, M. (2002) Four perspectives on classroom assessment reform. *American Educational Research Journal*, v.39, n.1, p. 69-95.

Maceno, N.G.; Lara, M. da S. & Giordan, M. (2018). Characterization of preferences and practices of teaching of Chemistry teachers of the state of Santa Catarina from survey TALIS. E-Book Proceedings of the ESERA 2017 Conference*: Research, Practice and Collaboration in Science Education*. Strand 10 (pp.1355-1364).

Nielsen, S.S.; Dolin, J.; Brunn, J. & Jensen, S.B. The design and implementation of an assessment method combining formative and summative use of assessment. E-Book Proceedings of the ESERA 2017 Conference*: Research, Practice and Collaboration in Science Education*. Strand 11 (pp.1468-1479).

Qualitative analysis software international. Nvivo 11 started for Windows, 2016. Version 11.3, 38p. www.qsrinternational.com (06.12.2018).

Wertsch, J. V. (1998). Mind as action. New York: Oxford University Press.

ASSESSING NOVICE AND EXPERIENCED STEM TEACHERS' PROFESSIONAL GROWTH

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Supporting novice STEM teachers during their first two years in the classroom is crucial for their occupational retainment. Experienced teachers that mentor them can also benefit from the mentoring process. This study examines a three-tier support system for novice teachers, including: 1) personal mentoring by experienced teachers, 2) participation in professional development workshops, and 3) being part of a STEM teachers' professional community formed through participation in a workshop. The study included novice STEM teachers (N=104) and experienced teachers (N=102). To understand the support system effect on both novice and expert teachers' growth, we used the framework of teacher development which identifies key aspects of social, professional, and personal growth. Interviews and a questionnaire with open- and closed-ended questions were utilized. Results showed that all three tiers of support facilitate substantive social, professional, and personal growth.

Keywords: Teacher Induction, Communities of Practice, In-service Teacher Training.

INTRODUCTION

Various induction programs that support novice teachers have been implemented worldwide (Bower-Phipps, Klecka, & Sature, 2016; Geva-May, & Dori, 1996; Luft, Firestone, Wong, Ortega, Adams, & Bang, 2011), because such support can make the difference between retention and attrition. Novice teachers require support in building competency for many of the aspects of successful teaching, including pedagogical knowledge (PK), pedagogical-content knowledge (PCK), and classroom management. Methods of support can include mentoring by more experienced teachers, professional development workshops, and being part of a community of teachers. Science, Technology, Engineering and Mathematics – STEM novice teachers' retention can be promoted by interpersonal support of other teachers, which can foster their morale and sense of belonging (Aspfors & Fransson, 2015). Communities of teachers provide an opportunity to learn and develop in an environment where novice and experienced teachers' voices have an equal impact, thereby empowering the novice teachers (Vangrieken, Meredith, Packer, & Kyndt, 2017).

The Teacher Induction Unit at our university supports novice STEM teachers’ transition into the classroom, during their first two years of teaching. Most of these teachers are recent graduates of our undergraduate or graduate programs in STEM Education. As part of the unit’s initiatives, these novice teachers receive three tiers of support: 1) personal mentoring by experienced teachers, 2) participation in professional development workshops, and 3) being part of a STEM teachers' professional community that is promoted by participation in our ongoing workshops. We analyzed the data collected based on the theoretical model of teacher development (Bell & Gilbert, 1994; Dori & Herscovits, 2005), which consists of three distinct aspects of growth over the course of one's career: *social* – interpersonal interactions with colleagues, such as valuing collaborative ways of working, *professional* – learning and developing new ideas and teaching activities (Avargil, Herscovitz, & Dori, 2012), and *personal* – emotional characteristics, including those needed to overcome the challenges inherent in integrating new ideas and methodologies into one's teaching. The three aspects are dynamic and interact with each other. Within each aspect of growth are three levels.

Self-efficacy, rooted in the social-cognitive theory (Bandura, 1986), is one's belief in her own ability to act in order to achieve desired performance. Self-efficacy develops by personal direct and indirect experiences, verbal persuasions by others, and self-belief, based on the emotional and physical feeling of the individual. Teaching self-efficacy is the teachers' belief of in his/her own ability to bring a positive change and students' learning outcomes (Siwatu, 2007). Science teaching self-efficacy relates to the teachers' belief in their ability to teach science (Ramey-Gassert, Shroyer, & Staver, 1996). Novice teachers have been found to have lower levels of teaching self-efficacy. A mentor, a role model with whom the teacher can identify, can contribute to a higher level of teaching self-efficacy through modeling and supporting. Support by colleagues and community can also make a significant contribution to the teachers' self-beliefs (Tschannen-Moran & Hoy, 2007).

Our research goal is to assess novice STEM teachers' professional growth as well as the professional growth of their mentors who are experienced STEM teachers. In what follows, we use the term 'teachers' growth' to refer to changes and development teachers go through, because the term 'professional development' is used to describe the workshops the teachers attended rather than their actual influence on the teachers.

METHOD

The research participants included 104 novice and 102 experienced STEM teachers who attended a series of professional workshops conducted in the Teachers' Induction Unit at our university. All the participants were involved in mentoring partnerships, either as a mentor—the experienced teachers—or as a mentee—the novice teachers. Mentors were expected to meet the novice teachers weekly, observe them in their classrooms, and provide feedback and support. The workshop duration was 60 hours for novice teachers and 30 hours for 2nd year teachers and mentors. Workshops consisted of four-hour sessions, in which real-life issues were discussed and support was offered by workshop facilitators and peers. Some of the sessions combined novice, 2nd year, and experienced teachers together to form a heterogeneous community. To build the community, novice teachers (first and 2nd year) met with the experienced teachers to develop strategies for addressing content-specific and pedagogical topics and to share their knowledge and perspectives about the many personal and professional issues that arise over the course of a teaching career. The sessions included discussion of STEM content-related topics, class management issues, and navigating a STEM education career path.

Table 1. Research setting

Activity	Frequency	Content
Mentor-Novice meetings	weekly	Lesson planning Best practices and instruction pedagogies Observations Feedback
Novice teachers' workshops (N=104)	bi-weekly	Class managements practices Emotional support Pedagogical topics
Mentors' workshops (N=102)	bi-weekly	Mentoring skills Emotional intelligence Pedagogical topics
Teachers community meetings	bi-monthly	Emotional intelligence Content knowledge Pedagogical topics

*Data collected along three years

Research tools included open- and closed-ended questionnaires for all of the participants and semi-structured interviews with four novice teachers and their four mentors. The interviews included questions such as "Describe your relationship with your mentor/mentee," and "In what ways do you think you contributed to the mentor-mentee relationship?" The questionnaires included three parts: questions regarding the novice teachers' teaching self-efficacy (N=205), questions included in the Mentoring for Effective Primary Science Teaching (MEPST) instrument (N=88), adapted for secondary school (Hudson, Skamp & Brooks, 2005), and perceptions of the novice teachers regarding the workshops' effect on their professional growth (N=166). It is important to note that unlike the novice teachers who responded to the teaching self-efficacy questionnaire, the mentors were asked about their mentees' teaching efficacy. The data were collected and analyzed in a convergent parallel mixed methods design. Combining data from the interviews and questionnaires enabled deeper understanding and data triangulation (Creswell & Creswell, 2017).

RESULTS

Our findings show a gradual elevation in the novice teachers' teaching self-efficacy. We also found a significant difference between the novice teachers' teaching self-efficacy and the perceptions of the mentors regarding the novice teachers' teaching efficacy ($F_{(2, 202)} = 4.25$, $p<.05$), see Figure 1.

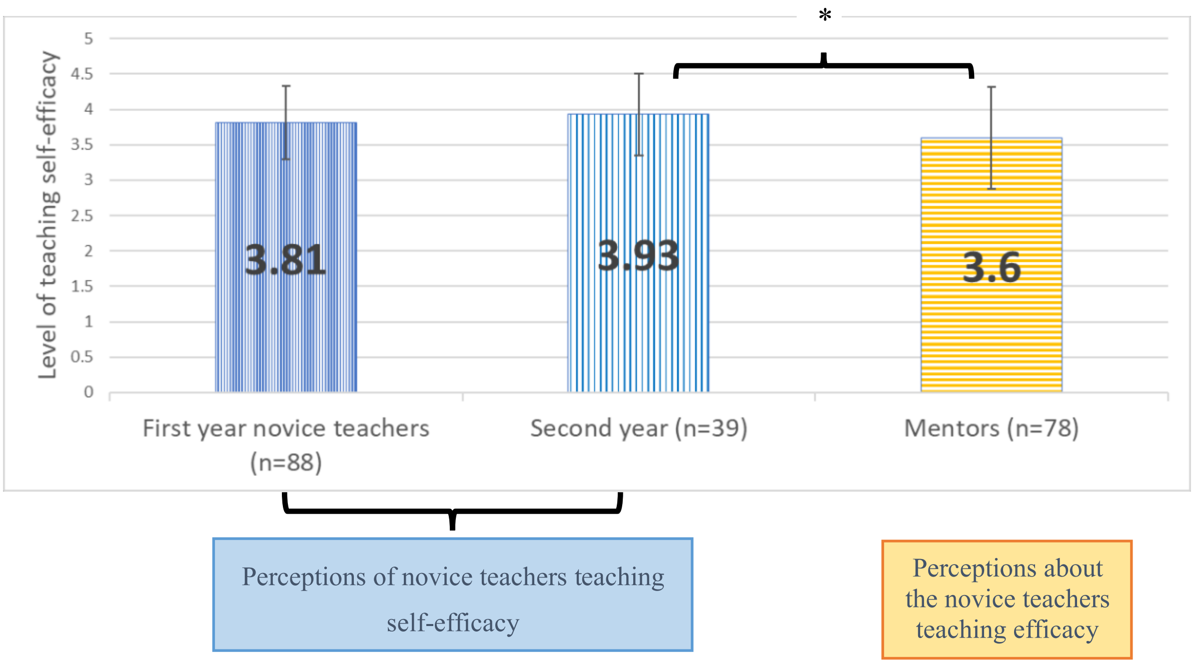

Figure 1. Perceptions regarding novice teachers' teaching self-efficacy

In order to compare the novice teachers' and mentors' perceptions of the mentoring factors, we used the MEPST instrument, adapted for secondary school (Hudson, Skamp & Brooks, 2005). Using this instrument, teachers grade mentoring elements of the mentoring process in a scale of one through five. The mentoring elements are grouped into five factors: personal attributes, system requirements, pedagogical knowledge, modeling, and feedback (see Table 2).

Table 2. Novice teachers' and mentors' perceptions on effective mentoring factors

Factors	Novice Teachers (N=40) M(SD)	Mentors (N=47) M(SD)
Personal Attributes	3.95 (.87)	4.11 (.92)
System Requirements	3.51 (.96)	3.68 (.87)
Pedagogical Knowledge	3.55 (.85)	3.95 (.71)
Modeling	3.75 (.83)	4.05 (.72)
Feedback	3.97 (.75)	3.89 (.76)

Novice STEM teachers and mentors viewed four of the five factors of effective mentoring with similar importance, as a significant difference in the mentoring process was found only between the perceptions of the experienced teachers—the mentors (M=3.95, SD=.71) and the novice teachers (M=3.55, SD=.85) in the pedagogical knowledge factor (t=–2.42, p<.05). The Modeling factor differences were borderline (t=-1.83, p=0.07).

Grouping the mentoring factors into personal, professional (system requirements and pedagogical knowledge), and social (modeling and feedback), we found correlations between these three factor groups and teaching self-efficacy. Teaching self-efficacy is also correlated to general self-efficacy.

Table 3. Self-Efficacy and Mentoring Factors Pearson correlation (N=87)

Factors Group	Teaching Self-Efficacy	Personal	Professional
Self-Efficacy general	.354**		
Personal personal attributes	.229*		
Professional system requirements and pedagogical knowledge	.301**	.766**	
Social modelling and feedback	.230*	.871**	.801**

*p<0.05, **p<0.001

Significant correlations between the teaching self-efficacy of the novice teachers and the mentoring factors show that development in a certain factor group is correlated with development in the other factor groups, as well as with the teaching self-efficacy.

Evidence for professional growth presented below is arranged by the three tiers of support – mentoring, workshops, and community.

(a) **Mentoring** facilitated the professional and personal growth of novice and experience teachers in different aspects.

(b) **Workshops** provided the novice teachers with both professional and social support. Meeting other teachers with difficulties like their own (social) helped them accept their struggle (personal) and seek solutions together (professional). As one participant [417221]said: "*I met other teachers in my situation, with similar struggles. I was exposed to many suggestions and examples of coping strategies.*"

(c) **Community** activities in the meetings showed a gap in novice and mentor teachers' perceptions regarding the needs of novice teachers during their first years and their expectations from the mentoring process. Teachers discussed the mentoring factors in the community meetings and analyzed the gaps in expectations and perceptions of the mentoring relationships aims. The discussion helped communicate the needs and improve the communication and mentoring processes. Reflections about perceptions of the workshops' effect revealed that the community meetings enabled the teachers to understand a different perspective and to develop new classroom practices (professional). A novice teacher [417210] said: "*I watched how she was managing her very busy schedule and learned how to form habits*". In some cases, mentors initiated development activities (professional). An experienced teacher [417414] stated: "*...but* *now I can do more things, I can combine something I learned in a different program and create something new…".*

Table 4. Aspects of teachers' growth

Expression of growth	Techers' Statements
Personal Establishing a mentoring relationship based on equal partnership which contributes to the empowerment of the novice teacher	A novice teacher [50001820213]: "*I bring my ideas, she [the mentor] brings her ideas, we have a partnership.*"
Professional Mentor and novice thinking about possible solutions	A novice teacher [510011921211]: "*One of the ideas I found with the help of my mentor was to have a tutoring session after each subject I teach, and guide them in the subject via teamwork.*"
Social The experienced teacher is exposed to innovative ideas (professional), while the novice teacher feels meaningful	A mentor [511191720221]: "*Working with him and the other teacher felt like working as a team…his main contribution was in the green chemistry project, based on his prior knowledge and experience.. I consulted with him regarding the data analysis and we drew the conclusions together.*"
Development of Mentoring Practices A mentor learned how to focus her feedback to make it productive	A mentor [50519821223]: "*although I saw the wider picture in terms of things I wanted to say [in the observations reflection on her lesson], I highlighted one or two aspects for improvement and two things that were good and she should continue to do, I neutralized background noises.*"

DISCUSSION AND LIMITATION

The three tiers of support address complementary needs of novice and experienced teachers, cultivating the social, professional, and personal growth of novice and experienced teachers. Each tier addresses different levels of the aspects, contributing to the growth of novice and experienced teachers (Bell & Gilbert,1994). The induction years include a process of learning to teach and a process of socializing (Luft et al., 2011).The interactions between the three tiers provided the teachers with personalized support, a peer group in which they could see that their struggle was universal, and an opportunity to participate in a wider forum in which they could learn and contribute as equal members of the community (Vangrieken et al., 2017). Growth was enabled through learning content-specific STEM and pedagogical discussions. Empowering the novice teachers can enhance also the veteran teachers' self-efficacy and refines their teaching skills (Aspfors & Fransson, 2015).

A limitation of the research was that due to ethical constraints posed by the Ministry of Education, classroom observations could not be obtained.

CONCLUSIONS AND IMPLICATIONS

Retaining novice teachers in the school system requires providing them with effective support. Experienced teachers the partners for this mission. Creating a supportive community provides opportunities and scaffolds for the novice and experienced teachers to grow successfully in the teaching professions (Richmond, Bartell, Floden, & Jones, 2020).

The contribution of this research is the elucidation of the intertwined support tiers that provide a scaffolding to the novice teachers, while facilitating the growth of the experienced teachers.

ACKNOWLEDGEMENT

The generous financial help of

- STEM Novice Teachers' Induction Unit, Faculty of Education, Technion– Israel Institute of Technology
- The Irwin and Joan Jacobs Graduate School, Technion– Israel Institute of Technology

is gratefully acknowledged.

REFERENCES

Aspfors, J., & Fransson, G. (2015). Research on mentor education for mentors of newly qualified teachers: A qualitative meta-synthesis. *Teaching and Teacher Education*, *48*, 75-86.

Avargil, S., Herscovitz, O., & Dori, Y. J. (2012). Teaching thinking skills in context-based learning: Teachers’ challenges and assessment knowledge. *Journal of Science Education and Technology*, *21*(2), 207-225.

Bandura, A. (1986). *Social Foundations of Thought and Action: A social cognitive theory*. Englewood Cliffs, NJ: Prentice Hall.

Bandura, A. (2012). On the functional properties of perceived self-efficacy revisited. *Journal of Management* 38: DOI: 10.1177/0149206311410606

Bell, B., & Gilbert, J. (1994). Teacher development as professional, personal, and social development. *Teaching and Teacher Education*, *10*(5), 483-497.

Bower-Phipps, L., Klecka, C. V. S., & Sature, A. L. (2016). Developing mentors: An analysis of shared mentoring practices. The New Educator, 1-20.

Creswell, J.W., & Creswell, J.D, (2017). *Research design: Qualitative, Quantitative, and Mixed Methods Approaches.* Thousand Oaks, CA: Sage publications.

Dori, Y. J., & Herscovitz, O. (2005). Case-based long-term professional development of science teachers. *International Journal of Science Education*, *27*(12), 1413-1446.

Fairbanks, C. M., Freedman, D., & Kahn, C. (2000). The role of effective mentors in learning to teach. *Journal of Teacher Education*, *51*(2), 102-112.

Geva-May, I., & Dori, Y. J. (1996). Analysis of an induction model. British Journal of In-service Education, 22(3), 333-354.

Hudson, P., Skamp, K., & Brooks, L. (2005). Development of an instrument: Mentoring for effective primary science teaching. *Science Education*, *89*(4), 657-674

Luft, J. A., Firestone, J. B., Wong, S. S., Ortega, I., Adams, K., & Bang, E. (2011). Beginning secondary science teacher induction: A two-year mixed methods study. *Journal of Research in Science Teaching*, *48*(10), 1199-1224.

Ramey-Gassert, L., Shroyer, M. G., & Staver, J. R. (1996). A qualitative study of factors influencing science teaching self-efficacy of elementary level teachers. *Science Education*, *80*(3), 283-315.

Richmond, G., Bartell, T. G., Floden, R. E., & Jones, N. D. (2020). How Research Sheds Light on the Pivotal Role of Mentors in Teacher Preparation. *Journal of Teacher Education*, *71*(1), 6-8.

Siwatu, K. O. (2007). Preservice teachers’ culturally responsive teaching self-efficacy and outcome expectancy beliefs. *Teaching and Teacher Education*,*23*(7), 1086-1101.

Tschannen-Moran, M., & Hoy, A. W. (2007). The differential antecedents of self-efficacy beliefs of novice and experienced teachers. *Teaching and Teacher Education*, *23*(6), 944-956.

Vangrieken, K., Meredith, C., Packer, T., & Kyndt, E. (2017). Teacher communities as a context for professional development: A systematic review. *Teaching and Teacher Education*, *61*, 47-59.

DESIGN AND ASSESSMENT OF A SCORING RUBRIC FOR EVALUATING SCIENCE TEACHERS' CLASSROOM PRACTICES

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The aim of the present study was the development of an evaluation system for secondary science teachers teaching practices based on PCK. In the present work, we present the evaluation framework, the evaluation criteria and the development of an observation tool and an evaluation scoring rubric for classroom observations. The evaluation criteria were designed to constitute aspects of teachers' PCK. A pilot study was carried out aiming at examining the reliability of the rubric and of the observation tool. In this pilot application two evaluators used the rubric and the observation tool independently to evaluate twelve science teachers. The data recorded by the two evaluators have a strong positive correlation as indicated by the values of the correlation coefficient Spearman rho. The results showed that the use of the tools led to reliable and objective findings.

Keywords: Evaluation Methods, Teaching Practices, Science Education Policy

INTRODUCTION

Over the last 30 years, researchers have formed and developed a notion that describes the aspects of teacher knowledge, namely Pedagogical Content Knowledge (PCK). PCK is α widely accepted notion among researchers (e.g., Berry, Friedrichsen, & Loughran, 2015) and teachers as it creates possibilities to find common bases upon which criteria for teacher evaluation systems can be build.

Data gathering differs among evaluation systems but the most common source of data is classroom observation (Isoré, 2009; Santiago, 2009), which provides data on teaching practices in real classroom settings. Concerning classroom observations, it is a common practice for evaluators to use a scoring rubric. A rubric contains the criteria and descriptions of performance, which define levels of achievement that match a score. Rubrics are used because they can guide evaluators in focusing on specific aspects of teacher performance and enhance a common scoring strategy. Additionally, rubrics can reduce the possibility of arbitrariness and misunderstanding and connect the evaluation procedure to a post-evaluation program of professional development (Panadero & Jonsson, 2013).

In what follows, we present the design and development of an evaluation scoring rubric and an observation tool and the assessment of these tools through a pilot study.

THE EVALUATION SCORING RUBRIC AND THE OBSERVATION TOOL

Evaluation criteria

The evaluation criteria are based on a PCK analysis that was first introduced by Jang (2011). The evaluation criteria are divided into four domains, namely: Subject Matter Knowledge (SMK), Instructional Representations and Strategies (IRS), Instructional Objectives and Context (IOC) and Knowledge of Students Understanding (KSU). Data are collected through classroom observations for 15 evaluation criteria. The domains, the criteria and the aspects of teaching recorded through observation (scoring rubric) are described in Table 1.

Table 1: The domains, the evaluation criteria and the aspects of teaching recorded through observation and included in each criterion

Domain 1: Subject Matter Knowledge	
Criteria	**Aspects included in each criterion**
Quality of the language used during the lesson	*Quality of the language used during the lesson*
Connection between the teaching notion or phenomenon and everyday life	*Connection between the teaching notion or phenomenon and everyday life*
Domain 2 : Instructional Representation and Strategies	
Criteria	**Aspects included in each criterion**
Instuctional Strategies	*Instructional Strategies (Variety and appropriateness)* *Strategies for maintaining students' interest*
Students' attentiveness-related reactions during instruction	*Students' attentiveness-related reactions during instruction*
Instructional representations	*Appropriateness and usefulness of instructional respresentations*
Inquiry	*Type of Inquiry*
Scientific skills promoted by the teacher	*Scientific skills promoted by the teacher*
Questioning	*Conceptual Level of teaching questions* *Students' participation in questioning*
Domain 3:Instructional Objectives and Context	
Criteria	**Aspects included in each criterion**
Instructional objectives and goals	*Instructional objectives and goals (communication and understanding)*
Interactive atmosphere	*Teaching Adjustment based on students' reaction*
Students' participation	*Students' participation*
Classroom management and mutual respect among students	*Classroom management* *Mutual Respect*
Domain 4: Knowledge of Students' Understanding	
Criteria	**Aspects included in each criterion**
Alternative concepts investigation	*Alternative concepts investigation* *Strategies to handl students' alternative concepts*
Knowledge of students' difficulties	*Knowledge of students' difficulties*
Assessment during the lesson	*Formative Assessment during lesson* *Variety of assessment methods and adjustment related to students' diversity*

Development and Description

The observation tool, a part of which is presented in Figure 1, is a practical guide for the observer. It helps him/her focus on specific aspects of teaching, record data by ticking the appropriate boxes, and take notes on them. These notes help the observer keep track of all the teacher's practices and the decisions he/she makes during instruction when the observer grades the teacher's performance in the rubric. The observer/evaluator uses an observation sheet for each separate lesson. Data are collected from two observations of each teacher by completing the score in the evaluation scoring rubric.

In the scoring rubric, the observer finds the aspects of teaching that have to be recorded and five short descriptions of the teacher's performance. Based on the observation tool and his/her recorded notes, the observer decides which description best fits the teacher's actions.

Observational Tool

Class: Subject:

Number of students: Time of observation:

Instructional Representations and Strategies

Note 1 for the main teaching practice and 2, 3, etc. for the other practices observed during the lesson.

Strategies

	Lecture		Students' Presentations		Experiments conducted by students
	Demonstration of experiment		Discussion or work in small groups		Use of models to introduce a notion or an idea
	Discussion led by the teacher		Inquiry		

Type of student involvement during instruction

	Passively attends teacher's lesson		Participates in discussion (led by the teacher or in small groups)		Carries out an experiment
	Participates in an inquiry activity		Completes work sheets as part of an activity		Writes a laboratory report
	Writes an assessment test		Uses a simulation		Uses lab equipment and technology to conduct an experiment
	Uses a PC program to analyse data		Makes a presentation or attends other students' presentations		Develops or uses a model to comprehend an idea

Use of Instructional Representations

☐ Examples ☐ Analogies ☐ Graphs and Diagrams

☐ Everyday objects ☐ other: ....

Observer Recordings

Appropriateness (manner and time of their use):

....

Usefulness for the students:

....

Figure 1: Part of the Observation Sheet

Each description corresponds to a score that the observer inserts under the name of each aspect. Figure 2 shows two of the aspects of teaching recorded, which concerns appropriateness and usefulness of instructional representations (IRS).

The development of the evaluation scoring rubric and observation sheet was done through a long collaboration with expert Science teachers, Educational Advisors, and Evaluators.

Criteria	Aspects of teaching recorded	5	4	3	2	1
Instructional Representations	**Appropriateness of the instructional representations (IR)**	IR: * Were appropriate for the activity * The time and the manner of their use was appropriate and consistent with the lesson goals	IR: * Were appropriate for the activity *The time of their use was sufficient and the manner was consistent with the lesson's goals	IR: were appropriate for the activity but not consistent with the lesson's goals	IR: were generally appropriate for the activity, but other IR could be more appropriate and more consistent with the lesson's goals	IR: were inappropriate for the activity and inconsistent with the lesson's goals
	Score:					
	Usefulness of instructional representations	IR seemed to help all the students understand	IR seemed to help the majority of students understand	IR seemed to help half or more of the students understand	IR seemed to help a minority of the students understand	IR seemed not to help the students understand
	Score:					

Figure 2: Part of the Evaluation Scoring Rubric

The implementation of the evaluation scoring rubric and the observation tool

The implementation of the evaluation, using the observation tool and the scoring rubric, is conducted through direct, first-hand observations of two one-hour lessons. The evaluator performs these observations as a spectator (Gay, 1992) and records them on the observation tool. After the observation, the evaluator grades the teaching in the evaluation scoring rubric.

METHODOLOGY

The aim of this study was to evaluate the reliability of the tools designed and the objectivity of the findings from the observation-based data. In order to assess the reliability of the evaluation scoring rubric simultaneous observations were carried out by two observers/evaluators. The first evaluator was an Educational Advisor and trained Evaluator serving in Secondary Education and the second one was the first author of the presented work.

Sample

The observations were carried out in six Gymnasiums and Lyceums, representative of the different context of the Greek educational system, which were proposed by the Educational Advisor. The two evaluators observed twelve (12) Science teachers (eight Physics and four Chemistry Majors) using the observation sheet and they independently evaluated every teacher using the Evaluation Scoring Rubric.

Data analysis

The data of the Scoring Rubrics were statistically analysed. The reliability of the rubric was assessed through the calculation of the Spearman rho coefficient between the two independent scores of the evaluators. The above mentioned methodology is the most common practice to assess the reliability and the objectivity of the findings of a rubric (Jonsson & Svingby, 2007). The data collected by the two observers were, also, analyzed with regard to everyday teachers' practices.

FINDINGS

A significant positive correlation was found between the scoring of the two observers/evaluators ranging from 0.704 to 0.894 ($p<.0001$). Additionally, the mean of the differences of the observers was calculated and was found 0.1905 (N: 252, St. Deviation 0.414, N refers to the number of scores for all teachers) indicating very small differences between the two observers. These findings suggest that the observers, using the scoring rubric and the observation tool, were led to score similarly teachers' performance based on their observations.

With regard to teachers' practices, the findings from the observations indicated that all or almost all teachers who participated in the study use appropriate language, a variety of teaching strategies that maintain students' interest, make proper use of instructional representations, communicate the instructional objectives, manage their classroom efficiently, promote mutual respect, know the students' difficulties regarding the teaching topic and succeed in having most of their students actively participate in the lesson (these teachers are evaluated as 'Excellent' on these criteria). On the criteria concerning the connection between the subject being taught and everyday life, the type of inquiry used (mainly structured inquiry), the scientific skills promoted, the questioning and the use of formative assessment during the lesson, the majority of the teachers were evaluated as 'Adequate' and a minority as 'Excellent'. One third of the teachers were evaluated as 'Weak' on criteria related to their knowledge of the students' understanding, specifically regarding investigating and handling students' alternative conceptions and the use of a variety of assessment methods.

However, the specific findings produced by the Observation Tool and Scoring Rubric cannot be generalized, as the sample of teachers observed is not big enough. The future use of our tool in a larger and more representative sample will provide a clearer picture of the teachers' practices.

CONCLUSIONS

The results indicate that the observational tool and the scoring rubric created a framework within which the observers, using a common scoring strategy, produced the same findings when evaluating the same teacher.

Based on the findings concerning the reliability of the tools and teachers' practices, we consider that the evaluation of the teachers through the proposed procedure and tools could provide rich and objective findings about teachers' every day practice.

ACKNOWLEDGEMENT

This research is co-financed by Greece and the European Union (European Social Fund- ESF) through the Operational Programme «Human Resources Development, Education and Lifelong Learning» in the context of the project "Strengthening Human Resources Research Potential via Doctorate Research" (MIS-5000432), implemented by the State Scholarships Foundation (IKY).

REFERENCES

Berry, A., Friedrichsen, P., & Loughran, J. (2015). *Re-Examining Pedagogical Content Knowledge in Science Education*. Routledge. https://doi.org/10.4324/9781315735665

Isoré, M. (2009). Teacher Evaluation : Current Practices in OECD Countries and a Literature Review, (23), 1–49. https://doi.org/10.1787/223283631428

Gay, L. R. (1992). *Educational Research Competencies for Analysis and Application*. New York: Mackmillan.

Jang, S.-J. (2011). Assessing college students' perceptions of a case teacher's pedagogical content knowledge using a newly developed instrument. *Higher Education*, *61*(6), 663–678. https://doi.org/10.1007/s10734-010-9355-1

Jonsson, A., & Svingby, G. (2007). The use of scoring rubrics: Reliability, validity and educational consequences. *Educational Research Review*, *2*, 130–144. https://doi.org/10.1016/j.edurev.2007.05.002

Panadero, E., & Jonsson, A. (2013). The use of scoring rubrics for formative assessment purposes revisited: A review. *Educational Research Review*, *9*(May 2017), 129–144. https://doi.org/10.1016/j.edurev.2013.01.002

Santiago, P. (2009). Teacher Evaluation A Conceptual Framework and examples of Country Practices. *OECD Review*. Retrieved from http://www.oecd.org/edu/school/44568106.pdf

PART 15: STRAND 15

Early Years Science Education

Co-editors: *Christina Siry & Bodil Sundberg*

CONTENTS

STRAND 15: INTRODUCTION

EARLY YEARS SCIENCE EDUCATION

Strand 15 is dedicated to highlighting research focusing on Early childhood science education, specifically science education for children aged between 0 and 8 years of age. Young children's learning, participation, and engagement is a growing research field within the international science education community, and the studies presented in this strand explore numerous aspects and perspectives related to early childhood science education.

29 oral paper presentations and 13 poster presentations were accepted for ESERA 2019. Taken as a whole, the presentations in Strand 15 for the 2019 conference demonstrate a diversity of foci examining the complexities of science teaching and learning at the early childhood levels, revealing how early childhood science education has grown to reflect a vast amount of common topics within science education research, but with a special focus on the nuances of policies and practices of early childhood education. Session themes represent some of the international trends in the field, specifically as related to early childhood science education, such as: Emotional engagement, interest and motivation; Engineering and computational thinking; Learning in early childhood science; Modeling and representation; Play and inquiry; Support for learning outside the classroom; and Teacher education and beliefs as related to early childhood science. Eight papers that were submitted for inclusion in the e-proceedings met the technical requirements and are reproduced in the sections that follow.

The papers explore a variety of issues based on different theoretical perspectives and give examples of qualitative and quantitative as well as mixed methods approaches. Their authors come from Denmark, Greece, Spain, Sweden, Turkey and the United Kingdom.

Five of the papers present the results of interventional studies. In the paper A proposal for learning healthy nutrition with four-years-old schoolchildren, Luisa López-Banet, Isabel Baños-González, Belén Guardiola Haro and Athanasios Pappous present the results of an intervention aiming at introducing preschoolers to healthy nutrition. The results show that the pupils not only acquired knowledge about food that composes a healthy diet, but also were able modify breakfast and lunch menus so as to reduce the amount of unhealthy food while increasing healthier food choices. In Developing a robot-supported inclusive education (rosie): a play-based approach to STEM-teaching and inclusion in early childhood education Lykke Brogaard Bertel, Susanne Dau and Eva Brooks explore the possibilities of the play-based approach of Robot-Supported Collaborative Learning (RSCL) for facilitating inclusion and improving the challenging educational transfers in children's early life.

Kalliopi Kanaki and Michail Kalogiannakis present a further example of research focusing on interventions and STEM education for young children. In the paper Enhancing computational thinking skills in early childhood education, they explore a novel framework that aims to familiarize children in the first two grades of primary school with fundamental competencies of computational thinking. The next paper in the group of interventional studies is The examination of questioning methods on young children's conceptual understanding of astronomy by Sinem Güçhan-Özgül, Mesut Saçkes and Berrin Akman. The focus of this study is methodological, and the results show how different methods used for discovering children's mental models about scientific phenomena might generate different results, conflicting with each other. In the fifth contribution, Case studies of collaborative model-based reasoning for conceptual change in preschool children, Eleni Sakellaridi and Spyros Kollas investigate whether a collaborative model-based problem-solving learning environment may facilitate preschool children's conceptual change regarding the phenomenon of day and night cycle.

The next group of contributing papers explore children´s learning, reasoning and motivation. Drawing on theories of different cognitive learning styles Maria Kallery, Angelos Sofianidis, Popi Pationioti, Kaliopi Tsialma, Xristina Katsiana examine children´s motivation for science in the paper Cognitive style and motivation and learning in inquiry based early-years science activities. The findings indicate that structured inquiry activities may serve to trigger motivation and learning in science for young children. In Young children and personifying reasoning, Marida Ergazaki, Aggeliki Dimitrakopoulou, Alexandra Spai and Dimitra Nousi report on a case study that traces children´s reasoning about properties, behaviours or reactions of living things that they are not familiar with.

Strand 15 contributions culminate with a focus on preschool teacher´s views on science in preschool with particular focus on chemistry. In Characteristics of science teaching in preschool, Jesper Sjöström and Ann-Christine Vallberg Roth present results from a questionnaire and discuss a didactic model for preschool science teaching, drawn from the teachers' responses.

In summary, the eight papers representing this strand give important perspectives and provide diverse approaches to early childhood science education, each contributing new understandings to this diverse area of research. The contributions demonstrate a commitment within ESERA to researching facets of early childhood science teaching, learning, and learning to teach. We hope that you will enjoy reading the papers.

Bodil Sundberg & Christina Siry

DESIGN AND IMPLEMENTATION OF A PROPOSAL FOR THE LEARNING OF HEALTHY NUTRITION BY FOUR-YEAR-OLD CHILDREN

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The data showing the increase in diseases associated with food in recent decades are alarming. The World Health Organization has announced that childhood obesity is one of the most serious public health problems of the 21st century, its prevalence rising at a startling rate. The development of healthy habits in childhood is essential to maintain good health in the future, and for this schools and families are primarily responsible; therefore, both must work together in the concept of healthy eating. The present work explains a learning proposal on healthy nutrition, implemented in the classroom for 4-year-old children. The sequence of activities is structured in several stages, which have specific scientific and didactic objectives. The ultimate purpose of this work corresponds to a global and relevant objective for children, closely related to the initial development of their scientific competence. The results show that the pupils not only acquired knowledge about the food that composes a healthy diet, but also were able to carry out appropriate modifications to the menus of their breakfast and lunch, such as reducing the amount of unhealthy food and introducing the most appropriate food.

Keywords: Health Education, Preschool Education, future teacher training

INTRODUCTION

In wealthy societies, characterized by the availability of highly caloric foods, refined sugars, and saturated fats and by the emergence of sedentary leisure habits, numerous authors have pointed out the existence of an ‘obesogenic environment’, even at early ages (Díaz, 2017). Our children are becoming more overweight, and those estimated to be overweight or obese tend to remain this way as adults and will be more likely to suffer non-transmissible diseases, such as diabetes, or to have cardiovascular problems at younger ages (Baker, Olsen, & Sørensen, 2007; Lorenzo-Bertheau et al., 2017). Furthermore, several studies suggest a positive relationship between tooth decay and free sugars intake (Eley et al., 2019), with regard to sugars added to foods and drinks by the manufacturer, cook or consumer. For these reasons, the World Health Organization has enunciated certain recommendations aimed at reducing free sugar intake to below 10% of total energy intake (World Health Organization [WHO], 2015), involving health interventions, food labeling, and, above all, education. Besides, it is recognized that interventions aimed at reducing childhood obesity by improving nutrition and physical activity should be a priority for public health (Katz, 2009). It is widely acknowledged that prevention is an indispensable strategy to turn the tide of the global epidemic of obesity (Caballero, 2004). However, lifelong acquired behaviors are resistant to change and, therefore, acquisition of healthy habits should begin as early as possible. Thus, school-based interventions from early childhood are considered the most effective way to promote healthy behaviors (Peñalvo et al., 2013).

The preschool period is a time when children begin to develop lifelong habits related to proper and balanced nutrition (Başkale, Bahar, Başer, & Ari, 2009; Eley et al., 2019), and so nutrition is included in the Spanish Curriculum for children of 3-6 years of age (Ministry of Education and Science [MEC], 2007). Therefore, it is essential to promote proposals on current eating habits and physical practices (Arriscado-Alsina, Muros, Zabala, & Dalmau, 2015) which involve the entire educational community and which are put into practice using an inter-institutional and multidisciplinary approach (Espin, Pérez, Sánchez, & Salmerón, 2013). As pointed out by Hesketh and Campbell (2010), the literature on educational interventions with respect to prevention of obesity in early childhood is still limited; this suggests that more effort should be made in this research area (Reinoso, Delgado-Iglesias, & Fernández, 2019) to face the reality of this issue, and that specialized staff are necessary for this. In order to contribute to the didactic research regarding children at this age, in this work we show the design and implementation of a specific teaching intervention and explore its potential impact on children's learning about healthy food.

Educational interventions and learning about food

Nutritional proposals aimed at preschoolers (3 to 5 years old) are still scarce. It has been shown that interventions are more likely to succeed when the degree of family involvement is greater and when they are initiated at early ages (Skouteris, McCabe, Swinburn, & Hill, 2010). According to Summerbell et al. (2012), the most sustainable interventions reach out to the children's most proximal environment: their families, teachers, and school.

Parents act as models for young children and play an essential role in their children's nutritional behavior, shape children's eating patterns by determining what foods are available and in what quantities, and constitute a critical component in the preschool environment. In fact, some studies have shown that involving the children's proximal environment yields better results, by means of developing parents' knowledge about healthy food (Zarnowiecki, Sinn, Petkov, & Dollman, 2012), promoting healthier behaviors among adults and children (Herman, Nelson, Teutsch, & Chung, 2012), or increasing the intake of fruits and vegetables, while reducing that of fats and sugars (Epstein et al., 2001).

Nevertheless, teachers often complain about the lack of parental involvement in and/or support for the nutrition education taught by teachers at school, by not encouraging positive, healthy behaviors at home (for example, consumption of fruits and vegetables). In fact, they even consider that parents may represent a barrier to proper learning, likely because parents do not understand the importance of nutrition, are not interested in the subject, or have poor knowledge of it (Stage et al., 2018). Given the vital role of parents in facilitating real and sustainable behavioral changes during this early childhood period, some authors have suggested various strategies to improve the parental influence, including their participation in the classroom -with the provision of materials to take home, such as 'nutrition bulletins and healthy monthly recipes'- or in workshops and nutrition education classes (Hesketh & Campbell, 2010; Stage et al., 2018).

Other barriers to educational interventions have been found, such as the insufficient training of teachers, the scarcity of material to work with, or educational approaches that try to transmit information instead of reflecting on it. With respect to the educational material, different resources such as healthy stories, educational and audiovisual games, activities that families can participate in at home, or an annual School Health Fair have proven their effectiveness (Peñalvo et al., 2013). On the other hand, we suggest that isolated activities have a very limited impact, so we advocate the implementation of didactic sequences for diet, physical activity, parts of the human body, and contents to address the management of emotions (Peñalvo et al., 2013). In addition, schools should implement projects at the center level to promote healthy practices, such as the replacement of candy at birthdays and parties, involving parents in school activities, or improving the adequacy of the playground to promote physical activity during recreation.

The stage when children are 3-6 years of age is recognized as essential in the initiation of the progressive development of competences related to decision-making concerning, among other aspects, hygiene habits and healthy eating (García-Carmona, Criado, & Cañal, 2014). But, we must bear in mind that when children start school they have already established certain food preferences and eating behaviors, as a result of various influences, such as sensory, genetic, temperamental, social, and cultural factors and environmental learning (Xu & Jones, 2016), which will affect all their food experiences and their willingness to try new foods. In accordance with the relationship between children's early food preferences and eating-related behaviors, some studies have shown that the preferences and food consumption of preschoolers are strongly influenced by those of other children (Birch, 1980). Hence, when adults and partners act as active and positive social models, this can be effective in fostering healthier eating and the introduction of new foods; for instance, by brief, repeated tasting of food in a positive social context (Gibson et al., 2012). Therefore, it seems that people's dietary patterns will be determined by their exposure to certain actions, as well as their own personal choices (Ventura & Worobey, 2013). As a consequence, it is highly recommended that fresh fruits and vegetables be available daily, both at home and at school, while eliminating both junk food and sugary soft drinks (Katz, 2009).

OBJECTIVES

In this work, we describe the design of a didactic proposal for healthy eating that takes into account the current opinions of experts in nutrition and didactics, in order that children better recognize ingredients that are appropriate for their diets. Besides, we analyze the results of its implementation in a preschool classroom, and discuss how these activities might favor the initial development of healthy eating knowledge in Early Childhood Education.

METHODOLOGY

The sequence of activities was developed in a preschool classroom. The participants and context are described below, as are the characteristics of the activities and the analysis of the results obtained.

Design of the didactic sequence

The sequence was designed by a student teacher in her last year of the period of initial training, following Jorba and Sanmartí (1996). It is necessary to establish useful models to help teachers to develop educational interventions where the new information is connected to the previous ideas of children, in a constructivist model (López-Banet, Ayuso, & Martínez, 2020). This structure allows teachers to organize the educational interventions, not only taking into account the previous ideas of children regarding healthy practices and their respective cognitive development, using concepts and vocabulary relevant and comprehensible to them, but also involving families in activities in different points of the teaching and learning process. The new knowledge about healthy nutrition was organized in a sequence which was structured in four stages. Therefore, the implemented proposal consisted of a total of seven activities, developed in seven sessions of 45 minutes duration, distributed over two weeks (Table 1).

Table 1. Sequence within a competence framework.

Stage of the sequence	Main Objectives (sessions)
1. Explicitly state previous ideas and specify work proposals	To verbalize the previous ideas of the children about eating habits by means of guided questions during the assembly, coloring, or cutting and pasting of images of different foods and products that are usually included in their diet. To introduce children to the proposal of work on healthy eating by means of collective conversations (sessions 1 and 2) and to ask for collaboration that involves their families.
2. Introduction of new information	To discuss different types of foods, differentiating dairy-based food from unhealthy products. To compare menus elaborated by their families at home. To look at photographs of food and other industrial products that contain sugar, in order to promote considerations on reducing the sugar consumption (sessions 3, 4, and 5).
3. Structuring of information	To collectively reflect on the consumption of different sorts of foods and review the knowledge acquired, by comparison with their initial ideas and drawings (session 6).
4. Application	To apply the acquired knowledge by creating a recipe for a dessert that does not contain sugar; this recipe will be delivered to the families, so that they can prepare it in their homes, together with several pieces of advice on healthy eating (session 7).

The idea we pursued with this sequence was the participation of the children in activities with specific objectives that, globally, were focused on achieving their reflection on the problem of the consumption of sugary products, such as candies or sweets, encouraging them to select healthy recipes in their respective homes, with the involvement of their families in this learning process.

Participants and context

The didactic unit was designed and developed in a classroom of 4-year-old children of Preschool Education, with a total of 24 pupils. Among the several projects that the school follows, one is named the 'School Health Education Plan'. This is intended to gradually increase the consumption of fruit and vegetables by children, to develop other actions aimed at promoting healthy eating by them, and to raise the awareness among families and the educational community in general of the importance of a healthy and varied diet in the early acquisition of healthy habits.

Analysis of the results

In order to analyze the changes that the designed activities brought about regarding the kind of food chosen by the children, we collected their contributions at the beginning and end of the sequence for comparison. Thus, in relation to the previous ideas that the children expressed during the activities of stage 1 of the sequence, regarding the foods that they considered to be adequate, they had to identify them by coloring pictures in Figure 1. Besides, they selected the products that they had consumed the previous day by cutting out pictures of food from a large list and pasting them in their respective menus.

Figure 1. Initial activity to recognize food.

The respective families repeated the same activity by writing down the correct menu consumed, in order to check if all the important components were included and for comparison with those selected by the pupils. We elaborated a table including the results of not only the children but also their families. Finally, two recipes created by a sequence of pictures were given to the children; the idea was that they would color the one they chose after the implementation of the activities. Thus, we could identify the number of children that opted for the healthier one.

RESULTS

With this work, we set out to develop and design a didactic sequence of activities intended to achieve the overall objective of identifying less healthy food products and choosing more appropriate alternatives for the children's welfare. As a result, a proposal has been elaborated that includes contents related to healthy eating and, more specifically, that allows the identification, among the different food groups, of some ingredients that should be consumed in moderation, to finally select a recipe that can be prepared without the incorporation of the aforementioned ingredients. Specifically, the most notable results were obtained after the implementation of the sequence.

Regarding the results of the first stage, concerning the foods that the children initially preferred, all the children selected the packaged juice (100%), followed by fish (86%) and cookies, hamburgers, and pizza (73%). Chicken and muffins were chosen by 68%, followed by legumes (64%), vegetables, and bread (59%). Among the foods they considered less suitable were donuts (45%), French fries (41%), and olive oil (36%), explaining that 'the oil is not good' during the activity, while treats (32%) were the food selected least. In the next activity, the children selected some products that they consumed on a daily basis, from a list containing several kinds of food. They had to paint and cut the pictures corresponding to the products they had eaten the previous day, and paste them in a table representing the times of day when they usually ate (Figure 2). In addition, the collaboration of their parents was required, since they also had to choose the food corresponding to their children's menus, in order to later compare the two lists, the children's and the parents', and thus find important products on which to reflect during the sequence of activities; it was ascertained that most products selected by the parents were coincident with those mentioned by the children.

Figure 2. Food ingested by a child: breakfast, mid-morning snack, lunch, afternoon snack, and dinner.

When we compared the two lists, although the coincidence was not exact, we found that they corresponded to a large extent, especially in the main meals. As an example, data provided by a child (number 12) and his family are shown in Table 2.

Table 2. Menu selected by a child and his family.

	Child	Family
Breakfast	Milk with cereals	Milk with cereals
Mid-morning snack	Sandwich	Sandwich
Lunch	Macaroni and crème caramel	Macaroni
Afternoon snack	Sandwich	Omelet and ham
Dinner	Milk	Milk

The most ingested foods were milk (73%) and cookies (41%) for breakfast, a snack (68%) and packaged juice (36%) for the mid-morning snack, and a hot dish (55%) at lunch, along with meat (18%), fish (32%), or pasta (32%). For the afternoon snack, 36% of the children indicated a sandwich, followed by donuts, fruit, and muffins at the same percentage (18%), while for the dinner, milk (27%) and pizza (23%) were the most frequent foods; it must be highlighted that no child chose fruit for dinner. Despite being aware of the consequences of not eating correctly, such as '*having cavities*' or '*not growing up*', the pupils recognized their intake of some unhealthy products. It was striking that 41% of the participants selected a product of an industrial bakery as a regular element in their diet.

In the next stage, the realization of various activities involving the introduction of new knowledge favored the reflection by the children on the kinds of foods and diets which would be most suitable for them. For example, we built a food train by means of large wagons that represented the foods that had to be incorporated daily into the diet, such as fruits and vegetables, legumes, carbohydrates, water, meat, and fish, followed by a very small car with elements undesirable because of their sugar content, such as industrial products. Moreover, we analyzed the menus elaborated by the schoolchildren, which the families had to complete at home, in order to reflect on the main products present on a daily basis in all homes. As part of these activities, we showed the children, next to each high-sugar product that they had selected or mentioned in the previous activities (muffins, cookies, candies, soft drinks, juice), the equivalent number of sugar cubes contained in each of them. Then, we discussed with them what the cubes represented, so that they recognized the amount of sugar in their favorite foods. Their comments showed that they became worried, since they realized their diets were not so good.

In the third stage, the children had to reflect on the new knowledge acquired and complete a menu, which would be compared to the one they had completed initially, again by pasting images of a series of given foods. In this way it was found that all the children, except one, increased the amount of photographs that included fruits, while the number of children that selected cookies and industrial pastries fell, compared to the initial results. Finally, in the application stage, the children were individually provided with two recipes for a dessert by means of a prepared sequence of images. Thus, taking into account the ingredients that each one included, they identified and colored the one that they wished to prepare at home together with their families. On this occasion, 100% of the children colored, without difficulties, the appropriate (healthy) recipe, which was delivered to each family, along with a booklet of tips related to food that should be phased out of the schoolchildren's diets.

CONCLUSIONS

Early childhood constitutes a critical time to establish food preferences and eating habits. It is necessary that people around children (family, teachers, and health professionals) understand the ways in which preschoolers learn about food and encourage them to reflect on their own tastes and preferences, as a step prior to the acquisition of healthy habits. School-based interventions at this stage are widely considered the most effective way to promote healthy behaviors. For these reasons, in this work we show the design and implementation, in a class of 4-year-old children, of a sequence with a constructivist perspective in this education related to healthy foods.

It should be noted that, at the initial stage of the intervention, when activities aimed at verbalizing the previous ideas of the children about eating habits were performed, we realized that, for all the schoolchildren in our sample, juice was considered a healthy product despite the high sugar content, while vegetables were not valued so highly. Olive oil was considered an unhealthy product, practically at the same level as sweets, which demonstrates the importance of early childhood education in the development of the children´s evaluation of an adequate diet. However, after carrying out the proposed activities, the children seemed to realize the amount of sugar in many of the products they usually ate, according to their own data and those provided by their parents. In fact, at the end of the sequence practically all of them included many more healthy foods, such as fruits and vegetables, while drastically reducing those that should be consumed in moderation. Therefore, the teaching sequence described in this work seems to have made it possible to achieve the objectives of the different stages in which it was structured, reaching the overall goal of selecting a recipe containing healthier ingredients, since the pupils seemed to have acquired the most basic notions of healthy eating and to have been able to make critical judgments. In future work further activities for the learning of these contents will be developed, discussing with children their preferences for fruits and vegetables and trying to show them the need to eliminate sugar from their diets. The introduction of sessions where children must taste, smell, and touch fruits and vegetables could be useful in teaching programs that allow them to recognize a wide variety of healthy food while improving their preferences and the provision of this food.

To sum up, a school-based initiative should include not only a high-quality intervention but also a long-term, sustainable system to gradually introduce children to healthy choices, in order to boost the success in the learning of these contents. Moreover, not only is a close collaboration between families and schools required but also the current recommendations of experts and nutritionists need to be taken into account, by inviting them to visit schools.

ACKNOWLEDGEMENT

This research has been carried out within the project PGC2018-097988-A-I00 funded by: FEDER/ Ministry of Science and Innovation (MCI) of Spain - State Research Agency (AEI). Luisa López-Banet is grateful for the grant within the call for short stays in foreign centers aimed at the staff of the University of Murcia (young R2 researchers) and researchers in training (R1), for the year 2019 (R- 655/2019). The authors would also like to thank the Pre-school and Primary Education School of Cieza (Murcia, Spain) for its collaboration and for allowing these activities to be carried out in the classroom of 4-year-old children.

REFERENCES

Arriscado-Alsina, D., Muros, J. J., Zabala, M., & Dalmau, J. M. (2015). ¿Influye la promoción de la salud escolar en los hábitos de los alumnos? [Influence of school health promotion on the life habits of schoolchildren]. *Anales de Pediatría*, 83(1), 11–18. doi: 10.1016/j.anpedi.2014.07.013

Baker, J. L., Olsen, L. W., & Sørensen, T. I. A. (2007). Childhood Body-Mass Index and the Risk of Coronary Heart Disease in Adulthood. *The New England Journal of Medicine*, 357(23), 2329-2337. doi: 10.1056/NEJMoa072515

Başkale, H., Bahar, Z., Başer, G., & Ari, M. (2009). Use of Piaget's theory in preschool nutrition education. *Revista de Nutrição*, 22(6), 905–917. doi: 10.1590/S1415-52732009000600012

Birch, L. L. (1980). Effects of Peer Models' Food Choices and Eating Behaviors on Preschoolers' Food Preferences. *Child Development*, 51(2), 489–496. doi: 10.2307/1129283

Caballero, B. (2004). Obesity prevention in children: opportunities and challenges. *International journal of obesity*, 28(S3), S90. doi: 10.1038/sj.ijo.0802797

Díaz, J. (2017). Childhood obesity: Prevention or treatment? *Anales de Pediatría*, 86 (4), 173-175. doi: 10.1016/j.anpede.2016.12.001

Eley, C., Weston-Price, S., Young, V., Hoekstra, B., Gadhia, T., Muirhead, V., Robinson, L., Pine, C., & McNulty, C. (2019). Using oral hygiene education in schools to tackle child tooth decay: a mixed methods study with children and teachers in England. *Journal of Biological Education*, 1-15. doi: 10.1080/00219266.2019.1585380

Epstein, L. H., Gordy, C. C., Raynor, H. A., Beddome, M., Kilanowski, C. K., & Paluch, R. (2001). Increasing fruit and vegetable intake and decreasing fat and sugar intake in families at risk for childhood obesity. *Obesity Research*, 9(3), 171–178. doi: 10.1038/oby.2001.18

Espín Ríos, M. I., Pérez Flores, D., Sánchez Ruiz, J. F., & Salmerón Martínez, D. (2013). Prevalencia de obesidad infantil en la Región de Murcia, valorando distintas referencias para el índice de masa corporal [Prevalence of childhood obesity in the Murcia Region; an assessment of different references for body mass index]. *Anales de Pediatría*, 78(6), 374–381. doi: 10.1016/j.anpedi.2012.09.007

García-Carmona, A., Criado, A. M., & Cañal, P. (2014). Alfabetización científica en la etapa 3-6 años: un análisis de la regulación estatal de enseñanzas mínimas [Scientific literacy at the 3-6 year old stage: an analysis of Spain's national curriculum]. *Enseñanza de las ciencias*, 32(2), 0131-149. doi: 10.5565/rev/ensciencias.817

Gibson, E. L., Kreichauf, S., Wildgruber, A., Vögele, C., Summerbell, C. D., Nixon, C., Moore, H., Douthwaite, W., & Manios, Y. (2012). A narrative review of psychological and educational strategies applied to young children's eating behaviours aimed at reducing obesity risk. *Obesity Reviews*, 13(SUPPL. 1), 85–95. doi: 10.1111/j.1467-789X.2011.00939.x.

Herman, A., Nelson, B. B., Teutsch, C., & Chung, P. J. (2012). 'Eat Healthy, Stay Active!': A coordinated intervention to improve nutrition and physical activity among Head Start parents, staff, and children. *American Journal of Health Promotion*, 27(1), 27–36. doi: 10.4278/ajhp.110412-QUAN-157.

Hesketh, K.D.,& Campbell, K.J. (2010). Interventions to prevent obesity in 0–5 year olds: an updated systematic review of the literature. *Obesity*, 18(S1), S27-S35. doi: 10.1038/oby.2009.429.

Jorba, J., & Sanmartí, N. (1996). *Enseñar, aprender y evaluar: un proceso de evaluación continua. Propuesta didáctica para las áreas de ciencias de la naturaleza y las matemáticas* [Teaching, learning and assessment: a continuous assessment process. Didactic proposal for the areas of nature sciences and mathematics]. Barcelona. Ministerio de Educación y Cultura. Retrieved from https://sede.educacion.gob.es/publiventa/ensenar-aprender-y-evaluar-un-proceso-de-evaluacion-continua-propuesta-didactica-para-las-areas-de-ciencias-de-la-naturaleza-y-matematicas/administracion-educativa/41

Katz, D. L. (2009). School-Based Interventions for Health Promotion and Weight Control: Not Just Waiting on the World to Change. *Annual Review of Public Health*, 30(1), 253–272. doi: 10.1146/annurev.publhealth.031308.100307.

López-Banet, L., Ayuso Fernández, E., & Martínez Carmona, M. (2020). Educación nutricional infantil en la formación del profesorado [Teaching and learning of healthy nutrition in Early Childhoood Education Degree]. In XXXX (Eds.), *Innovación Docente e Investigación en Ciencias de la Educación. Volumen I* [Teaching Innovation and Research in Science Education. Volume I] (763-778). Madrid, Spain: Dykinson Editorial.

Lorenzo-Bertheau, E., Quintana, F. C., Pappous, A., Ruiz, Y. B., González, E. V., & Valle, J. S. R. (2017). Estigmas sociales relacionados con la obesidad en estudiantes de educación física [Social estigmas related to obesity in students of physical education]. *TRANCES. Transmisión del Conocimiento Educativo y de la Salud*, (3), 471-492. Retrieved from https://dialnet.unirioja.es/servlet/articulo?codigo=6428797

Ministry of Education and Science. (2007). Orden ECI/3960/2007 [Order ECI/3960/2007]. *Boletín Oficial Del Estado*, 5, 1-36. Retrieved from https://www.boe.es/buscar/pdf/2008/BOE-A-2008-222-consolidado.pdf

Peñalvo, J. L., Sotos-Prieto, M., Santos-Beneit, G., Pocock, S., Redondo, J., & Fuster, V. (2013). The Program SI! intervention for enhancing a healthy lifestyle in preschoolers: first results from a cluster randomized trial. *BMC Public Health*, 13(1208), 1–9. doi: 10.1186/1471-2458-13-1208.

Reinoso, R., Delgado-Iglesias, J., & Fernández, I. (2019). Pre-service teachers' views on science teaching in Early Childhood Education in Spain. *European Early Childhood Education Research Journal*, 27(6), 801-820. doi: 10.1080/1350293X.2019.1678720

Skouteris, H., McCabe, M., Swinburn, B., & Hill, B. (2010). Healthy eating and obesity prevention for preschoolers: a randomised controlled trial. *BMC Public Health*, 10(220), 1–9. doi: 10.1186/1471-2458-10-220

Stage, V. C., Wilkerson, K., Hegde, A., Lisson, S., Babatunde, O. T., & Goodell, L. S. (2018). Head Start administrator and teacher perceptions of parental influence on preschool children's nutrition education. *Journal of Early Childhood Research*, 16(2), 160–175. doi: 10.1177/1476718X17705415

Summerbell, C., Waters, E., Edmunds, L., Kelly, S., Brown, T., & Campbell, K. (2005). Interventions for preventing obesity in children (Review). *Cochrane Database of Systematic Reviews*, (3), 1–80. doi: 10.1002/14651858.CD001871.pub4

Ventura, A. K. & Worobey, J. (2013). Early influences on the development of food preferences. *Current Biology*, 23, R401–R408. doi: 10.1016/j.cub.2013.02.037.

World Health Organization. (2015). *Sugars intake for adults and children*. Geneva. Retrieved from https://www.who.int/nutrition/publications/guidelines/sugars_intake/en/

Xu, T. & Jones, I. (2016). An Investigation of Children's Understanding of Food and Nutrition. *Early Childhood Education Journal*, 44(4), 289–297. doi: 10.1007/s10643-015-0716-3

Zarnowiecki, D., Sinn, N., Petkov, J., & Dollman, J. (2012). Parental nutrition knowledge and attitudes as predictors of 5-6-year-old children's healthy food knowledge. *Public Health Nutrition*, 15(7), 1284–1290. doi: 10.1017/S1368980011003259

ROSIE: ROBOT-SUPPORTED INCLUSIVE EDUCATION - A PLAY-BASED APPROACH TO STEM EDUCATION AND INCLUSION IN EARLY CHILDHOOD TRANSITIONS

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The presence of educational robots in preschool and early primary school settings is getting stronger and has shown to have powerful playful qualities and to support interest in STEM. The question is whether it is possible to make use of these advantages and apply a play-based approach to Robot-Supported Collaborative Learning (RSCL) to facilitate inclusion and improve the challenging educational transfers in children's early life (5-8 years of age). Based on research in inclusive education, playful learning and educational robotics as well as an empirical pilot study on the educational robot KUBO in Denmark, this paper proposes a design-based research approach to the development of situated and practice-based RObot-Supported Incluve Education (ROSIE) specifically aimed at the transition between preschool and primary school. The aim is to support and empower children's essential life skills including imagination, collaboration and communication skills and to provide pathways capable of including and detecting a diversity of children's needs, skills and interests in STEM early and in a more advanced way than currently offered by traditional usage of educational technology.

Keywords: STEM education, robot-supported learning, inclusion

BACKGROUND

Getting ready for school is a crucial life change in a child's life. Yet, teachers experience challenges in finding ways to include all children in activities targeting a smooth transition between preschool and primary school as well as developing inclusive learning environments (Larsen, 2014). In Denmark, studies have concluded that bigger shifts in learning environments, such as in the transition between preschool and primary school, include risks of a child experiencing difficulties and failures (UVM, 2016). An unsuccessful transition can result in socio-economic and individual difficulties, e.g. becoming an early leaver from the school system, social and work life alienations, and passive citizenship. To give all children equal chances of developing into active participants in their own learning, as well as experiencing success and progression in learning activities, teachers and pedagogic professionals need competences in designing inclusive learning environments and adequate pedagogical practices. Institutions offer various approaches and methods to education and transitions in early childhood, all promoting the benefits of their own particular methods (Broström, 2013). However, the inclusion of digital tools and technologies in these processes is usually limited to information distribution when 'handing over' the child from one institution to another and does not include technology-supported and play-based learning designs that promote cross-disciplinary collaborations between these institutions (Larsen, 2014).

Educational Robotics and Robot-Supported Collaborative Learning (RSCL)

The presence of robot technology in educational settings is becoming more prevalent, often with the aim of supporting what is generally referred to as 21st century skills; collaboration, communication, critical (and computational) thinking and creativity (Rusk, Resnick, Berg, & Pezalla-Granlund, 2008; Toft & Nørgård, 2015). Research within educational robotics and hands-on robotic kits show, that working with programmable robots can influence children's development of cognitive, conceptual, language and social (collaborative) skills, however research has mostly been outcome-focused with robots as instrumental means to support other subjects in STEM (Science, Technology, Engineering and Math) teaching, particularly programming (Bertel & Rasmussen, 2013). When it comes to human-robot interaction and socially assistive robotics, on the other hand, research in special needs education and inclusion specifically suggests that social robots may facilitate social engagement as robotic tutors particularly in autism education (Robins & Dautenhahn, 2014; Feil-Seifer & Matarić, 2009; Scassellati, Admoni, & Matarić, 2012), however with the risk of reinforcing the enactment of specific user groups as passive/disabled 'consumers' as opposed to active/able 'producers' of digital practice (Hansbøl, 2016).

Some research in social robots for education indicate a potential in bridging the two; sustaining a process of integration and social inclusion through collaborative learning while also developing key competencies in educational practices and STEM (Tosato & Baschiera, 2013; Alimisis, 2013; Mubin et al., 2013; Majgaard et al., 2014). Thus, the past clear distinction between robots in general education and special needs education carries the risk that the benefits children with diverse needs and skills could have from robot-supported collaborative learning (RSCL) is overlooked.

Play-Based RSCL and Inclusive Educational Ecosystems

One approach that has gained momentum in recent years is play-based learning (Brooks, 2019). Research shows that play-based learning has an inclusive character and enhances children's academic and developmental learning outcomes, setting them up for essential skills in children's life in the 21st century (Eguchi, 2014). A play-based approach builds on children's natural engagement and interest, using play as a context for learning, where children can explore, experiment, discover and solve problems in imaginative and playful ways (Bers, Seddighin & Sullivan, 2013). Such an approach involves both child-initiated and teacher-supported learning, for example by encouraging children's learning and inquiry through interactions that aim to include and, at the same time, stretch children's thinking to higher levels (Brooks, 2019).

To summarize, programmable, embodied robots do have the potential to encourage playful inquiry and problem-solving and facilitate experiences of meaningfulness and creativity, however due to the cross-disciplinary character of a play-based approach to Robot-Supported Collaborative Learning (pRSCL), implementation may challenge institutional practice greatly. Thus, there is a need for research-based models and methods for teacher support, situated development and practical implementation of pRSCL as well as evidence-based knowledge and studies validating such learning designs and models (Bertel, Rasmussen, Majgaard &

Hannibal, 2016). Thus, this paper suggest an ecosystem approach to Robot-Supported Inclusive Education (ROSIE) as a whole in which teachers, pedagogic professionals, teacher trainers and researchers jointly develop inclusive technology-enhanced and play-based learning designs, methods and models across educational institutions and embedded within specific pedagogic practices related to early childhood transitions.

CO-DEVELOPING PRSCL DESIGNS: A CASE STUDY ON KUBO

As part of identifying needs and challenges in the development of pRSCL designs for inclusion, we applied a design-based research approach to a cross-case study on the educational robot KUBO implemented at ten different pre/primary school institutions in Denmark. In the following, we will describe the platform and case study design as well as report findings from one particular case study involving two institutions focusing on early childhood transitions.

The KUBO Robot

KUBO is a mobile educational robot developed by Danish startup company KUBO Robotics (KUBO Robotics, 2019) designed to support learning for children in preschool and early primary school in various subjects such as coding, language, and music through a tangible coding language; TagTiles with commands in the shape of puzzle pieces (see figure 1). KUBO consists of two separate units attached through a build-in magnetic mechanism. The body has two motorised wheels and an RFID scanner underneath. The head (control unit) has eyes that light up in response to certain commands and when KUBO moves. When placed on a TagTile, the RFID scanner reads the chip corresponding to the symbol on the tile and executes a command, e.g. turning left in response to "left arrow". With the KUBO kit comes an activity map with coordinates, illustrated on one side and blank on the other.

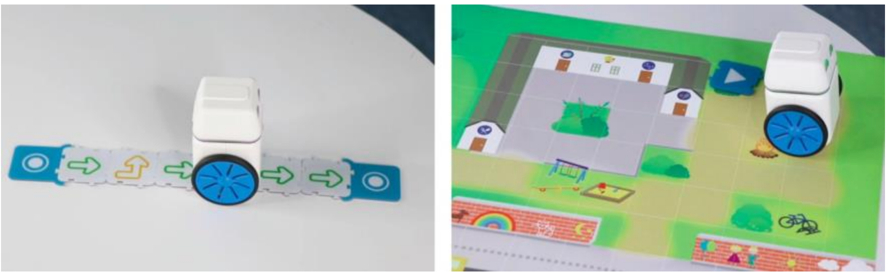

Figure 1. Kubo reading the TagTiles (left) and on the activity map (right)

There are two different ways to code KUBO; *Sequences* in which the robot is placed directly onto the tile, e.g. an arrow tile and moves in the direction of the arrow; and *Functions* in which the sequence of the tiles is organized as code in between two function tiles and replayed when placed on the ‘play’ tile. There are two sets of functions and play tiles in addition to loop tiles, so KUBO can be used to teach *subroutines* and *recursive functions* as well as *loops*.

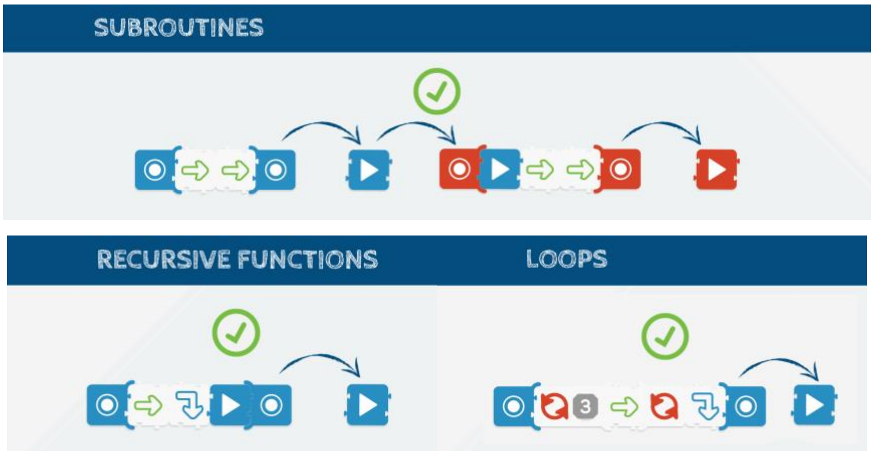

Figure 2. Programming Subroutines, Recursive functions and Loops with TagTiles

The purpose of KUBO like most other educational robots for STEM-teaching is to teach children the basics of coding, however in addition to this, humanoid features such as eyes and a head as well as the assigned intention-driven coding tasks on the activity map invites social robotic narratives and frames KUBO within a social robotic context. This seems to invite children with diverse needs and interests in playful learning scenarios, however the potential of KUBO to support inclusion specifically, have yet to be explored in a systematic way.

Case Study Design

In this specific case study, two sets of ten KUBO robots each were tested at two different locations; a school in the city of Odense and a kindergarten close to the school with which the school was attempting more cross-disciplinary collaboration focusing on early childhood transitions. A total of 24 children participated in the study. The teachers and pedagogic professionals co-developed a robot-supported learning collaborative design in which sixteen 2nd grade pupils (age 8-9) would teach eight so called 'school ready' kindergarten kids (age 5-6) how to code using KUBO over the course of three weeks. The older children spent two math classes preparing and worked in pairs or groups of three to design programming tasks and exercises for the preschoolers to complete as well as accompanying narratives involving the TagTiles and the activity map. After an introductory visit at the kindergarten, they were then paired with one of the preschoolers to teach the concept of coding using KUBO and the map.

Data collection in this case study consisted of four instances of participatory observations including pictures and notes over the course of three weeks as well as interviews with the math teacher, the school's headmaster about transition policies, and interviews with two pedagogic professionals at the kindergarten as well as in-situ interviews with the children.

In the following, we will present and discuss some of the valuable insights this case study provided into both existing and emerging inclusive practices in relation to the implementation of this particular robot-supported collaborative learning design and pRSCL in general.

PRSCL FOR INCLUSION: PRELIMINARY FINDINGS

In the case study we observed inclusive practices both in the preparation for the specific playful collaborative learning activity (i.e. when school children were preparing programming tasks to bring to the kindergarten), as well as during the activity itself and in informal or ‘in between’ formal learning settings. We have divided these inclusive practices into three categories related to; *structure*, *play* and *social status or self-efficacy*, respectively.

Inclusion through structure

In this first category, the teacher or pedagogic professional were facilitating inclusion specifically through *structure*. For instance, utilizing a story-telling approach to facilitate computational thinking and understanding of coding concepts and by this including groups of students who were motivated specifically by creating stories rather than designing the movements of KUBO on the designated map itself. This way, students were engaged either with writing stories, building code with building blocks or ‘reverse engineering’ through analyzing the behavior of the robot and formalizing it in simple written code.

Other inclusive practices facilitated by structure included reflections regarding group size (a maximum of three) to facilitate participation, limitation of and clear communication about the TagTiles availabability on the whiteboard at any given time to reduce complexity (see figure 3), classroom layout and spatial limitations when working with the robots (e.g. at the table, on the floor) as well as general classroom management, e.g. assigning different roles and responsibilities (e.g. who is in charge of the robot, the TagTiles, the map etc.) as well as specific and clearly communicated practices for common activities and information distribution (e.g. all students were sitting on their hands briefly when receiving essential information).

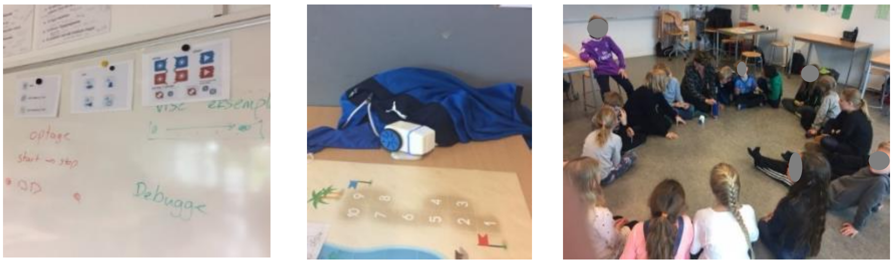

Figure 3. Examples of existing and emerging inclusive practices through structure

Inclusion through play

In the second category*,* imagining games and *play* scenarios with KUBO, such as designing new looks for the robot was a way to facilitate inclusion of children with diverse interests. Furthermore, in some instances playful inquiry as an approach to coding with the TagTiles showed potential to reveal a particular child’s specific needs and skills. For instance, a child was special needs was testing the limitations of KUBO’s perception by building code impossible to execute. When interviewed, the child explained trying to ‘confuse’ or ‘hack’ the robot. The same child would then later the following week be able to build a loop (without instruction) to ‘make the robot run forever’ (see figure 4).

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Figure 4. Examples of existing and emerging inclusive practices through play

Inclusion through social status and self-efficacy

In the final category, the act of teaching others became an inclusive practice in of itself. For instance, the responsibility of having to prepare and explain coding exercises for younger children emerged as an inclusive practice (see figure 5), giving children who were otherwise considered 'vulnerable' (in terms of socio-economic status, learning ability etc.) the opportunity take on the role as the 'more knowledgeable other' and to develop in the role as the facilitator and 'teacher'. This also allowed for valuable discussion between the children about what it means to 'learn' and the value of failure in trial-and-error exercises.

Figure 5. Examples of existing and emerging inclusive practices through social status and self-efficacy

DEVELOPING A ROSIE MODEL: NEXT STEPS

In addition to the three categories of inclusive practices existing around and emerging from this particular KUBO-supported collaborative learning design, findings from the case study highlighted particular potentials and challenges in relation to developing Robot-Supported Inclusive Education (ROSIE) specifically targeted at the transition between preschool and primary school. For instance, the exercises developed in the classroom and applied by the students in kindergarten were very much task-based and solution-oriented, whereas pedagogic professionals at the kindergarten level emphasized and encouraged a more open-ended, problem-oriented and curiosty/inquiry-based pedagogic approach, which suggests the need for a more systematic co-designing and co-development process between teachers and pedagogic professionals preceding implementation of pRSCL in practice. Similarly, findings indicate that to successfully develop and adjust such learning designs to the needs and skills of individual children and teachers, it must include highly contextual knowledge and be embedded within and address a situated, cross-institutional practice. Finally, the case study highlighted the need for evidence-based methods and models for assessing the effects of pRSCL designs on e.g. learning, collaboration, self-efficacy and overall well-being in early childhood transitions.

CONCLUSIONS AND FUTURE WORK

Based on these preliminary findings, we claim that to develop Robot-Supported Inclusive Education (ROSIE) it is necessary to: (1) engage with children, teachers and pedagogic professionals in focused interactions to mobilize tacit knowledge about existing inclusive and collaborative learning practices within a particular context; (2) explore in-situ how novel robot technology can facilitate the emergence of new inclusive practices within set context; and (3) ongoing assess how existing practices change by introducing this new technology.

Thus, for future work we aim to co-develop a participatory and value-sensitive ROSIE-model specifically focused on early childhood transitions and test it in three iterations, allowing for continuous cycles of validation and re-design to ensure that playful robot-supported collaborative learning (pRSCL) designs and activities meet the expectations of all stakeholders, and that valuable feedback and findings gained through this participatory process is effectively incorporated into pRSCL designs and development regardless of the choice of robotic platform.

REFERENCES

Alimisis, D. (2013). Educational robotics: Open questions and new challenges. *Themes in Science and Technology Education, 6(1), 63-71.*

Bers, M., Seddighin, S., & Sullivan, A. (2013). Ready for robotics: Bringing together the T and E of STEM in early childhood teacher education. *Journal of Technology and Teacher Education, 21(3), 355-377.*

Bertel, L. B., & Hannibal, G. (2016). Tema 2: The NAO robot as a Persuasive Educational and Entertainment Robot (PEER)–a case study on children's articulation, categorization and interaction with a social robot for learning. *Tidsskriftet Læring og Medier (LOM), 8(14).*

Bertel, L. B., & Rasmussen, D. M. (2013). On being a peer: What persuasive technology for teaching can gain from social robotics in education. *International Journal of Conceptual Structures and Smart Applications (IJCSSA), 1(2), 58-68.*

Bertel, L. B., Rasmussen, D. M., Majgaard, G., & Hannibal, G. (2015). Design-Based Research in Child-Robot Interaction: Bridging the gap between the intended and the implemented. *In 7th International Conference on Social Robotics (ICSR).*

Brooks, E. I. (2019). Kinds of Learning with Digital Technologies in Early Childhood Education. In *Playful Learning–Digital Leg Og Læring I Dagtilbud.* Aalborg Universitetsforlag.

Broström, S. (2013). Play as the main road in children's transition to school. Varied perspectives on play and learning: Theory and research on early years education, 37-53.

Danish Ministry for Children and Education (2016). Afrapportering af inklusionseftersynet. https://www.videnomlaesning.dk/media/2035/afrapportering-af-inklusionseftersynet.pdf

Eguchi, A. (2014). Robotics as a learning tool for educational transformation. In *Proceeding of 4th international workshop teaching robotics, teaching with robotics & 5th international conference robotics in education Padova (Italy).*

Feil-Seifer, D., & Matarić, M. J. (2009). Toward socially assistive robotics for augmenting interventions for children with autism spectrum disorders. In *Experimental robotics (pp. 201-210).* Springer, Berlin, Heidelberg.

Hansbøl, M. (2015). Tema 2: Robot technologies, autism and designs for learning. *Tidsskriftet Læring Og Medier (LOM), 8(14).*

Kubo Robotics, (2020). *KUBO*. Retrieved from https://kubo.education/

Larsen, M. R., Akselvoll, M. Ø., Jartoft, V., Knudsen, H., Kousholt, D., & Raith, J. K. (2014). *Forældresamarbejde og inklusion: Afdækning af et vidensfelt i bevægelse.*

Majgaard, G., Hansen, J. J., Bertel, L., & Pagh, A. (2014). Fra digitalt design til fysisk udtryk–anvendelse af 3-d-printere og NAO-robotter i folkeskolen. *MONA-Matematik-og Naturfagsdidaktik, (4).*

Mubin, O., Stevens, C. J., Shahid, S., Al Mahmud, A., & Dong, J. J. (2013). A review of the applicability of robots in education. *Journal of Technology in Education and Learning, 1(209-0015), 13.*

Robins, B., Dautenhahn, K. Tactile Interactions with a Humanoid Robot (2014). Novel Play Scenario Implementations with Children with Autism. *Int. Journal of Social Robotics 6, 397–415*.

Rusk, N., Resnick, M., Berg, R., & Pezalla-Granlund, M. (2008). New pathways into robotics: Strategies for broadening participation. *Journal of Science Education and Technology, 17(1), 59-69.*

Scassellati, B., Admoni, H., & Matarić, M. (2012). *Robots for use in autism research.* Annual review of biomedical engineering, 14, 275-294.

Toft, H., & Nørgård, R. T. (2015). Tema 1: Pla (y) ceskabelse: når børn og robotteknologi mødes. *Tidsskriftet Læring Og Medier (LOM), 8(14).*

Tosato, P., & Baschiera, B. (2013). Educational Robotics and Social Inclusion. The *Joy of Learning.*

ENHANCING COMPUTATIONAL THINKING SKILLS IN EARLY CHILDHOOD EDUCATION

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Nowadays, cultivating computational thinking in PK-12 emerges as a compelling vision. In this sense, we introduce an educational framework that aims to familiarise children in the first two grades of primary school with fundamental competencies of computational thinking, such as: collection, organisation and analysis of data, algorithmic thinking and abstraction. The basis of the proposed framework is a novel computational educational environment, which establishes an innovative hybrid schema of visual and text-based programming techniques, focusing on object-orientation. We also suggest a relevant assessment tool, in order to examine if the objectives of our educational approach are met. This paper reports two pilot studies, conducted within the context of physical and natural science courses in a first and a second grade class, in a primary school in Crete, Greece, in May 2018. Findings provide very promising indications for meeting our goals to introduce and practice computational thinking concepts in the first stages of schooling, actualising at the same time a mild first contact of young students with object-oriented programming syntax.

Keywords: computational thinking, early childhood education, science education

INTRODUCTION

Computational thinking is expected to be a fundamental skill for everyone by the middle of the 21st century, just like reading, writing and arithmetic are at the moment (Wing, 2006). Over the last two decades, the idea of introducing computational thinking in compulsory education has gained the attention of educators, researchers and policymakers (Barr et al., 2011; Barr & Stephenson, 2011; Grover, 2015; Kalogiannakis & Kanaki, 2020; Kalogiannakis & Papadakis, 2020). In fact, contemporary literature proposes its systematic cultivation even from the first stages of schooling, starting from kindergarten (Angeli et al., 2016; Kanaki & Kalogiannakis, 2018; Kazakoff et al., 2013; Papadakis et al., 2016; Sullivan & Bers, 2016; Sung et al., 2017). Furthermore, a substantial body of literature has been developed designating computational thinking as an essential ingredient of studying a plethora of disciplines in PK-12 (Grover & Pea, 2013). It is worth mentioning that Next Generation Science Standards (https://ngss.nsta.org/Practices.aspx?id=5) include computational thinking, together with mathematics, in the list of well educational practices in the case of science courses in K-12.

Elements that are widely accepted as comprising computational thinking are: collection, organisation and analysis of data, algorithmic thinking and abstraction (Barr et al., 2011; Barr & Stephenson, 2011). These elements constitute the basis of policies that aim to cultivate computational thinking and provide means of assessing its development (Barr & Stephenson, 2011; Grover & Pea, 2013).

The essence of our research is enhancing the above-mentioned computational thinking elements in the elementary grades, since these elements correspond to skills applicable and beneficial in everyday life. Our main research question can be formulated as follows: "Can fundamental computational thinking elements be introduced in the first and second grade of primary school within the context of physical and natural science courses, through the creation of digital games using a developmentally appropriate computational environment?" To answer this question we developed a novel educational framework established on the theory of constructivism (Mattar, 2018; Richardson, 2005) and game-based learning (Akman & Özgül, 2015; Sung & Hwang, 2013). Its backbone is the educational computational environment PhysGramming (an acronym derived from Physical Science Programming), which we implemented from scratch for children ages 5-8, based on their needs and skills (Kanaki & Kalogiannakis, 2018). Its innovative feature is that, while children create their own digital games within the context of physical and natural science courses, they become familiar with basic computational thinking concepts, even though no specific reference is made to them (Kanaki & Kalogiannakis, 2018).

Through PhysGramming we also focus on familiarising young children with object-oriented programming syntax, establishing a novel hybrid schema of visual and text-based programming techniques, following the recent years' trend of encouraging cultivating the basic programming skills as soon as possible in schooling, starting from kindergarten (Voogt et al., 2015). We opt in favor of object-oriented programming since it is inseparable from object-oriented thinking, a skill people cultivate from the beginning of their lives (Hillar, 2015).

The educational framework we propose is accompanied with a relevant assessment tool that enables educators to assess the potential development of skills related to computational thinking. We paid extra attention to constructing an assessment tool that provides valid and reliable results, since we are aware that without attention to assessment, no research effort could ever gain a serious role and place in the academic and educational scene (Grover & Pea, 2013). Enriching the assessment tool to evaluate learning of object-oriented syntax is one of our near future research interests.

This paper presents the proposed educational framework and its relevant assessment tool. It also reports two pilot studies, conducted in a first and a second grade class, in a primary school in Crete, Greece, in May 2018, aiming to answer the research question and, supplementally, to assess the feasibility of PhysGramming and to detect its impact on students regarding their satisfaction.

METHOD

In this section, we are going to briefly present the functionality of PhysGramming, the relevant assessment tool we propose and the methodology of the pilots conducted.

PhysGramming

PhysGramming is a computational educational environment compatible with any operating system. It is also compatible with smart mobile devices, taking advantage of the benefits of using mobile devices in the classroom (Zhu et al., 2016). It was implemented using the Java programming language (Arnold et al., 2015), in the Eclipse programming environment (Wiegand, 2004). It can be used in the classroom without the need of pre-educational interventions for the enhancement of computational thinking.

It should be mentioned that the term classroom refers to the human resources, i.e. the students and does not imply spatial constraints. The proposed educational framework can not only be applied in the school's Information Technology laboratory, but in any place, provided that smart portable devices are available. It can even be applied outside the school during educational visits and school trip activities, taking advantage of the benefits of outdoor learning activities (Dillon et al., 2006).

PhysGramming provides a writing and audio mode. Audio mode is suitable for students who have not developed writing skills yet. In attempting to briefly describe it, we should mention that, through PhysGramming, students practice assigning values to the attributes of a group of entities, within the context of a thematic unit. Which entities will be studied is the students' own choice. The entities are visualised through images embedded into PhysGramming by the teacher, while preparing the lesson. In the case of outdoor learning activities, students can photograph the entities under study with their smart portable devices and then use the photographs they took. Alternatively, students can paint their own pictures using a painting application we implemented and embedded into PhysGramming. When the assignment of the values of the entities' attributes is completed, PhysGramming automatically creates puzzles, matching games and group games. The uniqueness of these games is ensured by the uniqueness of the students' paintings and photographs, as well as by which entities each student chooses.

To understand the functionality of PhysGramming, as well as the methodology for integrating it into the educational process, let's focus on the study of the animals and especially on their eating habits. The content of this lesson must be presented to the students by the teacher before using PhysGramming. The example is illustrative, since PhysGramming is designed to allow the study of any entity, living or non-living. In any case, the teacher chooses what characteristics of the entities are going to be studied, but the students themselves define the values of the attributes. For example, if the subject of the lesson is material objects, the teacher may specify that the characteristics under study will be the "NAME" and the "MATERIAL" of the objects. The attribute "MATERIAL" has three possible values (solid, liquid, gas), which are entered into PhysGramming by the students.

In the case of studying the animals, and particularly their eating habits, the first thing the student/user of PhysGramming must do is to select and/or paint the pictures of the animals they want to deal with. When the selection and/or creation of the images is completed, a number of command lines appear on the screen (Figure 1). The next step is to determine the value of the attribute "NAME" for each animal. The child can add as many lines as they wish and delete some of the lines they have already added. As shown in Figure 1, through PhysGramming we propose a hybrid schema of visual and text-based programming techniques, with emphasis on object-orientation. However, no direct reference is made to programming concepts and practices.

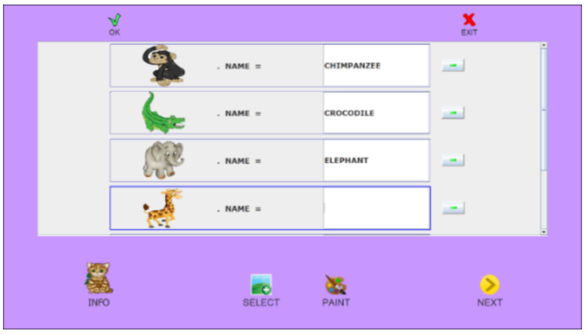

Figure 1. Assigning values to the attribute NAME

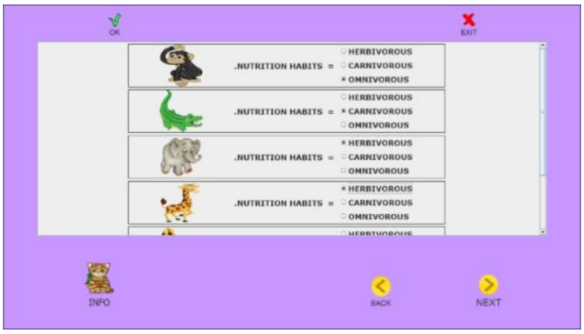

Figure 2. Assigning values to the attribute NUTRITION HABIT

Once the student/user of PhysGramming has identified the names of the animals, they must identify their eating habits (Figure 2). For each animal, the attribute "NUTRITION HABIT" can get a unique value from a set of three values: herbivorous, carnivorous and omnivorous. These values are given by the child as an entry into PhysGramming through a form specifically designed for this purpose.

When the assignment of values to the attribute "NUTRITION HABITS" is completed, all the information needed for the creation of the digital games has been entered into PhysGramming. Thus, it automatically creates puzzles, matching games and group games and the students choose which games they want to play with.

In group games, the pictures of the animals the student has selected to deal with are arranged randomly into groups that are defined by the values of the attribute under study. The child has to rearrange the pictures by dragging and dropping them into the right group (Figure 3).

In matching games, the student has to drag and drop the values of a particular attribute into the panel of the right entity (Figure 4).

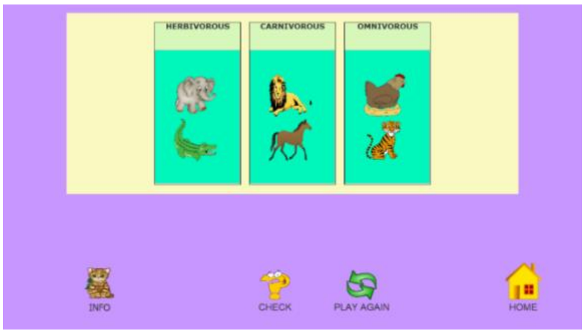

Figure 3. Group games

Figure 4. Matching games

PhysGramming creates puzzles for each animal image that the student has selected or painted. The user can choose the picture of the puzzle and its pieces: 4, 6, 9 or 12. Each puzzle (Figure 5) is a grid that contains mixed pieces of an animal's image. But, a part of the picture is missing. Thus, a cell of the grid is empty. Each piece can be moved horizontally, vertically or diagonally, provided that a neighboring part of the grid is empty. The piece to be moved will occupy the empty part of the grid and the previous part of the grid occupied by the piece moved will be empty. The user must reposition the pieces of the image until the puzzle is solved. The difficulty of solving the puzzles increases as the number of their pieces increase.

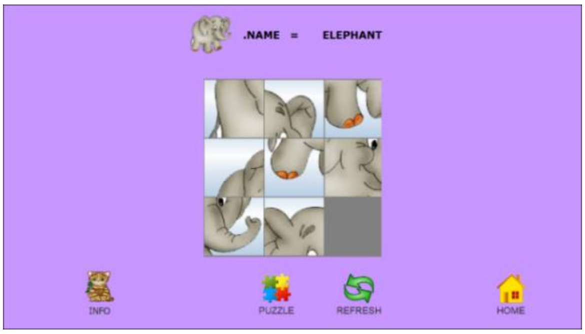

Figure 5. A puzzle game

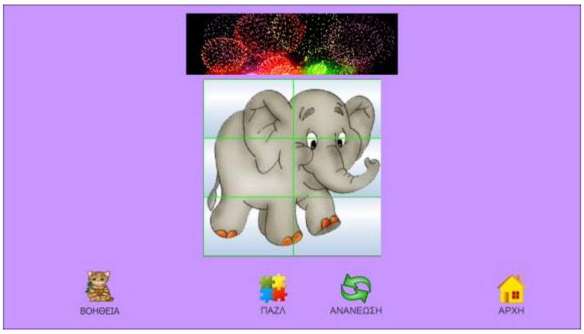

Figure 6. Rewarding the students when they solve a game

In all three games, students are rewarded with audiovisual media when they solve them. Specifically, when students manage to solve a game, a fireworks animation appears on the screen (Figure 6), accompanied by an audio reward. Our decision to include a fireworks animation aims to enhance the attractiveness and friendliness of PhysGramming, as these factors contribute to the effectiveness of educational software in achieving their learning goals (McManis & Gunnewig, 2012). International literature highlights the value of immediate reward, which encourages young children to increase their efforts to achieve their goals (Shoukry et al., 2015) and increases the chances for students to stay focused on what they are doing (Peijnenborgh et al., 2016; Richter et al., 2015). In addition, it fosters friendly competition among users (Montola et al., 2009) and enhances their self-confidence (Bleumers et al., 2012) and their acceptance by third parties (Richter et al., 2015).

The assessment tool

The relevant assessment tool we propose focuses on each one of the computational thinking concepts we aim to cultivate (Kanaki & Kalogiannakis, 2019). For each concept, we examine qualitative and quantitative factors (Cohen et al., 2002) that could lead us to conclusions about its cultivation (Table 1).

Table 1. Methods of collecting data

Skill		Methods of collecting data	
		Quantitative	Qualitative
Algorithmic thinking		Log files	Personal interviews
Abstraction		Worksheets	Observation
Data collection		Log files	Observation
Data organisation		Log files	Observation
Data analysis	Identify misconceptions	Personal interviews	Observation
	Reconsider choices	Worksheets	Observation

Applying the proposed assessment tool in the classroom requires two instructional hours. Before applying it, the teacher should have taught the section under study. During the first instructional hour, students construct their own digital games through PhysGramming and then they play with them. For the second instructional hour, they complete worksheets that are part of the assessment tool and are personally interviewed by the researcher.

The detailed presentation of the assessment tool is not the subject of this paper. However, in order to present its philosophy, let's discuss the way algorithmic thinking is evaluated. The quantitative data are provided by PhysGramming itself, which is programmed to keep track of students' actions and depict them in log files. These files, that do not include sensitive personal data (Livingstone & Locatelli, 2012), give information about the students' ability to solve puzzles. The qualitative data are derived from personal interviews, in order to determine if students hatch out a plan to solve the puzzles or if they act randomly. In the second case, the whole process involves just luck and no algorithmic thinking. Quantitative and qualitative data are analysed together for each student, in order to determine whether algorithmic thinking was successfully practiced.

The methodology of the pilots

The pilots were conducted by the first author attuned to the ethical guidelines of educational research and were both followed by an assistant researcher - observer. The target group was 27 children: 15 first grade students (four girls and eleven boys) and 12 second grade students (seven girls and five boys). The subject of both pilots was the fauna of Crete, focusing on the animals' eating habits.

The pilots (one for each class) were implemented in the Information Technology laboratory of the school as part of the Study of the Environment course. In Greece, this course encompasses the study of physical and natural sciences. Each pilot lasted three instructional hours (each instructional hour lasts 45 minutes). Children sat in pairs at the workstations. The researcher gave brief instructions about the functionality of PhysGramming. Each child had one hour to create their games and play with them. When both children of a pair had completed their tasks, they could play their games together.

Each one of the three kinds of games created through PhysGramming targets to cultivate fundamental computational thinking skills and introduce object-oriented programming concepts in playful and engaging ways. Through puzzles, we intend to cultivate algorithmic thinking (Hsu & Wang, 2018). Through group games, we aim to exercise the children's ability to organise data. Matching games aim to empower the skill to identify and to designate the attributes of an object.

While preparing the pilots, the researchers integrated into PhysGramming pictures of animals that do not live in Crete. Children should collect only the appropriate pictures and ignore the irrelevant ones. In this way, their skill of collecting data is exercised.

One of the pictures integrated into PhysGramming, portrayed a crocodile. Not much time had passed since a crocodile, the so-called "Sifis", was spotted in a lake of Crete. However, this does not mean that crocodiles are part of the island's fauna. In fact, the students' ability of abstraction should lead them to that conclusion and thus they should not select the crocodile's image. It should be noted that while discussing the content of the lesson, no reference was made about the animals that live in Crete. Therefore, selecting the crocodile's picture or not, did not depend on understanding the content.

Regarding data analysis, we exercise the students' ability to point out mistakes. Thus, we provide the children screenshots in which command lines are constructed with mistakes deliberately made, which children have to point out.

RESULTS

The thorough examination and study of the obtained data revealed that the overwhelming majority of children successfully practiced the computational thinking competencies. Difficulties that children faced were detected with defining the eating habits of the animals. Moreover, few of the children faced difficulties within the context of data analysis, when designating wrong perceptions regarding the eating habits of the animals. Nevertheless, we suspect that these difficulties might result from the poor understanding of the content of the relevant topic. This hypothesis is about to be examined shortly in a research we plan to conduct. As regards to the rest of the computational thinking competencies, they were successfully practiced by all the members of the target group.

As far as the qualitative results of the pilots is concerned, the students tended to paint their own images rather than choosing the ones embedded into PhysGramming. In addition, the syntax of the command lines did not trouble any of the students. This confirms our research hypothesis that the best period for introducing object-oriented programming into education is at the first stages of schooling.

After conducting the pilots, recording students' perceptions and experiences was considered necessary before proceeding with larger-scale research. Through personal interviews, we attempted to capture the general feeling left in the classroom after the pilots. Interviews were semi-structured (Newcomer et al., 2015) and lasted approximately 10 minutes for each child. All 27 of the children that participated in the pilots were interviewed immediately after the interventions. The open-ended questions asked intended to cover two main points: (a) highlighting the problems that students might encounter during the proposed educational framework and (b) identifying its most attractive features. The above mentioned points were also the main pillars of the research protocol of the interviews. Their semi-structured nature allowed children to discuss their experiences regarding the educational activity (Longhurst, 2003).

The proposed educational approach proved to be warmly received by students. While interviewing students, we investigated aspects of the approach they liked or disliked. We received a vast majority of enthusiastic responses and no negative response. A very interesting response was; "I liked it because I had to think, to create and to improvise".

DISCUSSION

The rationale for our research arose from the limited literature on cultivating computational thinking in early elementary grades. In this paper, we present the idea of enhancing fundamental computational thinking concepts at early childhood ages, through a fruitful, creative and engaging educational framework. The most important characteristic of the proposed framework is that children turn into creators, according to the theory of constructivism, while participating in physical and natural science courses, in a way that provides familiarity with basic aspects of computational thinking, without a direct reference to them. Furthermore, it satisfies the self-reliant philosophy of digital natives, the contemporary educational trend to disseminate computational thinking and the need for encouraging technological culture.

Our research is of general interest to the ESERA community, especially to scholars that applaud developing computational thinking in the first grades of primary school. It also concerns educators, researchers and policymakers that opt in favor of the learning theory of constructivism, endorse student-centered education, advocate game-based learning and are ready to adopt educational approaches that transform students from passive consumers to active creators of new technologies.

The limitations of our research have to do with the small sample used. However, we believe that the results of this small-scale research are significant, as they confirm the ease with which the proposed educational framework is implemented in the classroom as well as the positive impact it can have on enhancing computational thinking.

ACKNOWLEDGEMENT

We are especially indebted to the Special Account of Research of the University of Crete, which financially supports our research effort, KA 4713, PsysGramming (Physical Science Programming): An innovative game-based educational framework for the development of computational thinking in early childhood education within the context of physical science study.

REFERENCES

Akman, B., & Özgül, S. G. (2015). Role of play in teaching science in the early childhood years. In *Research in early childhood science education* (pp. 237-258). Springer, Dordrecht.

Angeli, C., Voogt, J., Fluck, A., Webb, M., Cox, M., Malyn-Smith, J., & Zagami, J. (2016). A K-6 computational thinking curriculum framework: Implications for teacher knowledge. *Journal of Educational Technology & Society*, *19*(3), 47-57.

Arnold, K., Gosling, J., & Holmes, D. (2005). *The Java programming language*. Addison Wesley Professional.

Barr, D., Harrison, J., & Conery, L. (2011). Computational thinking: A digital age skill for everyone. *Learning & Leading with Technology*, *38*(6), 20-23.

Barr, V., & Stephenson, C. (2011). Bringing computational thinking to K-12: what is Involved and what is the role of the computer science education community? *Acm Inroads, 2*(1), 48-54.

Bleumers, L., All, A., Mariën, I., Schurmans, D., Van Looy, J., Jacobs, A., Willaert, K. & de Grove, F. (2012). State of play of digital games for empowerment and inclusion: a review of the literature and empirical cases. *European Comission.*

Cohen, L., Manion, L., & Morrison, K. (2002). *Research methods in education*. London: Routledge.

Dillon, J., Rickinson, M., Teamey, K., Morris, M., Choi, M. Y., Sanders, D., & Benefield, P. (2006). The value of outdoor learning: evidence from research in the UK and elsewhere. *School science review*, *87*(320), 107-113.

Grover, S. (2015). "Systems of Assessments" for deeper learning of computational thinking in K-12. In *Proceedings of the 2015 annual meeting of the American educational research association* (pp. 15-20).

Grover, S., & Pea, R. (2013). Computational Thinking in K–12 *A Review of the State of the Field. Educational Researcher, 42*(1), 38-43.

Hillar, G. C. (2015). *Learning Object-oriented programming*. Packt Publishing Ltd.

Hsu, C. C., & Wang, T. I. (2018). Applying game mechanics and student-generated questions to an online puzzle-based game learning system to promote algorithmic thinking skills. *Computers & Education, 121*, 73-88.

Kalogiannakis, M., & Kanaki, K. (2020). Introducing Computational Thinking Unplugged in Early Childhood Education Within the Context of Physical and Natural Science Courses: A Pilot Study in Greece. In J. Keengwe, & P. Wachira (Eds.), *Handbook of Research on Integrating Computer Science and Computational Thinking in K-12 Education* (pp. 164-190). Hershey, PA: IGI Global.

Kalogiannakis, M., & Papadakis, St. (Eds). (2020). Tools for Teaching Computational Thinking in P-12 Education. USA-PA: IGI Global (under publication).

Kanaki, K., & Kalogianakis, M. (2019). Assessing Computational Thinking Skills at First Stages of Schooling. In *Proceedings of the 2019 3rd International Conference on Education and E-Learning* (pp. 135-139). New York: ACM.

Kanaki, K., & Kalogiannakis, M. (2018). Introducing fundamental object-oriented programming concepts in preschool education within the context of physical science courses, *Education and Information Technologies, 23(6)*, 2673-2698.

Kazakoff, E. R., Sullivan, A., & Bers, M.U. (2013). The Effect of a Classroom-Based Intensive Robotics and Programming Workshop on Sequencing Ability in Early Childhood*, Early Childhood Education Journal, 41*(4), 245-255.

Livingstone, S., & Locatelli, E. (2012). Ethical dilemmas in qualitative research with youth on/offline. *International Journal of Learning and Media, 4*(2), 67-75.

Longhurst, R. (2003). Semi-structured interviews and focus groups. *Key methods in geography*, *3*, 143-156.

Mattar, J. (2018). Constructivism and connectivism in education technology: Active, situated, authentic, experiential, and anchored learning. *RIED. Revista Iberoamericana de Educación a Distancia*, *21*(2), 201-217.

McManis, L. D., & Gunnewig, S. B. (2012). Finding the education in educational technology with early learners. *YC Young Children, 67*(3), 14.

Montola, M., Nummenmaa, T., Lucero, A., Boberg, M., & Korhonen, H. (2009). Applying game achievement systems to enhance user experience in a photo sharing service. In *Proceedings of the 13th International MindTrek Conference: Everyday Life in the Ubiquitous Era* (pp. 94-97). ACM.

Newcomer, K. E., Hatry, H. P., & Wholey, J. S. (2015). Conducting semi-structured interviews. *Handbook of practical program evaluation*, *492*.

Papadakis, St., Kalogiannakis, M., & Zaranis, N. (2016). Developing fundamental programming concepts and computational thinking with ScratchJr in Preschool Education. A case study. *International Journal of Mobile Learning and Organisation, 10*(3), 187-202.

Peijnenborgh, J. C., Hurks, P. P., Aldenkamp, A. P., van der Spek, E. D., Rauterberg, M. G., Vles, J. S., & Hendriksen, J. G. (2016). A study on the validity of a computer-based game to assess cognitive processes, reward mechanisms, and time perception in children aged 4-8 years. *JMIR serious games*, *4*(2), e15.

Richardson, V. (2005). Constructivist teaching and teacher education: Theory and practice. In *Constructivist teacher education* (pp. 13-24). Routledge.

Richter, G., Raban, D. R., & Rafaeli, S. (2015). Studying gamification: the effect of rewards and incentives on motivation. In *Gamification in education and business* (pp. 21-46). Springer, Cham.

Shoukry, L., Sturm, C., & Galal-Edeen, G. H. (2015). Pre-MEGa: a proposed framework for the design and evaluation of preschoolers' mobile educational games. In *Innovations and Advances in Computing, Informatics, Systems Sciences, Networking and Engineering* (pp. 385-390). Springer, Cham.

Sullivan, A., & Bers, M. U. (2016). Robotics in the early childhood classroom: learning outcomes from an 8-week robotics curriculum in pre-kindergarten through second grade. *International Journal of Technology and Design Education*, *26*(1), 3-20.

Sung, H. Y., & Hwang, G. J. (2013). A collaborative game-based learning approach to improving students' learning performance in science courses. *Computers & Education*, *63*, 43-51.

Sung, W., Ahn, J., & Black, J.B. (2017). Introducing Computational Thinking to Young Learners: Practicing Computational Perspectives Through Embodiment in Mathematics Education, *Technology, Knowledge and Learning, 22*(3), 443-463.

Voogt, J., Fisser, P., Good, J., Mishra, P., & Yadav, A. (2015). Computational thinking in compulsory education: Towards an agenda for research and practice. *Education and Information Technologies*, *20*(4), 715-728.

Wiegand, J. (2004). Eclipse: A platform for integrating development tools. *IBM Systems Journal*, *43*(2), 371-383.

Wing, J. M. (2006). Computational thinking. *Communications of the ACM, 49*(3), 33-35.

Zhu, Z. T., Yu, M. H., & Riezebos, P. (2016). A research framework of smart education. *Smart learning environments*, *3*(4), 1-17.

THE EXAMINATION OF QUESTIONING METHODS ON YOUNG CHILDREN'S CONCEPTUAL UNDERSTANDING OF ASTRONOMY

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This study aims to examine the coherency of children's responses to the sub-dimensions of the interview protocol, including different types of data collection modes (open-ended questions, modeling, and model selection) at different measurement times. The sample of the study consisted of 56 children (31 girls, 25 boys) aged between 60-72 months attending a kindergarten in a city center located in the northwestern part of Turkey. The 3 classes of 56 children are randomly assigned to the groups (Experiment [n:15], Control [n:20], Placebo: [n:21]). Inquiry-based play activities (12 activities for six weeks) designed for developing young children's conceptual understanding of astronomy are implemented in the experiment group. The curriculum-based astronomy activities were designed and implemented by the teacher of the placebo group, and there was no intervention in the control group. Data collection tools of this study were Earth and Day-Night Concepts Interview Protocol and Earth-2 test. "Earth and Day-Night Concepts Interview Protocol" consists of three parts, such as answering questions with verbal expressions, creating models, and making selections among models. Earth-2 enables children to choose the representations (2D) of their conceptual understandings on the shape of Earth and the day/night cycle. The coherency of children's responses was examined using Intra-Class Correlation Coefficients. The results demonstrated that the consistency of children's responses was weak for the shape of the Earth part of the interview protocol. On the other hand, the consistency of children's responses to the day and night concepts part of the interview protocol varied according to the measurement times.

Keywords: Conceptual understanding, Early childhood education, Science education

INTRODUCTION

Children tend to explore and discover everything around them with their natural and inborn curiosity (Mantzicopoulos et al., 2008) and desire to learn (Akman, Üstün, & Güler, 2003; Eshach & Fried, 2005; French, 2004; Gelman & Brenneman, 2004; Saçkes, Trundle, Bell, & O'Connell, 2011; Tu, 2006). The amount and diversity of children's knowledge in the first years of their lives increases surprisingly; especially children between the ages of two and seven can learn thousands of words, counting and reasoning, reading other people's feelings and thoughts, and develop concepts and phenomena related to biology, physics, and astronomy as well (Gelman, 2005). Young children have a passion for Earth, celestial bodies, and space (Kallery, 2011; Özsoy, 2012; Saçkes, Smith, & Trundle, 2016). Therefore, children are curious about the physical properties of the Earth and other planets, the cycles of the moon and the sun, and the day and night cycle, which in turn supports them to make observations, ask questions and produce explanations.

In the last 40 years, there has been a remarkable increase in the study of early childhood children's reasoning and conceptual understanding within their own development and learning patterns. The conceptual understanding of young children on astronomy has become one of the most investigated subjects recently. Pioneering studies of Vosniadou and Brewer (1992,1994) on children's conceptual understandings about the shape of Earth and the day-night cycle indicated that children might have three distinct mental models regarding these scientific phenomena. These mental models are; (1) Initial model, (2) Synthetic model, and (3) Scientific model. These models serve as frameworks underlining children's conceptual understandings about the physical properties of Earth and day-night phenomena. Initial models are derived from daily observations and show no interaction with scientific knowledge. On the other hand, synthetic models are blended with everyday experiences and cultural/ instructional information but still away from scientific knowledge. Synthetic mental models are defined as consistent and durable conceptual understandings within themselves. Scientific models consist of understandings aligning with scientific explanations.

The works of Vosniadou and Brewer (1992, 1994) have been criticized and challenged by researchers. One aspect of these criticisms focuses on the consistency of children's responses and suggests that children might not have a consistent conceptual understanding regarding scientific phenomena. While Vosniadou and Brewer (1992, 1994) assume that children use coherent mental structures based on their interpretations of daily observations and/or beliefs, the other theory proposed by diSessa (1983) advocates fragmented pieces of knowledge that derive from everyday experiences, are weakly organized and should be discussed within the coordination agents. From this point of view, children are thought as "theory-free"- have no strongly held opinions while they reflect their conceptual understanding of astronomy, i.e., the shape of the Earth (Panagiotaki, Nobes, & Banerjee, 2006). The other challenging aspect derives from the works of Vosniadou and Brewer is the methodological considerations. Two opponent theories about the conceptual understanding of children on astronomy concepts have used different methods to reveal children's ideas. These methods differ from each other in terms of questioning types and the tools used (Hannust & Kikas, 2012; Kampeza, 2006; Siegal, Butterworth, and Newcombe, 2004; Straatemeier, van der Maas, Jansen, 2008; Valanides et al., 2000). Thus, different probing ways produce conflicting results regarding the verbal explanations, drawings, 2D, and 3D structures of tasks of the interview protocols. Vosniadou and Brewer's (1992; 1994) interview protocols about the shape of the Earth and the day-night cycle comprise of open-ended questions and drawing tasks. Likewise, Hayes, Goodhew, Heit, and Gillan (2003), and Hannust and Kikas (2012) have used Vosniadou and Brewer's form with only a few alterations. The findings of these studies that use underline the coherent mental structures of children assessed instead of a collection of fragmented facts. Proponents of 'fragmented knowledge' assume that children's representations of the Earth (drawing pictures, making models) might make their knowledge look like limited or they might have coherent mental models (Nobes and Panagiotaki, 2009; Panagiotaki, Nobes & Banerjee, 2006; Siegal et al., 2004). Moreover, the recent critics underline the inadequacy of open and generative questions that are challenging and confusing to reveal children's scientific knowledge about the matter (Frede et al., 2011; Nobes and Panagiotaki, 2009). On the contrary, the studies challenging with the mental model account put the importance of the recognition of child forward and use selection tasks (making selection from a set of models or pictures) and forced-choice tests (Frede et al., 2011; Nobes, Martin, and Panagiotaki, 2005; Panagiotaki, Nobes, and Banerjee, 2006; Straatemeier et al., 2008). These two-opponent views interfere with each other regarding the methods used to identify children's answers, whether scientific or naïve. Besides these methodological issues, recent studies have also investigated the effect of an instructional intervention on conceptual change and even the coherence of children's answers to different probing methods (Hannust and Kikas, 2007; Hayes et al., 2003).

From this point forth, this study takes the different point of views and questioning methods using open and forced-choice questions and model selection tasks regarding the intervention effect. The present study aims to examine the coherency of children's responses to the sub-dimensions of the interview protocol targeting children's conceptual understandings of the shape of the Earth and day-night cycle at different measurement times.

METHOD

This study is designed as a pre-test post-test quasi-experimental design within the embedded experimental mixed method, which might aim to embed both qualitative and quantitative data within the qualitative interpretation.

Participants

The sample of the study consisted of 56 children (31 girls, 25 boys) aged between 60-72 months attending the kindergarten in a city center located in the northwestern part of Turkey. The 3 classes of 56 children are randomly assigned to the groups (Experiment [n:15], Control [n:20], Placebo: [n:21]).

Instruments

Data collection tools of this study were Earth and Day-Night Concepts Interview Protocol (Saçkes, 2015) and Earth-2 test (Straatemier et al., 2008). "Earth and Day-Night Concepts Interview Protocol" consists of three parts, such as answering questions with verbal expressions, creating models, and making selections among models created by researchers. Besides, Earth-2 enables children to choose the representations (2d) of their conceptual understandings on the shape of Earth and the day/night cycle. This protocol allows for gathering different types of data to reveal children's conceptual understandings on Earth and the day-night cycle.

Data Analysis, Categorization and Coding

Children's responses to the interview protocol were coded by the researchers within the framework of mental models presented in the literature on the shape of the Earth and the day-night cycle. Responses were analyzed by coding as 0 (initial), 1 (synthetic), and 2 (scientific). This coding is based on the scientific/non-scientific nature of the mental models that children have, the use of daily observations, or the effect of acculturation. The coherencies of children's responses were examined using Intra-Class Correlation Coefficients within SPSS version 24.

Intervention Procedure

In the present study, inquiry-based teaching is used as a suitable method to teach children the nature of science and scientific concepts since this method enables children to involve in practical activities, meaningful discussions, and requiring active participation of learners. Inquiry-based activities are integrated activities that might be comprised of play, science, drama, and the other domains of early childhood curriculum and directly target to develop young children's conceptual understanding of astronomy, especially the shape of Earth and day-night cycle phenomenon.

Inquiry-based play activities (12 activities for six weeks) designed for developing young children's conceptual understanding of astronomy are implemented in the experiment group. The curriculum-based science activities deal with astronomy designed by the teacher of the placebo group are implemented in the placebo, and there was no intervention in the control group.

RESULTS

The consistency of the responses of the interview protocol to the sub-dimensions of the Earth's shape concepts can be interpreted as very weak (ICC_{PRE} = .017, ICC_{POST} = .277, ICC_{FOLLOW} = .277) (Cicchetti, 1994). The consistency of the responses to the sub-dimensions related to the day and night concepts of the interview protocol (ICC_{PRE} = .134, ICC_{POST} = .507, ICC_{FOLLOW} = .634) varies according to the measurement times. These results indicate that the responses of children to the questions related to the day and night formation were moderately compatible in the post-test and that children produced well-matched responses in the follow-up test.

Table 1. Consistency of Responses to Interview Protocol Sub-Dimensions (Whole Group).

		Pre-test	Post-test	Follow-up test
The shape of Earth	**Whole group (N=56)**	ICC_{PRE} (p= .402)	ICC_{POST} (p=.001)	ICC_{FOLLOW} (p= .001)
		.017 (-.121-.189)	*.277* (.113-.452)	*.277* (.112-.452)
Day-night cycle		ICC_{PRE} (p=.046)	ICC_{POST} (p= .001)	ICC_{FOLLOW} (p= .001)
		.134 (-.021-.313)	*.507* (.350-.651)	*.634* (.498- .750)

*ICC: Intraclass Correlation Coefficency (%95 Confidence Interval)

It is seen that there is no consistency in the responses of children when the whole group are considered. However, Table 2. shows that the consistency of the answers given by the experimental group children to the questions and tasks related to the day and night increases over the course of three measurement occasions. The consistency in children's responses has started to increase immediately after inquiry-based play activities and continue to increase in the follow-up test ($ICC_{PRE} = .195 < ICC_{POST} = .567 < ICC_{FOLLOW} = .729$). For the control group, there was a poor agreement between the sub-dimensions of interview protocol, whereas in the placebo group there is a partial but non-gradual increase in the follow-up test ($ICC_{PRE} = .283 > ICC_{POST} = .253 < ICC_{FOLLOW} = .610$).

Table 2. Consistency of Responses to Interview Protocol Sub-Dimensions (Within Group)

		Pre-test	Post-test	Follow-up test
The shape of Earth	Experiment	ICC$_{PRE}$ (p=.197)	ICC$_{POST}$ (p=.681)	ICC$_{FOLLOW}$ (p= .094)
		.129 (-.150-.498)	-*.079* (-.288-.276)	*.207* (-.091-.565)
	Control	ICC$_{PRE}$ (p=.618)	ICC$_{POST}$ (p=.352)	ICC$_{FOLLOW}$ (p= .451)
		-*.045* (-.243-.257)	*.045* (-.180-.359)	*.010* (-.205-.321)
	Placebo	ICC$_{PRE}$ (p=.645)	ICC$_{POST}$ (p=.061)	ICC$_{FOLLOW}$ (p= .300)
		-*.053* (-.244-.239)	*.205*(-.050-.504)	*.064* (-.162-.369)
Day-night cycle	Experiment	ICC$_{PRE}$ (p= .107)	ICC$_{POST}$ (p=.001)	ICC$_{FOLLOW}$ (p= .001)
		.195 (-.100-.555)	*.567* (.264-.807)	*.729* (.485-.889)
	Control	ICC$_{PRE}$ (p= .513)	ICC$_{POST}$ (p=.001)	ICC$_{FOLLOW}$ (p= .176)
		-*.010* (-.219-.297)	*.419* (.143-.681)	*.122* (-.122-.436)
	Placebo	ICC$_{PRE}$ (p= .018)	ICC$_{POST}$ (p=.029)	ICC$_{FOLLOW}$ (p= .001)
		.283 (.018-.571)	*.253* (-.009-.546)	*.610* (.369-.800)

*ICC: Intrarclass Correlation Coefficency (%95 Confidence Interval)

DISCUSSION

The findings of this study obviously indicate that different probing modes may produce different results. In a similar study, it was observed that forced-choice questions provide more accurate answers than open-ended questions, and open questions frequently produced responses assigned to initial and synthetic models (Panagiotaki et al., 2006). In a study by Siegal et al. (2004), a multidimensional interview protocol was used to examine the understanding of preschoolers on the concepts of astronomy, and the findings of this study showed that the questions that were easily understood and directly addressed produced more consistent and meaningful answers than the open-ended productive questions. Likewise, Panagiotaki, Nobes, and Potton (2009) adapted confusing and vague questions into more direct and clear ones, by the way, they elicited more accurate answers indicate children's mental models as scientific rather than naïve synthetic.

The methods used for discovering children's mental models about the scientific phenomena might generate different results conflicting with each other. The results of these studies suggest that poor compliance between the sub-dimensions of interview protocol presented in table 2 may be due to method effects. Children might undergo short-term conceptual changes that eventually produce consistent answers to different modes of data collection (drawing, model building, and open / closed-ended questions) (Blown & Bryce, 2006). Hannust and Kikas

(2012) also conclude that even 4th-grade students can produce scientific answers cannot express their knowledge by using other mediums like drawings or making a model.

Another aim of this study deals with the change of consistency among responses to sub-dimensions according to different measurement times. The present study explains that children generate more accurate and consistent answers, especially about the day-night cycle phenomenon as they get knowledge and have experience with it. Inquiry-based activities as an intervention program may explain the increase in consistent responses to different types of questioning methods in the experimental group. The studies examine the conceptual change, and the consistency of assessment methods have similar results show that children provide more coherent and scientifically acceptable answers in interviews as they get older and become informed about the phenomena (Bryce and Blown, 2013; Frede et al., 2011; Hannust and Kikas, 2010; Hayes et al., 2003; Nobes, Martin and Panagiotaki, 2005).

The overall findings of the present study suggest that different probing modes may cause children to produce inconsistent responses and as children's understandings about the scientific concepts and phenomena develop, children provide consistent answers to varying types of data collection tools.

REFERENCES

Akman, B., Üstün, E., & Güler, T. (2003). 6 yaş çocuklarinin bilim süreçlerini kullanma yetenekleri. *Hacettepe Üniversitesi Eğitim Fakültesi Dergisi*, 24, 11–14.

Blown, E. J., & Bryce, T. G. K. (2006). Knowledge Restructuring in the Development of Children' s Cosmologies Knowledge Restructuring in the Development of Children's. *International Journal of Science Education*, 28(12), 1411–1462. http://doi.org/10.1080/09500690600718062

Bryce, T. G. K., & Blown, E. J. (2013). Children's Concepts of the Shape and Size of the Earth , Sun and Moon. *International Journal of Science Education*, 35(3), 388–446. http://doi.org/10.1080/09500693.2012.750432

Cicchetti, D. V. (1994). Guidelines, criteria, and rules of thumb for evaluating normed and standardized assessment instruments in psychology. *Psychological Assessment*. 6(4):284–290.

diSessa, A. A. (1993). Toward and epistemology of physics. *Cognition and Instruction*. 10(2-3), 105-225.

Eshach, H., & Fried, M. N. (2005). Should science be taught in early childhood? *Journal of Science Education and Technology*, 14(3), 315–336. http://doi.org/10.1007/s10956-005-7198-9

French, L. (2004). Science as the center of a coherent, integrated early childhood curriculum. *Early Childhood Research Quarterly,* 19(1), 138–149. http://doi.org/10.1016/j.ecresq.2004.01.004

Frede, V., Nobes, G., Frappart, S., Panagiotaki, G., Troadec, B., & Martin, A. (2011). The Acquisition of Scientific Knowledge : The Influence of Methods of Questioning and Analysis on the Interpretation of Children ' s Conceptions of the Earth. *Infant and Child Development*, 20 (April), 432–448. http://doi.org/10.1002/icd

Gelman, S. A. (2005). Early conceptual development. In K. McCartney & D. Phillips (Eds.), *Blackwell Handbook of Early Childhood Development.* Singapore: Blackwell Publishing.

Gelman, R., & Brenneman, K. (2004). Science learning pathways for young children. E*arly Childhood Research Quarterly*, 19(1), 150–158. http://doi.org/10.1016/j.ecresq.2004.01.009

Hannust, T., & Kikas, E. (2007). Children's knowledge of astronomy and its change in the course of learning. *Early Childhood Research Quarterly*, 22(1), 89–104. http://doi.org/10.1016/j.ecresq.2006.11.001

Hannust, T., & Kikas, E. (2010). Young children's acquisition of knowledge about the Earth: A longitudinal study. *Journal of Experimental Child Psychology*, 107, 164-180.

Hannust, T., & Kikas, E. (2012). Changes in children's answers to open questions about the earth and gravity. *Child Development Research,* 2012, 1–10. http://doi.org/10.1155/2012/613674

Hayes, B. K., Goodhew, A., Heit, E., & Gillan, J. (2003). The role of diverse instruction in conceptual change. *Journal of Experimental Child Psychology*, 86, 253–276. http://doi.org/10.1016/j.jecp.2003.09.002

Kallery, M. (2011). Astronomical Concepts and Events Awareness for Young Children. *International Journal of Science Education*, (October 2013), 341–369. http://doi.org/10.1080/09500690903469082

Kampeza, M. (2006). Preschool children's ideas about the Earth as a cosmic body and the day / night cycle. *Journal of Science Education*, 7(2), 119–122.

Mantzicopoulos, P., Patrick, H., & Samarapungavan, A. (2008). Young children's motivational beliefs about learning science. *Early Childhood Research Quarterly*, 23(3), 378–394. http://doi.org/10.1016/j.ecresq.2008.04.001

Nobes, G., Martin, A. E., & Panagiotaki, G. (2005). The development of scientific knowledge of the Earth. *British Journal of Developmental Psychology*, 23, 47-64.

Nobes, G., & Panagiotaki, G. (2009). Mental models or methodological artefacts? Adults' 'naïve' responses to a test of children's conceptions of the earth. *British Journal of Psychology*, 100, 347-363.

Özsoy, S. (2012). Is the Earth Flat or Round? Primary School Children's Understandings of the Planet Earth: The Case of Turkish Children. *International Electronic Journal of Elementary Education*, 4(2), 407–415.

Panagiotaki, G., Nobes, G., & Banerjee, R. (2006). Children' s representations of the earth: A methodological comparison. *British Journal of Developmental Psychology*, 24, 353–372. http://doi.org/10.1348/026151005X39116

Panagiotaki, G., Nobes, G., & Potton, A. (2009). Journal of Experimental Child Mental models and other misconceptions in children ' s understanding of the earth. *Journal of Experimental Child Psychology*, 104(1), 52–67. http://doi.org/10.1016/j.jecp.2008.10.003

Saçkes, M. (2015). Kindergartners' mental models of the day and night cycle: Implications for instructional practices in early childhood classrooms. *Educational Sciences: Theory & Practice*, 15(4), 997-1006.

Saçkes, M., Smith, M. M., & Trundle, K. C. (2016). US and Turkish preschoolers ' observational knowledge of astronomy. *International Journal of Science Education*, 38(1), 116–129. http://doi.org/10.1080/09500693.2015.1132858

Saçkes, M., Trundle, K. C., Bell, R. L., & O'Connell, A. a. (2011). The influence of early science experience in kindergarten on children's immediate and later science achievement: Evidence from the Early Childhood Longitudinal Study. *Journal of Research in Science Teaching*, 48(2), 217–235. http://doi.org/10.1002/tea.20395

Siegal, M., Butterworth, G., & Newcombe, P. A. (2004). Culture and children's cosmology. *Developmental Science*, 7(3), 308–324. http://doi.org/10.1111/j.1467-7687.2004.00350.x

Straatemeier, M., van der Maas, H. L. J., & Jansen, B. R. J. (2008). Children's knowledge of the earth: a new methodological and statistical approach. *Journal of Experimental Child Psychology*, 100(4), 276–96. http://doi.org/10.1016/j.jecp.2008.03.004

Tu, T. (2006). Preschool Science Environment: What Is Available in a Preschool Classroom? *Early Childhood Education Journal*, 33(4), 245–251. http://doi.org/10.1007/s10643-005-0049-8

Valanides, N., Gritsi, F., Kampeza, M., & Ravanis, K. (2000). Changing Pre-school Children's Conceptions of the Day/Night Cycle. *International Journal of Early Years Education*, 8(1), 27–39. http://doi.org/10.1080/096697600111725

Vosniadou, S., & Brewer, W. F. (1992). Mental models of the earth: A study of conceptual change in childhood. *Cognitive Psychology*, 24(4), 535–585. http://doi.org/10.1016/0010-0285(92)90018-W

Vosniadou, S., & Brewer, W. F. (1994). Mental models of the day/night cycle. *Cognitive Science*, 18, 123–183. http://doi.org/10.1016/0364-0213(94)90022-1

CASE STUDIES OF COLLABORATIVE MODEL-BASED REASONING FOR CONCEPTUAL CHANGE IN PRESCHOOL CHILDREN

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Contemporary multi-dimensional approaches conceptualize the notion of conceptual change as a slow and gradual affair that requires not only the restructuring of students' intuitive theories, but also the restructuring of their modes of learning, the creation of metaconceptual awareness and intentionality. Towards this goal many researchers emphasize the importance of model based reasoning and argumentation, as instructional practices that provide a fruitful combination of dissonance with knowledge building strategies, and also crucial understandings about the nature of science. Whereas such means have been proved successful in secondary education, there is a debate about their effectiveness among preadolescent students, due to developmental constraints. In our study, we investigated whether a collaborative model-based problem-solving learning environment could facilitate preschool children's conceptual change regarding the phenomenon of day and night cycle. Key features of the learning environment were: a) the use of narrating and theatrical play parts, inspired by the tale of the Little Prince, aiming to meaningfully engage preschool children, b) the construction and manipulation of play dough models by the children as means to help them make their implicit ideas overt and explain the phenomenon of day and night cycle, c) collaborative discourse and argumentative reasoning processes among students in order to examine and juxtapose each other's models, and d) a collaborative problem-solving task that incorporated the fact, that the day and night cycle phenomenon takes place on another planet, data that could be anomalous for the geocentric intuitive conceptions. Regarding the implications of a learning environment with such characteristics to three groups of preschool children, the results show important aspects of intentional conceptual change, including reasoned change in children's geocentric models towards heliocentric representations. We argue that these changes were the outcome of a deep engagement process, where children's implicit ideas were gradually transformed into reasoned views.

Keywords: Conceptual Change, Model-based reasoning, Pre-school Education

THEORETICAL BACKGROUND

Conceptual change (CC) has become a common conception of meaningful learning, treating learning as an intentional, dynamic, and constructive process (Duit & Treagust, 2012). Contemporary CC approaches denote a gradual and multi-dimensional learning process, rather than a sudden and radical restructuring of knowledge (Vosniadou, 2003), overcoming the individualistic and radical construvistic perspectives of the early 80's. Framework theory suggests that CC includes not only the restructuring of student's intuitive ideas and the creation of new ontologies. It also signifies considerable metacognitive, epistemic and representational abilities that allow learners to be aware of their ideas, relate them to the scientific ones, notice the discrepancy between them, engage in hypothesis testing, and proceed with conceptual change as reasoned change (Vosniadou & Skopeliti, 2014). A central challenge for contemporary CC approaches is how to simultaneously promote conceptual understanding as well as growth in reasoning, epistemic cognition and interest about science (Duit & Treagust, 2012). To this end, new science education standards highlight the importance of students' participation in first-hand experiences that reflect communally recognized scientific practices (Kidn & Osborne, 2017).

In search of instructional practices

Model-based reasoning and collaborative problem-solving tasks are considered significant means of developing not only learners' conceptual understanding, but also their epistemic believes and appreciation of science, reflecting core scientific practices. Nersessian (2008) argues that model-based reasoning is fundamentally related to conceptual innovation and change, mediating scientists reasoning to the new representations. Lehrer and Schauble (2015) also argue that modeling is the most defining practice of science and they suggest conceiving other practices in relation to this foundational one, whereas Osborne (2010) suggests that collaborative and argumentative practices reflect the social construction of scientific knowledge.

It is well documented that model-based reasoning and collaborative problem-solving environments can foster CC, providing a fruitful combination of cognitive dissonance with knowledge building strategies (Vosniadou, 2003). In educational settings, modeling transforms implicit physical knowledge into an explicitly coded external model, making it available for examination, questioning, revision, and further theorizing in either an individual base or a group discussion (Vosniadou, 2013). Therefore, it is argued that it could enable learners become aware of their beliefs and the presuppositions that define their reasoning.

Arguments about problem-solving suggest that it could help students be purposeful and planful, thus caltivating intentional learning. Hatano and Inagaki (2003) suggest, that alongside collaborative, argumentative or discourse practices, problem-solving environments ensure that students understand the need to fundamentally revise their believes, instead of engaging in local repairs. And furthermore, that they spend a considerable amount of time and effort in order to engage in the conscious and deliberate belief revision required for CC (Vosniadou, 2003). Argumentative practice is, moreover, suggested to enable learners to transform their personal beliefs into reasoned views, learning gradually to transfer this way of thinking beyond the specific dialogical contexts (Osborne, 2010).

Whereas such means have been proved successful in secondary education, there is a debate about their effectiveness among preadolescent students, due to developmental constraints. Research in cognitive developmental phycology (Pintrich & Sinatra, 2003) suggests that the cognitive abilities that are required for CC are not formed in preschool children. Previous research (Kuhn & Weinstock, 2002; Kyriakopoulou & Vosniadou, 2014) suggests that preschool students lack the cognitive flexibility and the epistemological sophistication to engage in hypothesis testing. The literature is inconclusive on how and when students' reasoning capabilities develop. A subset of scholars argues that they develop through adolescence, while another strand of researchers suggests that even preadolescent children are capable of making evidence-based inferences (Osborne, 2010).

In our study, we investigate whether such a learning environment of collaborative model-based problem-solving could facilitate preschool children's CC processes regarding the phenomenon of day and night cycle. Adopting Vosniadou's approach about the CC processes, we also investigate the characteristics of any possible changes in children's perceptions and representations, i.e. if can they be described as intrinsically motivated and reasoned changes.

METHODOLOGY

The research procedure

Considering the call for inclusive children-centered research methodologies for early childhood (Fleer & Robbins, 2003), the current study used a story, inspired by the tale of the Little Prince, in order to set a friendly and appealing environment to meaningfully engage preschool children in the problem-solving and modeling procedure. The story was adapted in a theatrical play, so that the children and the researcher would be actively participating in it. In the context of this play the children and the interviewer followed the Little Prince through his journey from Earth to his planet and were asked to address specific questions and tasks regarding the phenomenon of day and night cycle.

The research was designed as a semi - structured procedure, taking place in three stages:

(a) In the first stage the goal was to investigate children's ideas about the phenomenon of day and night cycle. Kids were asked to use play-dough in order to create models of the Earth, the Sun, the Moon and other celestial objects. Alongside the modelling, kids were asked a set of questions that were based on the questionnaire of Vosniadou and Brewer (1992 & 1994), in order to explain the phenomenon The questions were addressed, at first, to each kid individually.

Our hypothesis was that children would express multiple representations of the phenomenon, but would be committed to their ontological presupposition when answering to open ended generative questions Vosniadou & Brewer 1992; Vosniadou & Brewer, 1994; Vosniadou & Skopeliti, 2017).

(b) On the second stage our purpose was to engage kids into collaborative and argumentative discourses. We asked them to present their models to the team, and notice if their models and explanations were different. In order to challenge them deeper into collaborative model-based reasoning we asked them to try to make a joint decision about the most plausible and fruitful representation of the phenomenon. The aim was to provoke argumentation amongst different models, so that the children would examine their beliefs in comparison to the different models presented and question each other's explanatory adequacy.

At this phase we investigated the way that kids would deal with data that confront their ontological presuppositions. Based on previous research (Chinn & Brewer 1993; Vosniadou & Skopeliti 2017) our hypothesis was that they would ignore or reject the confronting data.

(c) The third phase included/implicated the kids into a problem-solving task, derived from the emerging/set by the story data that day and night cycle takes place not only on Earth, but also on another planet (here on the Little Prince's planet). This data could be anomalous for the geocentric intuitive conceptions that many preschoolers hold, thus resulting to cognitive dissonance. The kids were asked to engage in model-based reasoning in order to find a solution to their problem. This took place first individually, then as a collaborative and argumentative process.

Based on (Hatano & Inagaki, 2003) we hypothesized that the problem would introduce anomalous data that would urge kids to re-examine their own beliefs and test new hypothesis on the grounds of the most fruitful, reasonable and plausible solution.

The sample

Three teams of preschool children participated in the aforementioned process. The 1st and the 2nd team consisted of three children (three girls and three boys correspondingly), while the 3rd team of two children (two girls). All children were chosen by the school director of a private kindergarten school in Athens and were in the same class. The researcher had no previous familiarization with the sample.

The method of analysis

The 'interviews' were videotaped and analysed with a qualitive method of context analysis (Erickson, 2012). More analytically, the videos were split in episodes in accordance to the three stages of the research procedure. Our focus was on any possible changes on children's perceptions and representations through these stages and the parameters that seemed to triggered them. Moreover, we investigate whether these changes follow the patterns of reasoned change or compliance.

For this reason, each episode was analysed with respect to: (a) the students' ideas about the shape of the Earth, their ontological beliefs and their explanations of day and night phenomenon, (b) the students' reactions when confronting the new data emerging either by their peers or the story and the kind of data that provoke a problem-solving procedure and/or an intrinsically motivated argumentation (i.e. in which circumstances do they reject the data, when do they ignore them and when do they get involved in a process of 'negotiating'/re-examining their perceptions), (c) the role and use of models through the process of the argumentation (i.e. do they use them only as means of making their beliefs explicit and communicating or additionally as means of revising their own beliefs, making 'inventing' ways of explaining a phenomenon and testing this hypothesis).

RESULTS

The students' ideas expressed in the three phases of the research are summarized in Table 1. As shown at the first column, in the first phase of the research where students individually expressed and modeled their ideas about the shape of the Earth and the way the day and night cycle phenomenon occurs, half of the participating kids initially created the model of the spherical Earth and attributed the phenomenon to the rotation of the Earth around its axis in a sun-centered system (scientific view). Two children (K2 and K3) created models of the flattened sphere, where the Earth seems spherical, but humans only live at the top, and the day and night phenomenon occurs due to the movements of the Sun and the Moon respectively (when the night comes, the Moon comes in front of the Sun). The Sun and Moon motions also 'create' the phenomenon in the models of K4 and K5, where the celestial bodies move vertically up and down the intuitive flat-earth model of the children.

As we can see in the second column, the initial representations of the children did not change during the second phase of the research, where the kids were exhorted to participate in a process of argumentation regarding the different representations and explanations presented. On the contrary, in the process they rejected or even ignored the ideas of their peers, which confirms our second hypothesis and replicates the results of Chinn & Brewer (1993) and Vosniadou & Skopeliti (2017). In addition, at this stage, children needed to be externally mobilized to engage in the dialogue. Usually the researcher asked questions and tried to provoke an argumentation, though the conversation seemed not to have any flow.

In the third phase of the research process, where children were involved in a collaborative problem-solving process, conceptual development was observed in four of the eight students. In particular, all children with initially geocentric ideas revised them in favor of the sun-centric ones. These data corroborate the third research hypothesis and are consistent with the literature of Hatano & Inagaki (2003). It seems that the problem raised at this stage did indeed bring anomalous data that caused cognitive dissonance among students with geocentric perceptions. At this stage, the students were acting with significantly greater autonomy and appeared to be internally motivated. As part of the problem-solving process, the students consciously reorganized their representations in their quest for a model that would be most plausible and fruitful for the data emerged (explain that phenomenon of day and night cycle takes place both on our planet and on others).

	1st Stage	2nd Stage	3rd Stage
Childrens' concepts about the day/ night cycle	4 kids **(K1, K6, K7, K8):** • <u>**Earth shape:**</u> **Spherical,** • <u>**Solar system:**</u> **Heliocentric,** • <u>**Explanation of day and night cycle:**</u> **Rotating Earth around axis** 2 kids **(K2, K3):**	**No conceptual change among students.**	**Students do not modify the shape of the Earth.** 6 kids **(K1, K4, K5, K6, K7, K8) in order to solve the problem of the appearance of the phenomenon on another planet, create cooperatively solar**

	• **Earth shape:** **Flattened sphere,** • **Solar system:** **Geocentric,** • **Explanation of day and night cycle:** The Sun and the Moon move vertically up and down 2 kids **(K4, K5):** • **Earth shape:** **Flat,** • **Solar system:** **Geocentric,** • **Explanation of day and night cycle:** When the night comes, the Moon comes in front of the Sun		**systems where the effect is due to the rotation of each planet around its axis.** 2 kids **(K2, K3) create a solar system so that the Sun can illuminate all the planets, but they still explain the phenomenon by putting in turns the Moon in front of the Sun to create the night and inversely for the day.**
The role and use of models	**They use the models in order to make their ideas explicit and to be able to explain them**	**They use the models in order to explain their ideas to each other and compare them**	**They use models to evaluate the explanatory power of their model under the light of the new data, to make new hypothesis and testify them**
Students' reactions when confronting the new data		**They engage into the argumentation process** exhorted **by the researcher (external mobilization).** **They ignore and / or reject new data arising from their peers' arguments.**	**They engage in intense dialogue and deal with cases and new data brought about by internal mobilization.** They re-examine and make **evolve their representations** consciously**, by accepting and incorporating new data into their thinking.**

Table 1. Students' ideas and how they use modelling in order to respond to new data in argumentation and problem-solving processes.

Two episodes

Two episodes presented below are illustrating the dynamics of student dialogue and reasoning. The first episode occurs during the second phase of the research process and is a typical case of data rejection, as presented to the team. In this group, as mentioned above, two of the three children (K5: George and K4: Paul) interpreted the phenomenon with vertical movements of the Sun and the Moon over a flat Earth. The third child (K6: John) constructed a solar-centric system in which the phenomenon of day-night rotation was explained as the rotation of the spherical Earth around its axis.

Episode 1: Juxtaposing models and ideas

Researcher: What do you think about John's idea?... Have you ever heard that the earth rotates?

George: Yes! I have a globe- puzzle game! You make it round, then you put the basis that holds it, then the axis.. And then you can rotate it!

R: A ok! So you have seen it.

John: If it weren't so...

Paul: ... Here (he shows one side of his model) it would be forever day and on the other side ...

John and Paul: Forever night!

John: Yes.

Paul: But on my model as well… When the sun is here it doesn't shine on the other side!

Episode 2: Problem Solving

On the contrary, this episode presents the dynamics of the process of the argumentation that took place in the third phase of the research process, as an outcome of the emerging by the story anomalous data. As shown, the discussion became more intense and the kids seemed to experiment more freely with their models in order to find a more plausible and fruitful explanation.

On this part, a dialogue taking place between John and Paul is presented, in which John's arguments result in Paul's reasoned change.

John: How long would it take for the sun to go to all the other planets? How long would it take to go shine to all of them?

Paul: Then it wouldn‘t leave Earth.

John: But then, on the other planets will there only be night? And we, on the Planet of Little Prince, won't we be able to play?

Paul: There should be day as well…

John: So? Why do you say that the Sun won't shine on them? I mean, on your (model) the Prince is here, on his planet, and the sun is above Earth. How will it get there to shine?

Researcher: What's your solution? Where is your sun?

John: In the center.

Paul: A ok! So the sun shines everywhere at the same time!

CONCLUSION

In the context of collaborative model-based problem-solving along with storytelling and theatrical play, we witnessed the gradual transformation of children's implicit ideas into reasoned views. Children treated their as well other's ideas as hypotheses that could be tested, shared, argued and changed through the use of self-constructed models. The results show important aspects of intentional CC, including reasoned change in children's geocentric models towards heliocentric representations. We argue that the story was an important factor, creating a safe as well as engaging environment, with narrating spaces between research tasks, and most importantly, providing reasons for the preschool children to construct their models, juxtapose and argue about their representations. The construction and manipulation of models clearly supported children in a metacognitive manner, and made it possible for different positions to be elaborated, compared and contrasted. Without the ability to see and manipulate each other's ideas, as incorporated to the models, such an intense and lasting argumentative reasoning process wouldn't be possible among children of such young age.

Our results support the notion that intentional CC could be greatly supported and facilitated by schooling even in young ages. The limitations of the current study include the small sample and the fact that idiosyncratic factors may have had an impact on the presented results. However, we believe that these case studies show the potential of preschool children to fully engage in tasks that reflect scientific practices, where reasoning is understood as a problem-solving process via which one arrives at justified beliefs about natural phenomena. After all, as Driver et al. (2000) highlight, the process of enculturation into science comes about in a very similar way to the way a foreign language is learned—through its use.

REFERENCES

Chinn, C. A. & Brewer, W. F. (1993). The role of anomalous data in knowledge acquisition: A theoretical framework and implications for science instruction. Review of Educational Research, 63(1), 1–49.

Driver, R., Newton, P., & Osborne, J. (2000), Establishing the norms of scientific argumentation in classrooms. Science Education, 84, 287-312.

Duit, R. & Treagust, D. (2012). How Can Conceptual Change Contribute to Theory and Practice in Science Education?. In: Fraser B., Tobin K., McRobbie C. (eds) Second International Handbook of Science Education. Springer International Handbooks of Education, vol. 24. Springer, Dordrecht.

Erickson, F. (2012). Qualitative Research Methods for Science Education. In: Fraser B., Tobin K., McRobbie C. (eds) Second International Handbook of Science Education. Springer International Handbooks of Education, vol. 24. Springer, Dordrecht.

Fleer, M. & Robbins, J. (2003). "Hit and Run Research" with "Hit and Miss" Results in Early Childhood Science Education. Research in Science Education. 33. 405-431.

Hatano, G.& Inagaki, K. (2003). When is conceptual change intended? A cognitive-sociocultural view. In G.M. Sinatra & P.R. Pintrich (Eds.), Intentional conceptual change. Mahwah: Erlbaum

Kind, P. & Osborne, J. (2017). Styles of scientific reasoning: A cultural rationale for science education? Science Education, 101(1), 8–31.

Kuhn, D. & Weinstock, M. (2002). What is epistemological thinking and why does it matter? In B. K. Hofer & P. R. Pintrich (Eds.), Personal epistemology: The psychology of beliefs about knowledge and knowing (p. 121–144). Lawrence Erlbaum Associates Publishers.

Kyriakopoulou N. & Vosniadou S. (2014) Using Theory of Mind to Promote Conceptual Change in Science. _Science & Education_ 23 (7):1447-1462.
Lehrer, R. and Schauble, L. (2015). The Development of Scientific Thinking. In Handbook of Child Psychology and Developmental Science, R.M. Lerner (Ed.).
Nersessian, N. J. (2008). Creating scientific concepts. Cambridge, Mass: MIT Press.
Osborne, J. (2010). An argument for arguments in science classes. The Phi Delta Kappan, 91(4), 62-65.
Pintrich P.& Sinatra G. (2003) Future Directions for Theory and Research on Intentional Conceptual Change. In G.M. Sinatra and P.R. Pintrich (Eds). Intentional Conceptual Change. Mahwah, NJ: Lawrence Erlbaum Associates, Inc.
Vosniadou, S. & Brewer, W. F. (1992). Mental models of the earth: A study of conceptual change in childhood. Cognitive Psychology, 24, 535–585.
Vosniadou, S., & Brewer, W. F. (1994). Mental models of the day/night cycle. Cognitive Science, 18, 123–183
Vosniadou, S., & Skopeliti, I. (2014). Conceptual Change from the Framework Theory Side of the Fence. Science & Education, 23(7), 1427-1445.
Vosniadou, S. & Skopeliti, I. (2017). Is it the Earth that turns or the Sun that goes behind the mountains? Students' misconceptions about the day/night cycle after reading a science text. International Journal of Science Education. 39. 1-25.
Vosniadou, S. (2003). Exploring the Relationships between Conceptual Change and Intentional Learning. In G.M. Sinatra and P.R. Pintrich (Eds). Intentional Conceptual Change. Mahwah, NJ: Lawrence Erlbaum Associates, Inc.
Vosniadou, S. (2013) Model based reasoning and the learning of counter-intuitive science concepts. Infancia y Aprendizaje, 36(1), 5-33.

COGNITIVE STYLE AND MOTIVATION AND LEARNING IN INQUIRY BASED EARLY-YEARS SCIENCE ACTIVITIES

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Differences in children's motivation for science can be explained by the theory of "systemizing " and "empathizing" brains. Researchers claim that people with "systemizing " cognitive style are more engaged in science and more motivated to do science than those with "empathizing". They propose a suitable formulation of themes and didactic approaches to motivate children with an "empathizing" cognitive style. The aim of this work is to investigate how preschool and early-primary school children react according to their cognitive style in activities with specific characteristics. The approach of the activities was structured inquiry having as main features the guided by specific questions of the teacher building of knowledge through experiments and investigations, problem solving situations, forming coherent arguments, drawing conclusions and reflection. In this context children also had the freedom to test their own ideas that emerged spontaneously. The results showed large percentages of the highest levels of engagement/involvement which are signs of motivation that can be observed and recorded, and high success rates in children's learning outcomes for all types of cognitive style. The findings indicate that such type of activities and approach may be appropriate for triggering motivation and learning in science of young children with all types of brain.

Keywords: cognitive style, structured inquiry, motivation in science

INTRODUCTION

Previous studies that looked at different factors that influence the motivation and learning of young children in science have come to different conclusions. One of the most prevalent views was that boys have greater interest and more motivation to learn science than girls have (e.g. Alexander, Johnson & Kelley, 2012). In other studies the results varied according to the type of teaching and the instructional context in which science was taught. For example, kindergarteners who participated in a Scientific Literacy program based on a conceptually coherent sequence of integrated science inquiry and literacy activities, regardless of sex, had greater motivation for science than children who had only the regular science experience. (e.g. Patrick, Mantzicopoulos & Samarapungavan, 2009). Indeed, research on the relationship of different factors and science learning is inconclusive and asks for a change of paradigm.

The researchers argue that differences in children's motivation for science can be explained by the Empathizing-Systemizing (E-S) theory (Baron-Cohen, 2009). "Empathizing (E) (the drive to identify another person's emotions and thoughts and to respond to these with an appropriate emotion) is held to be generally stronger in females, whilst systemizing (the drive to analyze, explore and construct a system) is held to be generally stronger in males" (Auyeung et al., 2009, p. 1). Researchers claim that, regardless of gender, people with Systemizing cognitive style are more engaged in science and motivated to do science than those with Empathizing cognitive style. They suggested that people with an empathizing or a systemizing cognitive style need different approaches to science because, due to their brain types, they are not similarly motivated in this field of education. In order to motivate empathizing children for science, they suggest to appropriately formulating context, themes as well as didactic approaches (Zeyer et al., 2012).

Recent studies of science activities in an inquiry-based context with topics from physics and astronomy have shown great interest and at the same time very good learning outcomes in boys and girls of pre-school age (e.g. Kallery, 2011; Kallery, 2015). The approach of the activities was structured inquiry having as main features the guided by the teacher's specific questions building of knowledge through experiments and investigations, problem solving situations, forming coherent arguments, drawing conclusions and reflection. In this context children also had the freedom to test their own ideas that emerged spontaneously. Through these, they discovered and realized additional relationships between the different variables involved in the activity. Work in the classroom included collaboration in small multiage groups (Kallery & Loupidou, 2016) as well as whole-class discussions. The pictures presented in Figure 1 are characteristic of the work in the classrooms where children experimented. In this figure, in the first row on the left, the children guided by the teacher's questions study the conservation of mass. The next two pictures show children working in small groups investigating conservation of mass of pliable materials and of fluids. In the second row, on the left, the children work on the concept "the air takes the shape of the container into which we place it" and on the right they are testing one of their own ideas and try to find out if the air "does the same thing as the water does". They had the spontaneous idea to fill a balloon with water and then empty it and fill it with air. The testing of this idea helped them comprehend similarities in the behavior and characteristics of liquids and gasses.

Figure 1. Structured inquiry activities: Experimentation in real classroom settings

In the present study we investigated whether activities with the above characteristics affect differently the motivation and learning in science of children with different cognitive styles. But motivation cannot be observed. However, there are different signs of motivation which can be observed and recorded, such as: engagement/involvement, (which are closely linked to academic achievement), interest, which creates motivation and guarantees the engagement/involvement of a person in content-specific activities, persistence and satisfaction (O'Keefe, Horberg & Plante, 2017). In this paper, we study the engagement/involvement of the children in the activities and their learning outcomes. This allows us to diagnose whether children with empathizing cognitive style exhibit a lower degree of engagement/involvement than those with systemizing cognitive style (as supported in literature). For this, we implemented 5 conceptually coherent modular inquiry activities with the above approach and characteristics in preschool and early-primary school. Our study includes: a) Identifying the empathizing and systemizing quotients of every child and b) Investigating the level of engagement/involvement of each child in the activities and its cognitive achievements.

METHODOLOGY

Identification of the empathizing and systemizing quotients: Questionnaire

The empathizing and systemizing quotients were determined by analysis of data collected by specially formulated and validated by Auyeung et al. (2009) questionnaire completed by the parents of the children. The questionnaire included 55 questions a sample of which is presented in Figure 2. The questionnaire was adapted by our team to the context of our study. Its reliability was calculated giving a high Cronbach's alpha (for E:0.83, for S:0.81). The study involved 47 children aged 4-7 years attending public kindergarten and primary school. The statistical analysis of the questionnaires identified 5 types of brains: Extreme Empathizers (EE), Empathizers (E), Balanced (B), Systemizers (S) and Extreme Systemizers (ES).

Level of engagement/involvement and cognitive achievements: Classroom observations/recordings

The collection of data from the classroom was done by systematically observing and recording the reactions of the children by teachers based on a specific observation tool and instructions for use. Teachers recorded on the special observation sheets the level of engagement/involvement of children on a five-level scale (Leuven scale) and the indications that justified their evaluations and decisions. On this scale the highest level of engagement/involvement is scored 5 (see Table 1). The recordings based on this tool allowed us to quantify the data for the purpose of their statistical analysis and the possibility of correlations of the brain type of each child with the signs of engagement/involvement. At the same time, the learning outcomes of all children were recorded during the planned systematic evaluation of each activity. The teachers who implemented the activities of our study had many years of experience in implementing inquiry-based science activities as well as many years of experience in observing and recording in the real classroom and participating in collaborative action research for the development and implementation of inquiry-based activities (Kallery, 2017).

Table 1. The Leuven scale of active engagement in learning

Level1	Level 2	Level 3	Level 4	Level 5
Extremely low: The child shows hardly any activity	**Low:** The child shows some degree of activity which is often interrupted	**Moderate:** The child is busy the whole time, but without real concentration	**High:** There are clear signs of involvement, but these are not always present to their full extend	**Extremely high:** During the observation of learning the child is continually engaged in the activity and completely absorbed in it

Please complete by ticking the appropriate box for each statement

		Definitely Agree	Slightly Agree	Slightly Disagree	Definitely Disagree
1.	My child likes to look after other people.				
2.	My child often doesn't understand why some things upset other people so much.				
3.	My child doesn't mind if things in the house are not in their proper place.				
4.	My child would not cry or get upset if a character in a film died.				
5.	My child enjoys arranging things precisely (e.g. flowers, books, music collections).				
6.	My child is quick to notice when people are joking.				
7.	My child enjoys cutting up worms, or pulling the legs off insects.				
8.	My child is interested in the different members of a specific animal category (e.g. dinosaurs, insects, etc.).				
9.	My child has stolen something they wanted from their sibling or friend.				
10.	My child is interested in different types of vehicles (e.g. types of trains, cars, planes, etc.).				
11.	My child does not spend large amounts of time lining things up in a particular order (e.g. toy soldiers, animals, cars).				
12.	If they had to build a Lego or Meccano model, my child would follow an instruction sheet rather than "ploughing straight in".				

Figure 2. Sample of questions included in the questionnaire completed by the parents

Analysis of recordings and results

For statistical analysis purposes, each type of brain was assigned a number from a five-point Likert-type scale. According to the literature, students with systemizing brains have a greater tendency to engage in science activities than those with empathizing. Therefore, ES was assigned to number 5, S to 4, B to 3, E to 2 and EE to 1.

Also, the results of the assessment of the children's learning outcomes gave us the opportunity to see the relationship between learning outcomes and the type of cognitive style for each child separately and for the whole sample. For the assessment of children's learning outcomes, we used concept cartoons. All children were assessed each of them individually. The assessment was carried out during the planned systematic evaluation and was recorded by the teachers. For the analysis of children's answers to the assessment task we assigned value 1 to the answers that were considered scientifically acceptable for the age of the children and were satisfying the aim of the activity, and value 0 for the non-acceptable ones (range of values from 0 to 1) .

The statistical analysis of the teachers' recordings showed high percentages of the highest levels of engagement/involvement and high success rates in activity assessments for all types of children's brain. Samples of the results are shown in Figures 3 and 4. Figure 3 presents the results from the activity 'Conservation of mass' which is considered one of the most difficult concepts for young children to understand. In Figure 4 the results from the Activity 'Floating and sinking' of solid bodies, which is an equally difficult activity, are presented.

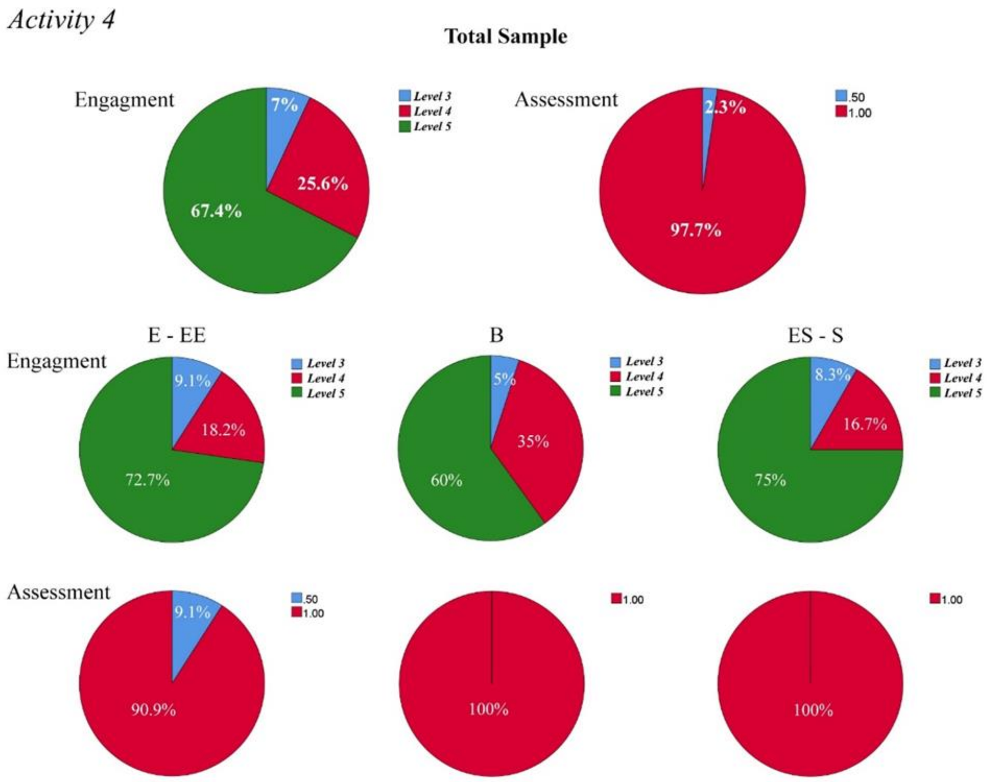

Figure 3. Results from the activity 'Conservation of mass'. Percentages for each level of engagement (values ranging from 1 to 5) and for learning outcomes (values ranging from 0 to 1) across the sample and per brain type.

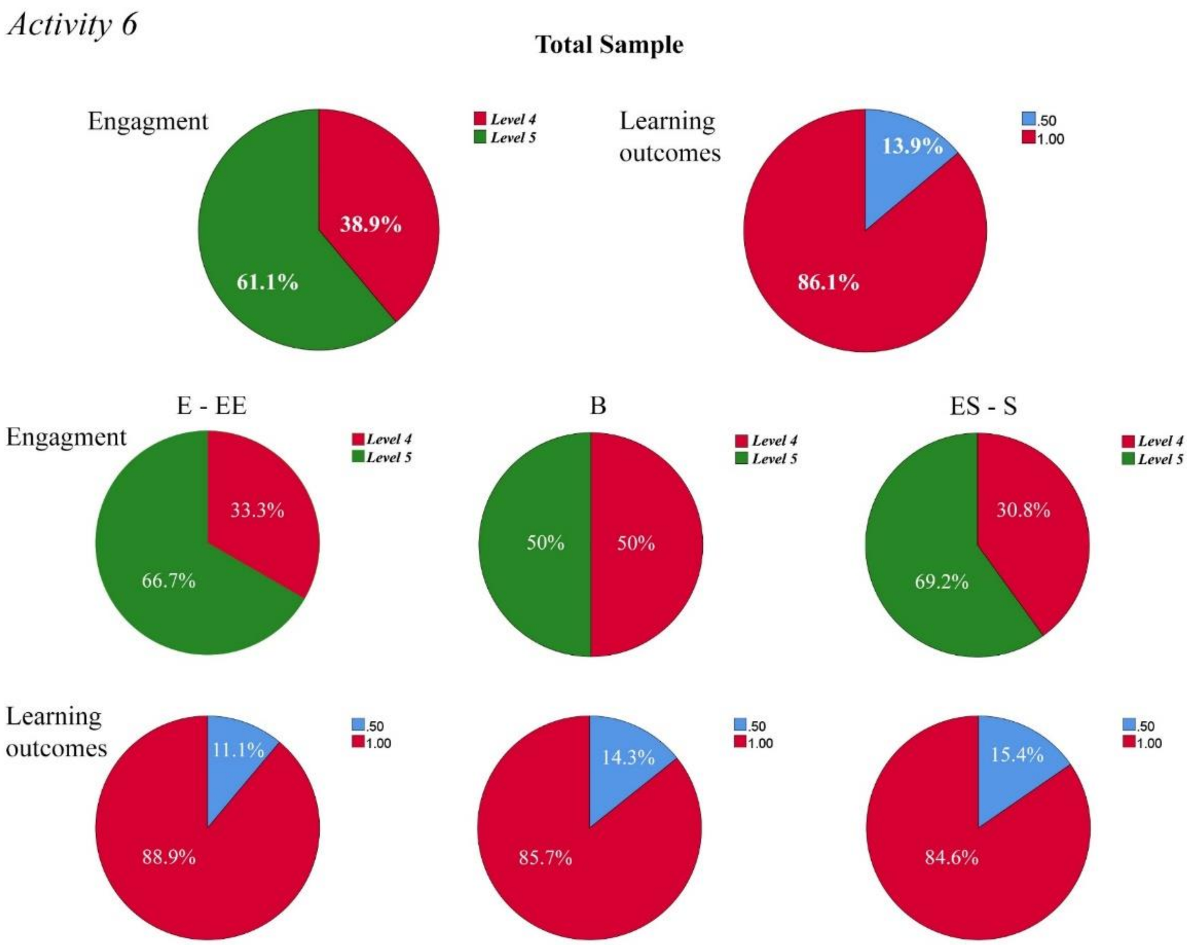

Figure 4. Results from the Activity 'Floating and Sinking' of solid bodies. Percentages for each level of engagement (values ranging from 1 to 5) and for learning outcomes (values ranging from 0 to 1) across the sample and per brain type.

Calculation of the Pearson rho coefficient to examine any association of the brain type with the level of engagement/involvement of children and with their learning outcomes showed no statistically significant correlation (indicative values of Pearson rho: 0.023 for learning, -0.092 for engagement).

CONCLUSIONS

The results of the descriptive statistics coupled with the fact that there is no correlation between the brain type and level of engagement/involvement and brain type and learning outcomes lead us to the conclusion that the inquiry activities of our study with the specific characteristics and approach can lead to high levels of engagement/involvement and similar learning outcomes for all types of pupils' cognitive style. These findings are inconsistent with the assumption that children with an empathizing cognitive style should have a lower degree of engagement in science than children with a systemizing cognitive style and create perspectives that such activities may be appropriate for triggering motivation and learning in science of young children with all types of brain.

REFERENCES

Auyeung, B.; Wheelwright, S.; Allison, C.; Atkinson, M.; Samarawickrema, N. & Baron-Cohen, S. (2009). The Children's Empathy Quotient and Systemizing Quotient: Sex Differences in Typical Development and in Autism Spectrum Conditions. *Journal of Autism and Developmental Disorder*, Vol. 39, p. 11.

Alexander, J. M., Johnson, K. W., & Kelley, K. (2012). Longitudinal analysis of the relations between opportunities to learn about science and the development of interests related to science. *Science Education*, 96 , 763–786.

Baron-Cohen, S. (2009). Autism: The Empathizing-Systemizing (E-S) Theory. *Annals of the New York Academy of Sciences, Vol. 1156*, p. 68–80.

Kallery, M. (2011). Astronomical Concepts and Events Awareness for Young Children. International Journal of Science Education, 33(3), 341–369.

Kallery, M. (2015). Science in Early -Years Education: Introducing Floating and Sinking as a Property of Matter. *International Journal of Early Years Education*, Vol. 23, No. 1, 31–5

Kallery, M. (2018). Early-Years Teachers' Professional Upgrading in Science: a Long-Term Programme. *Research in Science Education*, Vol. 48 Issue 2, p437-464. 28p, DOI: 0.1007/s11165-016-9575-1

Kallery, M. & Loupidou, T. (2016). Learning science in small multiage groups: the role of age composition, International Journal of Science Education, 38:9, 1570-1590, DOI: 10.1080/09500693.2016.1201871

O'Keefe, P., Horberg, E., & Plante, I. (2017). The Multifaceted Role of Interest in Motivation and Engagement, In P.A. O'Keefe, J.M. Harackiewicz (eds.), *The Science of Interest*, p.49-67.

Patrick, H., Mantzicopoulos, P., & Samarapungavan, A. (2009). Motivation for Learning Science in Kindergarten: Is There a Gender Gap and Does Integrated Inquiry and Literacy Instruction Make a Difference. *Journal of Research in Science Teaching,* Vol. 46, No. 2, pp. 166–191.

Zeyer, A.; Bölsterli, K.; Brovelli, D. & Odermatt, F. (2012). Brain Type or Sex Differences? A Structural Equation Model of the Relation Between Brain Type, Sex and Motivation to Learn Science. International Journal of Science Education, Vol. 34 (5), p. 779–802.

YOUNG CHILDREN AND PERSONIFYING REASONING

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Personifying reasoning is reasoning about less familiar living things by applying knowledge about humans. This paper reports on a case study addressing the questions of (a) whether young children use personifying reasoning to predict the properties and behaviours or reactions of living things about which they don't know much, and (b) whether they actually use it in a controlled manner or not. Our informants were 360 conveniently selected preschoolers (age 4-6), attending public kindergartens in several areas of Patras-Greece. Children's reasoning was traced through individual, semi-structured 15-20-minute interviews performed with the protocol of Inagaki and Hatano (1991). All questions require predictions and justifications about a person and another living thing, which is a grasshopper or a tulip. Half children were asked about a person and a grasshopper, while the other half about a person and a tulip. The tape-recorded interviews were transcribed and coded with 'NVivo'. We coded children's responses as personifying or not, by taking into account children's predictions and justifications the way Inagaki and Hatano (1991) did. Children appeared to use personifying reasoning quite often. Our findings are thoroughly discussed in the paper.

Keywords: Early childhood education, Preschool Education, Reasoning

introduction

Young children are very interested in the biological world. By the time they become kindergarten pupils, they already have their own ideas about living organisms and the ways they function or interact with each other (Ergazaki, 2018). Research has shown that young children do hold ideas about growth and life cycles (Rosengren et al., 1991; Shepardson, 2002); habitat, food relationships, and decomposition (Ergazaki & Andriotou, 2010; Leach et al., 1996); internal body structure (Prokop et al., 2006; Reiss & Tunnicliffe, 2001); germs and illness (Ergazaki et al., 2010; Solomon & Cassimatis, 1999); reproduction and inheritance (Zogza & Christopoulou, 2005; Ergazaki et al., 2014; Solomon et al., 1996); evolution (Evans, 2001; Legare et al., 2013). These intuitive ideas may be considered as the body of children's 'naive biology'. The latter is also known as 'naive biological theory' since its core includes reasoning devices that allow children to predict or explain things within the biological world (Inagaki & Hatano, 2002).

One of these reasoning devices allows children to predict the properties and behaviours or reactions of living organisms about which they don't really know much, by applying knowledge they have about humans. This kind of reasoning is known as 'personifying reasoning', 'person analogy' or personification', and it has been suggested that the more the target organism resembles humans, the more children tend to mobilize it (Inagaki & Hatano, 2002). An example of predictive personification, which is cited in Inagaki and Hatano (2002) and provided by an almost 6-year-old boy, is the following: *'We cannot keep a rabbit forever* *small. Because like me, if I were a rabbit, I would be five years old and become bigger and bigger'*.

Most of the literature on personifying reasoning is concerned with young children's predictions about the properties and behaviours or reactions of the target organisms, to ascertain whether these are similar to the ones about humans (Inagaki & Sugiyama, 1988; Tarlowsky, 2006). However, what seems to be important in order to identify personifying reasoning in children's responses is to highlight how they justify their predictions. In fact, it seems that making similar predictions about the properties and behaviours or reactions of humans and other non-human organisms does not necessarily derive from projecting human-related knowledge to them. This was taken into account by Inagaki and Hatano in a study they performed in 1991. Exploring the use of personifying reasoning in a more meaningful way (i.e. focusing on children's predictions and justifications as well), they reached the conclusions that (a) young children use personifying reasoning when making justified predictions about the behaviours or reactions of less familiar living things, and (b) they use it in a rather controlled manner (namely, just when it makes sense).

So, according to Inagaki and Hatano (1991), personifying reasoning appears to be a well spread, useful tool for the early understanding of the biological world. However, their study was performed with 40 six-year-old children in a non-western cultural context almost three decades ago. And since its conclusions are potentially important for early biology education, it seemed interesting to us to explore whether they could be crosschecked in a western context nowadays. Thus, our study addresses the questions of whether (a) young children use personifying reasoning to predict the behaviours or reactions of living organisms that are less familiar to them than humans, and (b) they use it in a controlled manner or not.

METHODS

The overview of the study

This is a case study that has to do with tracing young children's reasoning about the behaviours or reactions of non-human living things like a grasshopper or a tulip, to different types of novel situations. Our data were gathered through individual, semi-structured interviews and analyzed qualitatively and quantitatively.

The participants

The participants of the case study were 360 preschoolers (age 4-6), attending several public kindergartens. These were situated in semi-urban areas of Patras-Greece with low, medium, or high socio-economic status, and were selected due to the teachers' wish to facilitate our study. All children were already familiar with educational interactions, since they were kindergarten pupils for quite some time. Tracing their reasoning was performed through individual, semi-structured 15-20 minute-interviews, conducted by the authors, who had already met the children and gained their own assent for participating. The parents were also informed at the beginning of the study and no objections were raised

The interview protocol

The interview protocol was the one used by Inagaki and Hatano (1991). It includes open-ended questions requiring *both* predictions and justifications about the reaction of a person and the reaction of another living thing to novel situations. Each question was formulated first for a person and then for a grasshopper or a tulip. Half children were asked about a person and a grasshopper and the other half were asked about a person and a tulip. Everyone was asked six questions of three different types: one question per type in the first half of the interview, and one question per type in the second. Here we are concerned only with two of the three types of questions (in short, *'Qs'*): those that had to do with situations in which the reaction of a grasshopper or a tulip would be dissimilar from the reaction of a human being. More specifically:

- '*Qs of dissimilar/incompatible reactions'* (in short, 'incompatible-Qs'): The questions of this type ('Left behind', 'Left unfed/unwatered') concerned situations in which a person would react in ways (e.g. speak) that being projected to a grasshopper or a tulip would lead to implausible conclusions (Table 1).
- '*Qs of dissimilar/compatible reactions'* (in short, 'compatible-Qs'): The questions of this type ('Loosing a care-giver', 'Deprived of comfort') concerned situations in which a person would show mental reactions (feelings or thoughts) whereas a grasshopper or a tulip would not. However, this time, projecting a person's reaction to a grasshopper or a tulip would lead to conclusions that might seem plausible to young children (Table1).

Table 1. An overview of the two types of Qs about a grasshopper or a tulip (G/T-*Qs*).

Q-type	Q-title	Q-content (*)
Dissimilar/ incompatible reactions	Left behind	A woman buys a G/T. On her way home, she stops at a store with G in a cage/T in a pot. After shopping, she is about to leave without G/T. What do you think G/T will do? How come?
	Left unfed/unwatered	Some people have a G/T in cage/pot at their home. It is Sunday morning and nobody has fed/watered G/T because they're all sleeping. What do you think G/T will do? How come?
Dissimilar/compatible reactions	Loosing caregiver	Everyday a man takes care of a G/T. One day the man dies. Do you think that G/T will feel something? How come?
	Deprived of comfort	Some people have a G/T in a small cage/pot at their home. One day someone puts a large cage/pot next to the small. Do you think that G/T will think something? How come?

(*) person-Qs were similar and preceded G/T-Qs

The data analysis

The tape-recorded interviews were transcribed and prepared for coding with 'NVivo'. We coded children's responses as personifying (P) or non-personifying (N) by taking into account children's predictions and justifications the way Inagaki and Hatano (1991) did.

More specifically, when children provided human-like responses about a grasshopper or a tulip and they justified them (a) by appealing to humans, or (b) by using human-related logic or terms, their responses were coded as personifying (P). For instance:

- '*The grasshopper will cry because they haven't fed it. Without food, babies cry and grasshoppers cry'* (a);
- *'The grasshopper will feel sad that the caregiver died, like the child before'* (a);
- *'The tulip will water itself. It will go out to the watering can and drink before people wake up'* (b);
- *'The grasshopper will think of calling someone to unlock its cage so that it can move to the bigger one, to be more comfortable.'* (b).

On the other hand, when children (a) drew upon knowledge about a grasshopper or a tulip, or (b) did not follow the logic they followed about humans, or (c) did not come up with any reasoning strand at all, their responses were coded as non-personifying (N). For instance:

- *'A tulip will do nothing when the woman leaves the store, because flowers do not understand. If she leaves, the tulip will not realize that she left'* (a);
- *'The grasshopper cannot think about the larger cage. The grasshopper does not have the same voice, the same stomach, the same brain'* (a);
- *'The child will cry if she leaves, because the child will be afraid'* whereas *'The grasshopper won't cry'*(b);
- '*The child will feel sad if the man dies'* whereas *'The tulip will not feel anything'* (b); *'I don't know'* (c).

The coding was simultaneously performed by three of the authors and all cases of disagreement were discussed until reaching consensus. Moreover, we counted (a) the personifying responses for a grasshopper, for a tulip and in total, (b) the children who came up with such for a grasshopper, for a tulip and for both, and (c) the frequency of the possible 'individual response patterns' for the 2 Q-types (PP, PN, NP, NN). Each pattern is named with two letters: the first refers to a child's responses to the 'incompatible' Qs, whereas the second refers to a child's responses to the 'compatible' ones. So, the response pattern of a child was coded, e.g., as PP if they had provided at least one personifying response to the 'incompatible'-Qs *and* at least one personifying response to the 'compatible'-Qs. Similarly, the response pattern of a child was coded, e.g., as PN if the child had provided at least one personifying response to the 'incompatible'-Qs *and* none to the 'compatible'-Qs. The results of our analysis are presented below.

RESULTS

Children appeared to use personifying reasoning quite often. As shown in Table 2, the total number of personifying responses to both the 'incompatible' and 'compatible'-Qs was 795/1440; so, the total proportion of personifying responses to both Q-types was 0.55. Children gave personifying responses more often for a grasshopper and less often for a tulip. The total proportion of personifying responses for a grasshopper was 0.82 (594/724 responses), whereas the total proportion of personifying responses for a tulip was just 0.28 (201/716 responses). Moreover, children gave personifying responses more often to the 'compatible'-Qs and less often to the 'incompatible'-Qs (Table 2). The total proportion of personifying responses to the 'compatible'-Qs was 0.65 (466/720 responses), whereas the total proportion of personifying responses to the 'incompatible'-Qs was 0.46 (329/720 responses). Of course, the latter proportion, although lower than the former, is still rather high, which indicates that personifying reasoning seemed appealing to children regardless the type of the situation they are asked to reason about.

Table 2. Numbers and proportions of personifying responses.

	'Dissimilar/Incompatible Reactions'- Qs		'Dissimilar/Compatible Reactions'- Qs		Both Q-types	
	P-responses		P-responses		P-responses	
	Number	Proportion	Number	Proportion	Number	Proportion
Grasshopper*	284/362	0.78	310/362	0.86	594/724	0.82
Tulip*	45/358	0.10	156/358	0.40	201/716	0.28
Total*	329/720	0.46	466/720	0.65	795 /1440	0.55

(*) G: 181 children x2Qs per type; Tulip: 179 children x2Qs per type; Total: 360 children x2Qs per type

As shown in Table 3, there were more children with personifying responses to the 'compatible'-Qs (268/360) than to the 'incompatible' ones (194/360). In fact, 74.4% of the children gave at least one personifying response to the 'compatible'-Qs, whereas 53.9% of the children did so to the 'incompatible' ones (Table 3). Of course, the latter percentage, although lower than the former, is still rather high, which indicates once more that personifying reasoning seems appealing to children regardless the type of the situation they are asked to reason about. Finally, there were more children with personifying responses for a grasshopper than for a tulip. In the case of the 'compatible'-Qs, the difference (92.8% *vs.* 55.9%) was remarkable. However, in the case of the 'incompatible' ones (87.8% *vs.*19.5%) the difference was even bigger (Table 3).

Table 3. Numbers and percentages of children with personifying responses.

	'Dissimilar/Incompatible Reactions'- Qs		'Dissimilar/Compatible Reactions'- Qs	
	Children with P-responses		Children with P-responses	
	Number	Percentage	Number	Percentage
Grasshopper*	159/181 34 once / 125 twice	87.8%	168/181 26 once / 142 twice	92.8%
Tulip*	35/179 25 once / 10 twice	19.5%	100/179 44 once / 56 twice	55.9%
Total*	194/360 59 once / 135 twice	53.9%	268/360 70 once / 198 twice	74.4%

(*) G: 181 children x2Qs per type; Tulip: 179 children x2Qs per type; Total: 360 children x2Qs per type

As shown in Table 4 that concerns the individual response patterns, children gave personifying responses to both Q-types at the same time (PP), much more often than they did to the 'compatible'-Qs only (NP). More specifically, the percentage of children with the PP response pattern was 50.8%, whereas the percentage of those with the NP response pattern was less than half (23.6%). However, if we focus on the tulip, things seem quite different (Table 4). The percentage of children with the PP response pattern for the tulip in particular, was just 16.7%, whereas the percentage of those with the NP response pattern for the tulip was more than double (39.1%). Finally, the PN pattern, which indicates use of personifying reasoning to the 'incompatible'-Qs only, was rather rare since it was given by just 3% of the children in total. On the other hand, the NN pattern, which indicates the absence of personifying reasoning to both Q-types, was not very frequent either, since it was given by less than one forth of the children (22.5%) (Table 4).

Table 4. Children's individual response patterns.

	PP		PN		NP		NN	
Grasshopper	153/181	84.5%	6/181	3.3%	15/181	8.3%	28/181	15.5%
Tulip	30/179	16.7%	5/179	2.8%	70/179	39.1%	53/179	29.6%
Total	183/360	50.8%	11/360	3%	85/360	23.6%	81/360	22.5%

DISCUSSION

As already shown, the participants of this study used personifying reasoning quite a lot. In fact, it seems that they used it even more than the participants of Inagaki and Hatano (1991): the total proportions of personifying responses in the two studies were 0.55 and 0.36, respectively. Our participants used personifying reasoning more for a grasshopper (0.82) than for a tulip (0.28), just like those of Inagaki and Hatano (grasshopper: 0.44; tulip: 0.29). The lower frequency of personifying responses for a tulip in both studies might be attributed either to what Inagaki and Hatano call ‘similarity constraint’, or to children’s knowledge about plants. In other words, children may not be very keen on using personifying reasoning for a tulip, because it is not similar enough with humans or because they do hold plant knowledge that allows them to articulate non-personifying responses about it. Moreover, our participants used personifying reasoning more to the ‘compatible’-Qs (0.65) than to the ‘incompatible’ ones (0.46), similarly to the participants of Inagaki and Hatano (1991) (‘compatible’-Qs: 0.62; ‘incompatible’-Qs: 0,1). However, in our study personifying reasoning was quite popular to the ‘incompatible’-Qs as well: our total proportion of personifying responses to the ‘incompatible’-Qs was 0.46 whereas Inagaki’s and Hatano’s proportion was just 0.1.

Our participants’ tendency to use personifying reasoning to both Q-types was also indicated by the individual response patterns they gave. More specifically, they mainly gave the PP pattern unlike the participants of Inagaki and Hatano (1991) who mainly gave the NP pattern. In other words, the latter participants tended to use personifying reasoning just to the ‘compatible’-Qs, whereas ours tended to use it to both Q-types. In fact, 50.8% of our participants gave the PP pattern for both a grasshopper and a tulip, whereas less than half (23.6%) gave the PN pattern in total. So, the use of personifying reasoning in our study was not as selective as expected considering the findings of Inagaki and Hatano (1991). Of course, this is not true if we focus just on the tulip. Now the NP response pattern is given by 39.1% of the participants and gets dominant, whereas the PP response is given by less than half (16.7%). A possible account for this finding that indicates selective use of personifying reasoning *particularly* in the case of tulip has already been suggested above.

It should be noticed that quite often our participants avoided blind projections of human behaviours or reactions to a grasshopper or a tulip. What they did was trying to adjust the human reactions to the profile of the target entities in order to come up with more plausible predictions about them. For instance, according to their views, a child might cry to catch the attention of the adults and get fed, while a grasshopper might make noise by falling on the cage-rails or by flying near their ears; similarly, a child might call the police if their mother had left them accidentally in a store, whereas a grasshopper cannot make such a call so it might just try to leave the store and find the woman on its own.

Children’s attempts to adjust human reactions in ways that would lead them to more plausible predictions about other, non-human living things are actually remarkable, especially if one takes into account that children are exposed to an entertainment culture that is actually dominated by anthropomorphism. Most of the storybooks or the series that are addressed to young children are full of animals or even plants that look, feel, think, communicate and generally behave like human beings (Ganea et al., 2008; Ganea et al., 2014). Anthropomorphism may be considered as a major type of personification (Gallant, 1981), which does not seem to be quite useful to young children. In fact, it often manifests itself through teleological explanations (Tamir & Zohar, 1991) that biology education needs to challenge.

In sum, even if our results are not completely in line with those of Inagaki and Hatano (1991) since the use of personifying reasoning in our study does not seem to be as selective as expected, this reasoning device that lies at the core of children's 'naïve biology' still seems to be a flexible and thus potentially useful tool in children's attempt to reason about less familiar living things. Finally, we should not forget that it has been suggested (Hadjigeorgiou, 2016; Lindholm, 2018) that thinking about non-human living things by drawing on humans, may develop a lifelong friendship between children and the biological world and also nourish children's curiosity and joy of learning about it.

References

Ergazaki, M. (2018). Biology and young children. In K. Kampourakis and M. Reiss (Eds.), *Teaching Biology in Schools* (pp. 22-34). New York: Routledge.

Ergazaki, M. & Andriotou, E. (2010). From "forest fires" and "hunting" to disturbing "habitats" and "food chains": do young children come up with any ecological interpretations of human interventions within a forest? *Research in Science Education, 40*(2), 187-201.

Ergazaki, M., Saltapida K. & Zogza, V. (2010). From young children's ideas about germs to ideas shaping a learning environment. *Research in Science Education, 40*(5), 699-715.

Ergazaki, M., Alexaki, A., Papadopoulou, C. & Kalpakiori, M. (2014). Young children's reasoning about physical & behavioural family resemblance: is there a place for a precursor model of inheritance? *Science & Education, 23*(2), 303-323.

Evans, E. M. (2001). Cognitive and Contextual Factors in the Emergence of Diverse Belief Systems: Creation Versus Evolution. *Cognitive Psychology 42*(3), 217-266.

Gallant, R. A. (1981). Pitfalls of personification. *Science and Children, 19*(2), 16–17.

Ganea, P. A., Canfield, C. F., Simons-Ghafari, K., & Chou, T. (2014). Do cavies talk? The effect of anthropomorphic picture books on children's knowledge about animals. *Frontiers in Psychology, 5,* 283.

Ganea, P. A., Pickard, M. B., & DeLoache, J. S. (2008). Transfer between picture books and the real world by very young children. *Journal of Cognition and Development, 9*(1), 46-66.

Hadzigeorgiou, Y. (2016). *Imaginative Science Education. The Central Role of Imagination in Science Education.* Cham: Switzerland: Springer International.

Inagaki, K. & Sugiyama, K. (1988). Attributing Human Characteristics: Developmental changes in Over/Under-attribution. *Cognitive Development,* 3, 55-70.

Inagaki, K., & Hatano, G. (1991). Constrained Person Analogy in Young Children's Biological Inference. *Cognitive Development,* 6, 219-231.

Inagaki, K., & Hatano, G. (2002). *Young children's naive thinking about the biological world*. New York: Psychology Press.

Legare, C. H. & Lane, J. D. & Evans, E. M. (2013). Anthropomorphizing science: how does it affect the development of evolutionary concepts? *Merrill-Palmer Quarterly, 59*(2), 168-197.

Lindholm, M. (2018). Promoting curiosity? Possibilities and pitfalls in science education. *Science & Education, 27*, 987-1002.

Prokop, P., Prokop, M., Tunnicliffe, S. D. & Diran, C. (2006). Children's ideas of animals' internal structures. *Journal of Biological Education, 41*, 1-6.

Reiss, M.J. & Tunnicliffe, S.D. (2001). Students' understandings of human organs and organ systems. *Research in Science Education, 31*, 383-399.

Rosengren, K., Gelman, S., Kalish, c., & McCormick, M. (1991). As time goes by: Children's early understanding of growth in animals. *Child Development, 62*, 1302-1320.

Shepardson, D. P. (2002). Bugs, Butterflies, and Spiders: Children's Understandings about Insects. *International Journal of Science Education, 24*(6), 627-643.

Solomon, G. E. A., & Cassimatis, N. L. (1999). On facts and conceptual systems: young children's integration of their understanding of germs and contagion. *Developmental Psychology, 35,* 113-126.

Solomon, G. E. A., Johnson, S. C., Zaitchic, D., & Carey, S. (1996). Like father, like son: Young children's understanding of how and why offspring resemble their parents. *Child Development, 67,* 151-171.

Tamir, P. & Zohar, A. (1991). Anthropomorphism and teleology in reasoning about biological phenomena. *Science Education, 75*(1), 57-67.

Tarlowski, A. (2006). If it's an animal it has axons: Experience and culture in preschool children's reasoning about animates. *Cognitive development*, *21*(3), 249-26.

Zogza, V., & Christopoulou, G. (2005). Where do babies come from?': Ideas of five years old children about reproduction and birth. In M. Ergazaki, J. Lewis & V. Zogza (Eds) *Trends in Biology Education Research in the New Biology Era* (pp. 59-71). Patras: Patras University Press.

CHARACTERISTICS OF SCIENCE TEACHING IN PRESCHOOL

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This paper focuses on characteristics of science teaching in preschool. Science in general is in focus, but a special interest is put on what may characterize chemistry teaching in preschool. The study is part of a much broader R&D programme where in total almost three hundred preschool teachers/managers collaborate with a researcher group to which we belong. The participants (N=177) were in the autumn 2018 asked to answer a question in an e-mail-questionnaire about their views on science/chemistry teaching in preschool. On average a participant answered with 30 words, but obviously there was a big span, from 1 to 444 words in a single answer. In the word material (consisting of about 5400 words in total) we looked for common and prominent words, words used only low-frequently or not at all, and other patterns. We identified eighteen words that were used about 30 times or more. Among these words are: experiment, water, animal, plant, nature, forest, explore, examine, phenomenon, and baking. Low frequently used words were categorized in seven categories, among them chemistry. The words atom, molecule and particle could not at all be found in the word material. More qualitatively we also looked for patterns/traces based on the three main Didaktik questions: Why? What? and How?. Statements from the preschool teachers/managers were categorized in seven categories. In the discussion and forthcoming studies we will relate science/chemistry teaching in preschool both to the recently revised curriculum for the Swedish preschool and to other content areas and more general theories and ideas on what may characterize teaching in preschool.

Keywords: Pre-school Education; Continuing Professional Development; Didaktik

A R&D PROGRAMME ABOUT TEACHING IN PRESCHOOL

During the last years there has, at least in Sweden, been a growing interest in exploring what characterizes teaching in preschool (e.g. Hedefalk, Almqvist & Lundqvist, 2015; Melker, Mellgren & Pramling Samuelsson, 2018; Pramling et al., 2019, Thulin & Jonsson, 2018; Vallberg Roth, 2018) and not at least science teaching (e.g. Broström, 2015; Andersson & Gullberg, 2014; Fridberg, Jonsson, Redfors & Thulin, 2019; Gomes & Fleer, 2018; Sjöström, 2018; Sundberg, Areljung & Ottander, 2019). In the latest version of the Swedish curriculum for preschool (SKOLFS 2018:50), the mission of teaching was enhanced. The curriculum also includes science as a content area and the present study focuses on what may characterize teaching in and about the natural sciences, including chemistry. One of the goals in the curriculum for preschool is to provide each child with the conditions to develop “an understanding of natural sciences, knowledge of plants and animals, and simple chemical processes and physical phenomena”.

The study described here is part of a much broader R&D programme, which is a collaborative initiative involving eight Swedish municipalities and the independent Institute for Innovation, Research and Development in School and Preschool (Ifous), as well as Malmö University. In total almost three hundred (300) preschool teachers/managers collaborate with a researcher group of six, to which we belong and one of us (Prof. Vallberg Roth) is leading. The programme started in the summer 2018 and will contiue for three years in total. The aim of the present study is to get a better understanding of what may characterise science teaching, including chemistry, in preschool.

RESEARCH METHOD AND DESIGN

In the beginning of the R&D programme, the participants were asked to answer an e-mail-questionnaire about their views mainly on teaching in preschool, generally and in some specific content areas, among them natural science. Here we report results from the question (in the e-mail-questionnaire) about what may characterize teaching in and about the natural sciences, including chemistry. The specific question was (our translation): "What may characterize teaching in natural sciences, including chemistry, in preschool?". The collected and analysed empirical material consists of about 5400 words from in total 177 respondents, of which 131 were preschool teachers and 46 preschool managers. Of the words about 4400 words were from the preschool teachers and about 1000 from the preschool managers. The number of words per participant were as follows: On average a participant answered with 30 words, but obviously there was a big span, from 1 to 444 words in a single answer. For more details, see: Sjöström, 2019a.

Below, the results will be presented, analysed and discussed in a similar way as presented in some recent articles on teaching in Swedish preschools (e.g. Vallberg Roth, 2018; Vallberg Roth, Holmberg, Löf & Stensson, 2019). The analysis of the material can methodologically be described in terms of abductive analysis (Peirce, 1903/1990; Tavory & Timmermans, 2014), alternating between theory-loaded empiricism and empirically loaded theory. The purpose of the analysis is to identify traces and patterns in the "word data" (see further: Silverman, 2011), relating to the aim of and questions posed by the research. In the word data for the question about science/chemistry (i.e., about 5400 words from in total 177 respondents), we looked for common (and prominent) words, words used only low-frequently or not at all. The frequency of prominent words was counted using the "Find"-function in Word.

We also looked for qualitative patterns. How words interact with and reinforce each other in their contexts was analysed. The analysis was built on both high- and low-frequency traces in a second and qualitatively oriented interpretive path. The word-frequency analysis can be viewed as offering stabilising support in the analysis of the distinctive traces. Quotations were selected for their clear exemplification of the traces in the material. More concretely, the analysis involves identifying traces in the material in relation to the research aim. The analysis can be described in terms of the following interpretive paths (see e.g. Rapley, 2011; Tavory & Timmermans, 2014): close reading; distinctive traces were identified; and distinctive traces in the third interpretive path were problematized in relation to earlier research and concepts.

The so called *Didaktik* questions serve as both a practical tool and as a basis for analytical questions. In the context of research, such questions focus on what (content), how (teaching actions), who/whom (actor/actors), where (space/place), when (time) and why (goal and motivation). The three main *Didaktik* questions, What?, How?, and Why? are in focus in this paper.

Abductive moments in the analysis can involve suddenly seeing an alternative, discovering a previously undiscovered possibility: "Reality is not simply 'what is here-and-now' […] but also includes what potentially can be achieved – and which in the moment merely reflects a vague possibility" (Peirce, 1903/1990, p. 31). In this study, concepts were tested in relation to traces in the material that were revealed as possibilities by the analysis. Furthermore, cohesive analysis was performed in light of *Didaktik* models, resulting in a conceptualising focus. In practice, empirically based and theory-based interpretive paths are typically intertwined.

RESULTS AND DISCUSSION

We identified eighteen words that were used about 30 times or more. These high-frequently words (translated from Swedish) are below presented in a "word cloud" (Figure 1). Together these words give us an idea of the most common understanding and views on what may characterize science teaching in preschool in Sweden in 2018. The most common and prominent word was "child". It was used about 140 times, meaning about 2,5% of the total amount of words. On second place was "experiment", which was used about 100 times. This word was the typical answer for what may characterize science/chemistry teaching in preschool. More than half of the respondents used that word explicitly. Actually it was also the only single word used in an answer by one preschool teacher and in some other cases it was the only content: "We have experiments" and "experiments, for example".

Figure 1. High-frequency words (translated from Swedish) in the answers on the question of what may characterize teaching of science, including chemistry, in preschool year 2018. The word cloud was made in Wordle.

As seen in the word cloud, other common words were for example: water, animal, plant, nature, forest, explore, examine, phenomenon, and baking. Another word was "happens", which is about that something is happening during for example an experiment. Except experiment and water, it is mainly "baking" that can easily be related to chemistry. One preschool teacher answered: "In chemistry it is usually experiments and baking that are included."

Ever since the start of the Swedish preschool at the end of the 19th century, "nature meetings" have been central (Ärlemalm-Hagsér & Sundberg, 2016). Since the national curriculum for the preschool was introduced in 1998, the focus has also been on environmental work. Chemical processes and physical phenomena were introduced in 2010, when revising the curriculum (Thulin & Gustavsson, 2017). Sundberg, Areljung, Due, Ottander and Tellgren (2016) have claimed that science in preschool is dominated by the following content: water, human body, compost, nature and forest. These words, except for human body and compost, were – as seen in Figure 1 – common in the answer on what may characterize science/chemistry in preschool. On the other hand human body was a common word in the answers on what may characterize health teaching in preschool (another question in the questionnaire) and compost on what may characterize teaching about sustainable development in preschool (also another question). Except on the question on what may characterize science in preschool, nature, water and material were also high-frequent in the answers on what may characterize teaching about sustainable development in preschool (Sjöström, 2019b).

Except the high-frequently used words, we also identified many words used with lower or low frequency or not at all. For example the words atom, molecule and particle could not be found in the word material. The low frequently used words were categorized in the following seven categories: scientific work; physics (with or without connections to mathematics, technology, metrology and/or astronomy); chemistry; biology (including both green biology and human biology); general science linked to everyday-life; environmental science (including sustainability issues); and science pedagogy/teaching methods in preschool.

More qualitatively, we also looked for patterns/traces based on the three main *Didaktik* questions: Why? What? and How?. Statements from the preschool teachers/managers were categorized in the following seven groups: Why science in preschool?; What characterizes science in preschool?; Prerequisites: subject knowledge of the preschool teachers and educational teaching material; What content?; What activities and how?; Other pedagogical ideas; and, finally: The nature of chemistry teaching in preschool. We have a lot of quotations connected to the seven groups (Sjöström, 2019a), but here we focus on chemistry in preschool. Previous research on chemistry in preschool is very limited (e.g. Adbo & Vidal Carulla, 2019; Fridberg, Jonsson, Redfors & Thulin, 2019; Hansson, Löfgren & Pendrill, 2014; Åkerblom, Součková & Pramling, 2019).

Chemistry in preschool

One interesting quotation about what may characterize chemistry in preschool is (our translation): "Chemistry is more difficult, usually it becomes experiments that becomes ‘happenings’ without any follow-up or anchoring”. One example of a “happening experiment” is the “how to make a volcano”-experiment, which is common on the Internet and also – at least previously – in Swedish methods books about experiments to be done in preschool and primary school. “Volcano” is mentioned six times in the word material. However, the purpose of that experiment is unclear and its value can be questioned (see further discussion in: Sjöström, 2019a).

The empirical material (the word material) can also be discussed and problematized in relation to the chemistry triplet (macro; submicro; symbolic/representations) (see e.g. Johnstone, 1993; Talanquer, 2011). Furthermore, the statements by the preschool teachers/managers can be compared to the ongoing international discussion on when (what age) and how to introduce the concepts of particles and molecules to children (e.g. Sjöström, 2012; Åkerblom, Součková & Pramling, 2019). In forthcoming analysis and studies we will also relate our results to previous studies on science teaching in preschool and to more general theories and discussion on teaching/*Didaktik* in preschool.

Science content in preschool

According to Klaar (2016; see also: Klaar & Öhman, 2014), there are the following three main content areas related to nature/science, in the Swedish preschool:

1. to promote children’s personal development and health by being outdoors,

2. to care for the natural environment, and

3. to learn about nature, both in terms of scientific phenomena and processes and through inquiry.

The first content area links to a healthy lifestyle and the second to sustainable development. Scientific phenomena, products and processes are mainly to be found in the third content area. At the same time, ”nature teaching” in preschool can also be about nature experiences and wonder in a broad sense (Hadzigeorgiou, 2001; Hadzigeorgiou & Schulz, 2014), as well as about how scientific knowledge relates to technology, health and environmental work.

“Nature” is mentioned five times in the revised curriculum for preschool in Sweden. It is about stimulating the children’s “interest in and knowledge of nature, society and technology”. Furthermore, the preschool shall provide each child with the conditions to develop “an understanding of relationships in nature and different cycles in nature, and how people, nature and society affect each other”. Except in the curriculum goal about “natural sciences”, which was quoted above, “science” is mentioned three more times in the curriculum. It is about providing each child with the conditions to develop an ability to explore and discuss science and technology, and about language and communication in relationship to mathematics, science and technology (SKOLFS 2018:50).

In Figure 2, we suggest a *Didaktik* model on “nature / science content” in preschool. The corner “Experience of nature in a broad sense” includes for instance the human body and natural phenomena. Read more about different types of *Didaktik* models in e.g.: Sjöström 2019c; Sjöström, 2019d; and Vallberg Roth, Holmberg, Löf & Stensson, 2019.

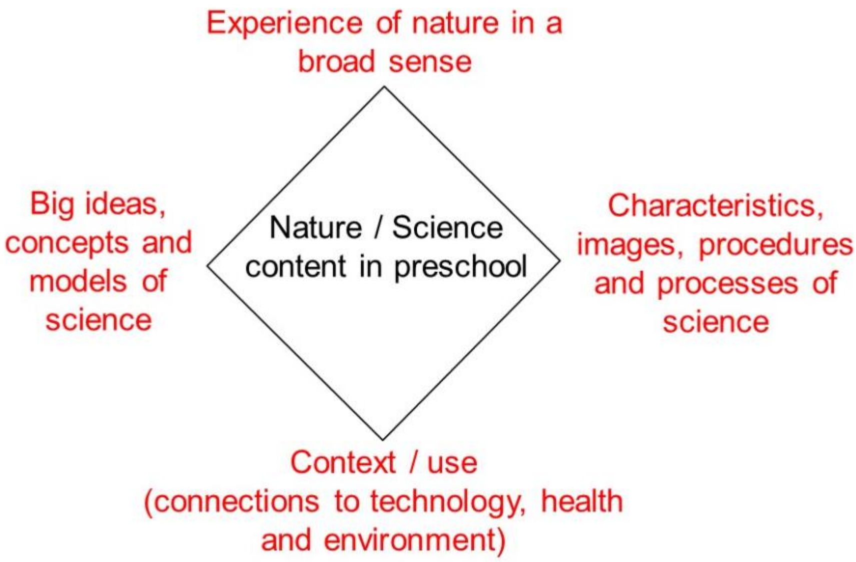

Figure 2. Didaktik model on nature / science content in preschool. The model is an English translation of a model in: Sjöström, 2019a.

In forthcoming scholarly work, based on the work presented here and related work, we will more in general discuss the concepts of *Didaktik* models and modelling in relation to preschool teaching praxis. Furthermore, we are interested in what happens when more general ideas about science teaching and *Bildung* (Sjöström, Frerichs, Zuin, & Eilks, 2017) are applied to a preschool context.

ACKNOWLEDGEMENT

We would like to thank eight Swedish municipalities (Eslöv, Enskede/Årsta/Vantörs SDF, Jönköping, Katrineholm, Skurup, Staffanstorp, Vallentuna, and Örebro) and Malmö University for financial support, and Ifous (the independent Institute for Innovation, Research and Development in School and Preschool) for coordinating the R&D programme, in which this research study is a part. We also would like to thank the other four authors of the research report *Vad kan känneteckna undervisning och sambedömning i förskola? Förskollärares och chefers/rektorers skriftliga beskrivningar år 2018* (Vallberg Roth et al., 2019) for their contributions in discussions about the results: Lecturer Sverker Aasa, Dr. Jan-Eric Ekberg, Dr. Ylva Holmberg, and PhD-student Catrin Stensson.

REFERENCES

Adbo, K., & Carulla, C. V. (2019). Designing play-based learning chemistry activities in the preschool environment. *Chemistry Education Research and Practice*, *20*, 542-553.

Andersson, K., & Gullberg, A. (2014). What is science in preschool and what do teachers have to know to empower children?. *Cultural Studies of Science Education*, *9*, 275-296.

Broström, S. (2015). Science in early childhood education. *Journal of Education and Human Development*, *4*, 107-124.

Fridberg, M., Jonsson, A., Redfors, A., & Thulin, S. (2019). Teaching chemistry and physics in preschool: a matter of establishing intersubjectivity. *International Journal of Science Education*, *41*, 2542-2556.

Gomes, J., & Fleer, M. (2018). Is science really everywhere? Teachers' perspectives on science learning possibilities in the preschool environment. *Research in Science Education*, Published online: 2018-09-24

Hadzigeorgiou, Y. (2001). The role of wonder and 'romance' in early childhood science education. *International Journal of Early Years Education*, *9*, 63-69.

Hadzigeorgiou, Y., & Schulz, R. (2014). Romanticism and romantic science: Their contribution to science education. *Science & Education*, *23*, 1963-2006.

Hansson, L., Löfgren, L., & Pendrill, A. M. (2014). Att utgå från frågor och situationer i förskolans vardag: Vilket naturvetenskapligt innehåll kan det leda till? [Starting from questions and everyday situations in preschool: What kind of science content could that lead to?]. *NorDiNa: Nordic Studies in Science Education*, *10*, 77-89.

Hedefalk, M., Almqvist, J., & Lundqvist, E. (2015). Teaching in preschool. *Nordic Studies in Education*, *35*, 20-36.

Johnstone, A. H. (1993). The development of chemistry teaching. *Journal of Chemical Education*, 70, 701-705.

Klaar, S. (2016). Ett mångfacetterat naturinnehåll och naturlärande i förskolan [Multifaceted nature content and nature learning in preschool]. In: S. Thulin (Ed.), *Naturvetenskap i ett förskoleperspektiv – kreativa lärandeprocesser* (pp. 49-65). Malmö: Gleerups. (in Swedish)

Klaar, S., & Öhman, J. (2014). Doing, knowing, caring and feeling: exploring relations between nature-oriented teaching and preschool children's learning. *International Journal of Early Years Education*, *22*, 37-58.

Melker, K., Mellgren, E., & Pramling Samuelsson, I. (2018). Undervisning i förskolan – en fråga om att stötta och att skapa gemensamt fokus [Preschool teaching – a matter of supporting and creating a common focus]. *ForskUL*, *6*, 64-86. (in Swedish)

Peirce, C. S. (1903/1990). *Pragmatism och kosmologi: Valda uppsatser* [Pragmatism and cosmology: Selected essays]. Gothenburg: Daidalos. (in Swedish)

Pramling, N., Wallerstedt, C., Lagerlöf, P., Björklund, C., Kultti, A., Palmér, H., Magnusson, M., Thulin, S., Jonsson, A., & Pramling Samuelsson, I. (2019). *Play-responsive teaching in early childhood education*. Springer.

Rapley, T. (2011). Some pragmatics of qualitative data analysis. In: D. Silverman (Ed.), *Qualitative Research: Issues of Theory, Method and Practice* (pp. 273-290). Los Angeles: Sage.

Silverman, D. (Ed.) (2011). *Qualitative research: Issues of theory, method and practice* (3rd ed.). Los Angeles: Sage.

Sjöström, J. (2012). Barn och kemi – vad säger den kemididaktiska forskningen? [Children and chemistry – what does the chemistry education research say?] In: M. Ideland & C. Malmberg (eds.) *Naturvetenskap och yngre barn – Om att forskningsanknyta utbildning för förskollärare och grundlärare* (pp. 35-53), Faculty of Education and Society, Malmö University. (in Swedish)

Sjöström, J. (2018). Allt mer forskning om naturvetenskap i förskolan [More and more research on science in preschool]. Published online: 2018-02-22 at https://liu.se/forskning/natdid (in Swedish)

Sjöström, J. (2019a). Vad kan känneteckna undervisning i förskola med fokus på naturvetenskap, däribland kemi? [What may characterize teaching in preschool with a focus on science, including chemistry?] Chapter 7 in: A.-C. Vallberg Roth et al. (ed.) *Vad kan känneteckna* *undervisning och sambedömning i förskola? Förskollärares och chefers/rektorers skriftliga beskrivningar år 2018* (pp. 89-104). Malmö: Malmö University. (in Swedish)

Sjöström, J. (2019b). Vad kan känneteckna undervisning i förskola med fokus på hållbar utveckling? [What may characterize teaching in preschool with a focus on sustainable development?] Chapter 9 in: A.-C. Vallberg Roth et al. (ed.) *Vad kan känneteckna undervisning och sambedömning i förskola? Förskollärares och chefers/rektorers skriftliga beskrivningar år 2018* (pp. 118-129). Malmö: Malmö University. (in Swedish)

Sjöström, J. (2019c). Didaktisk modellering [Didactic modelling]. In: K. Stolpe, G. Höst & A. Larsson (eds.) *Forum för forskningsbaserad NT-undervisning. Bidrag från konferensen FobasNT18 13 – 14 mars 2018 i Norrköping* (ss. 121-132), nr. 3 i skriftserien Naturvetenskapernas och teknikens didaktik. Linköping University. (in Swedish)

Sjöström, J. (2019d). Didactic modelling for socio-ecojustice. *Journal for Activist Science and Technology Education*, *10*, 45-56.

Sjöström, J., Frerichs, N., Zuin, V. G., & Eilks, I. (2017). Use of the concept of *Bildung* in the international science education literature, its potential, and implications for teaching and learning. *Studies in Science Education*, *53*, 165-192.

SKOLFS (2018:50). Skolverkets författningssamling [Statutes of the Swedish National Agency for Education], *Läroplan för förskolan Lpfö 18* [Curriculum for the Preschool Lpfö 18]. Stockholm: Skolverket. (in Swedish and English)

Sundberg, B., Areljung, S., Due, K., Ottander, C. & Tellgren, B. (2016). *Förskolans naturvetenskap i praktiken* [Preschool science in practice]. Malmö: Gleerups. (in Swedish)

Sundberg, B., Areljung, S., & Ottander, C. (2019). Opportunities for Education for Sustainability through multidimensional preschool science. *NorDiNa: Nordic Studies in Science Education*, *15*, 358-369.

Talanquer, V. (2011). Macro, submicro, and symbolic: the many faces of the chemistry "triplet". *International Journal of Science Education*, *33*, 179-195.

Tavory, I., & Timmermans, S. (2014). *Abductive Analysis: Theorizing Qualitative Research.* Chicago: University of Chicago Press.

Thulin, S., & Gustavsson, L. (2017). Lärares uppfattningar av undervisning och naturvetenskap som innehåll i förskolans verksamhet [Teachers' perceptions of teaching and science as content in preschool]. *NorDiNa: Nordic Studies in Science Education*, *13*, 81-96. (in Swedish)

Thulin, S., & Jonsson, A. (2018). Undervisning i förskolan – om möjligheter att integrera förskolans bildningsideal med nya uppdrag [Preschool teaching – about opportunities to integrate the preschool *Bildung* ideal with new assignments]. *BARN – Forskning om barn og barndom i Norden*, *36*, 95-108. (in Swedish)

Vallberg Roth, A.-C. (2018). What may characterise teaching in preschool? The written descriptions of Swedish preschool teachers and managers in 2016. *Scandinavian Journal of Educational Research*, Published online: 2018-06-18

Vallberg Roth, A.-C., Aasa, S., Ekberg, J.-E., Holmberg, Y., Sjöström, J., & Stensson, C. (eds.) (2019). *Vad kan känneteckna undervisning och sambedömning i förskola? Förskollärares och chefers/rektorers skriftliga beskrivningar år 2018* [What may characterize teaching and co-assessment in preschool? Preschool teachers' and principals' written descriptions in 2018]. Malmö: Malmö University (research report in Swedish). Available at: http://muep.mau.se/handle/2043/30324

Vallberg Roth, A.-C., Holmberg, Y., Löf, C., & Stensson, C. (2019). Multivocal didactic modelling: Collaborative research regarding teaching and co-assessment in Swedish preschools. *Problems of Education in the 21st Century*, *77*, 806-834.

Åkerblom, A., Součková, D., & Pramling, N. (2019). Preschool children's conceptions of water, molecule, and chemistry before and after participating in a playfully dramatized early childhood education activity. *Cultural Studies of Science Education*, *14*, 879-895.

Ärlemalm-Hagsér, E., & Sundberg, B. (2016). Naturmöten och källsortering – en kvantitativ studie om lärande för hållbar utveckling i förskolan [Nature meetings and source sorting – a quantitative study on Education for Sustainable Development in preschool]. *NorDiNa: Nordic Studies in Science Education*, *12*, 140-156. (in Swedish)

PART 16: STRAND 16

Science in the Primary School

Co-editors: *Federico Corni & Anna Spyrtou*

STRAND 16: INTRODUCTION

SCIENCE IN THE PRIMARY SCHOOL

In Strand 16, Science in the Primary School, 8 papers were included. Most of the studies come from the European Union (two from Greece, two from Ireland, two from Spain), while two papers are from Japan and Libanon groups. The theme common to all contributions is how specific teaching approaches can contribute to the acquisition of knowledge of modern (e.g., Nanoscale Science and Technology) and traditional scientific content (e.g., geology) by primary students and/or teachers.

Sarah Carroll, Veronica McCauley and Muriel Grenon (Ireland) investigated the effect of scientists on children's self-efficacy beliefs after participating in a hands-on informal science activity related to molecular biology. The intervention lasted for one hour, during which four pupils 11-12 years old got involved in the "Fantastic DNA" session. Changes to participants' self-efficacy beliefs were estimated via interviews, video observations and responses to a pre-post written questionnaire. All participants reported to feeling more confident on science after the intervention.

María-Antonia Manassero-Mas, Antoni J. Bennàssar Roig and Ángel Vázquez-Alonso (Spain) study deals with improving teacher training on epistemic aspects through games. To this aim, as the authors argue, games, such as with cubes and dices, offer an authentic analogy of scientific practices. The participants of the research were six Spanish teachers who prepared and implemented the cube game to their sixth-grade students, which involved about one hundred students. Taking into consideration the lack of resources and teachers' inadequate training concerning epistemic teaching and learning, the results seemed promising.

Eftychia Valanidou, Marida Ergazaki and Renia Gasparatou (Greece) examined whether having students practice in philosophy-inspired reasoning strategies may facilitate them in constructing the biological concepts of fish, amphibian, reptile, bird, and mammal. The learning environment that was designed consisted of seven teaching-learning activities with the aim 4th graders to engage in class-based groupings of vertebrates. Although, as the authors argue, the learning environment needs improvements, findings indicate that students made progress in grouping vertebrate animals in class-groups.

Naoki Komiya, Minami Yano, Kazuki Yamamoto, Ryohei Egusa, Shigenori Inagaki, Hiroshi Mizoguchi, Miki Namatame and Fusako Kusunoki (Japan) examined the reinforcement of knowledge about germination and plant growth. The writers developed a prototype system that supports learning using collaboration and full-body interaction. They applied it to a lesson at a primary school in Chiba, Japan, where multiple students learned about plant germination and growth conditions through quizzes and evaluated its effect. The results suggest that this system reinforces learners' knowledge of germination and plant growth conditions and that it is an effective tool for furthering students' learning.

Juan-Carlos Rivadulla-López, Susana García-Barros, María-Jesús Fuentes-Silveira and Cristina Martínez-Losada (Spain) put under inspection 671 activities on human nutrition included in year 6 primary education school texts in Spain and Portugal with the aim of examining the extent to which these activities promote scientific competency. According to the findings, both similarities and differences among the Spanish and Portuguese publishers were detected. For example, the Portuguese textbooks include more the abilities of describing explaining and justifying than their Spanish counterparts. The findings of the study could be exploited by schoolbook text writers and by teachers' trainers as well.

Pauline Abdouche[1], Assaad Yammine (Libanon) implemented project-based learning into teaching in order to introduce salient geology topics to 10 refugee grade 6 students and to study whether the project-based learning approach had an impact on the autonomy and motivation of the participants as well. The researchers acknowledge the challenge of the endeavor, given the special characteristics of the population on the one hand (the war situation in Syria) and the complexity of science topic on the other. However, findings were promising. The results showed that students motivation increased after the project was completed, though with fluctuations. Moreover, improvement in the acquisition of knowledge was evident.

George Peikos, Anna Spyrtou, Dimitris Pnevmatikos and Penelope Papadopoulou (Greece) deal with the inclusion of a modern topic such as Nanoscale Science and Technology (NST) to primary education. In particular, they study whether a six-unit pilot teaching approach about NST concepts (e.g. size), phenomena (e.g. superhydrophobicity) and applications (e.g. nanofiltration systems) addressed to 22 primary school students had an impact on students nano-related knowledge. Findings from the analysis of the pre-post questionnaire indicate the improvement of students' nanoliteracy.

Diana Bogusevschi, Odilla Finlayson and Gabriel-Miro Muntean (Ireland) analyze a Technology Enhanced Learning science, technology, engineering and maths (STEM) education case study, Earth Course, carried out in two primary schools in Dublin, Ireland. The authors focused on the assessment of learner motivation and affective state following the Earth Course case study. Most students found the Earth Course interesting and they would like to use similar lessons in other science classes. Students were extremely positive about the use of technology in the classroom, seeing it as a supporting tool for their teacher.

Federico Corni & Anna Spyrtou

'A SCIENTIST KNOWS WHAT S/HE'S DOING': EXPLORING THE EFFECT OF SCIENTIST-LED OUTREACH ON PRIMARY CHILDREN'S SCIENCE SELF-EFFICACY BELIEFS

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Recent years have seen an increase in scientist-led hands-on science outreach events aiming to improve children's performance and engagement with science. Despite positive links with performance and motivation, the effect of scientists on children's science self-efficacy beliefs is currently unknown. Science self-efficacy can be influenced through four sources: mastery experience, vicarious experience, verbal persuasion and emotional state. Scientists may provide verbal persuasion to children participating in hands-on science events. This proceedings paper describes a case study embedded in a larger mixed-methods quasi-experimental study investigating the effect of scientists on children's science self-efficacy beliefs after participating in a hands-on science event on molecular biology. This case study analysis explored four children's experiences of the scientist-led event and how it affected their science self-efficacy. Several sources of data were collected, including pre- and post-intervention questionnaire results, post-intervention interviews and recorded observations of the hands-on session. Findings indicated that children perceived the scientist facilitators to be credibly competent in science. However, the true potential effects of verbal persuasion from scientists remains unclear. Scientist facilitators may increase children's science self-efficacy in skills related to the session through the provision of a helpful and supportive environment. These findings will be further investigated through the analysis of the larger quasi-experimental study.

Keywords: Self-efficacy, Informal Learning, Primary School

SCIENCE SELF-EFFICACY AND SCIENTISTS IN OUTREACH

Science self-efficacy (SSE) can be described as the confidence an individual has in completing science-related tasks. SSE is positively linked to academic performance, motivation and engagement with science (Pajares, 2015). Self-efficacy in general can be influenced by four determinants, often referred to as 'sources': mastery experience, vicarious experience, verbal persuasion and emotional state. These four sources have been empirically shown to be associated with self-efficacy beliefs for several different school subjects, including mathematics and science (Britner & Pajares, 2006; Joët, Usher, & Bressoux, 2011; Usher & Pajares, 2008; Webb-Williams, 2017). Whilst mastery experience and emotion state stem from oneself, vicarious experience and verbal persuasion are provided by others. Vicarious experience originates from observing others successfully completing specific tasks and verbal persuasion is the influence of others expressing belief in an individual's abilities in certain tasks (Bandura, 1997). The provision of these sources by teachers, peers and family members is positively correlated with student's SSE beliefs (Stake, 2006). Scientists may be ideal candidates for the provision of verbal persuasion in SSE, as verbal persuasion is most effective when the performer perceives the encourager as credibly competent in the task at hand (Bandura, 1997). Yet, there has not been any published studies investigating the effect of scientists in hands-on informal science activities on student's SSE beliefs. Consequently, despite the increasing prevalence of scientists in informal science activities (Jeffers, Safferman, & Safferman, 2004; The Stem Education Review Group, 2016), there is currently no best practice specifically for scientist facilitators on increasing children's SSE beliefs. To explore the effect of scientist facilitators on children's SSE beliefs, this study was underpinned by the following research questions (RQs) and hypotheses (H_n).

RQ1: Do children perceive the scientist facilitators to be credibly competent in science? *H_1: Children perceive the scientist facilitators from this intervention to be competent scientists.*

RQ2: How are children's SSE beliefs affected after participation in one scientist-led hands-on outreach session? *H_2: Children's SSE beliefs are increased after participation in this hands-on science session.*

RQ3: How do scientists facilitators delivering hands-on outreach affect children's SSE beliefs? *H_3: Scientists increase children's SSE beliefs through the provision of verbal persuasion.*

METHODS

Study Design - a case study embedded in a quasi-experimental study

To answer these research questions, a quasi-experimental study was conducted (Figure 1). Participants in the treatment group (N=106) had their SSE beliefs assessed before and after participation in a scientist-led hands-on science session. Pre-/post-test changes in questionnaire responses were compared to participants from the control group (N=50), who did not participate in the intervention (Figure 1). This proceedings paper will describe a case study from the treatment group that was carried out as a first step towards answering the questions from the larger study as case studies can serve well as a complementary method to experimental studies (Yin, 2009).

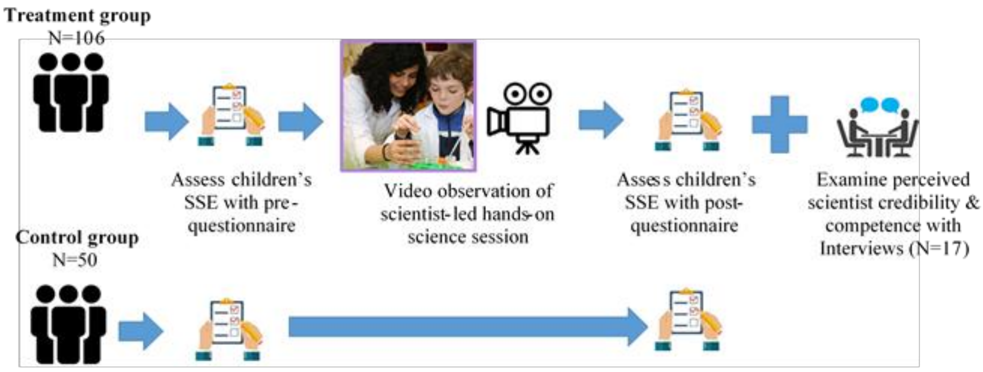

Figure 1. Pre-/post- quasi-experimental study design.

Data collection

A mixed methods approach to data collection was used to allow for the collection of a "…richer and stronger array of evidence than can be accomplished by any single method alone" (Yin, 2009). Six sources of data were collected: documentation, archival records, interviews, survey instruments, direct observations and participant-observation (Table 1). The interview schedule asked participants what happened during the session, whether participation in the session affected different aspects of their science confidence, and their perception of the scientist facilitator at their group.

Table 1. Sources of data collection in the case study.

Type of evidence	Data collected
Documentation	Description of the intervention
Archival records	Demographic data about the participant's school (the setting)
Interviews	Semi-structured interviews with participants after intervention
Survey instrument	Pre-intervention and post-intervention surveys completed by the participants
Participant-observation	Post-intervention survey completed by scientist facilitators
Direct observations	Recorded observations of the children's behaviours and interaction with others

The survey instrument used was the Irish Science Self-Efficacy Children's Questionnaire (IS-SEC-Q (Carroll et al., 2020). It comprises 5 scales (66 items): (i) General Academic Self-Efficacy, (ii) Performance-Related SSE, (iii) Knowledge-Specific SSE, (iv) Sources of SSE and (v) Task-Specific SSE. The Sources of SSE scale has four subscales, each approximating participant's exposure to the four sources of SSE and includes scientists as providers of vicarious experience and verbal persuasion (Carroll et al 2020). The post-test version has an additional 6th scale with items assessing participant's perception of their scientist facilitators. All items are answered using a 7-point Likert-like scale.

Immediately after the intervention, the scientist facilitators completed a short survey asking them to note any interesting interactions between themselves and the children and to note any child that was either particularly confident or withdrew from the session. For the video observations one video camera recorded a wide-angle shot of the classroom. Each group also had a small dictaphone to record the dialogue at the table.

The intervention

The intervention in this case study is a one-hour session on molecular biology called 'Fantastic DNA' and is delivered by the Irish science outreach and education programme Cell EXPLORERS (www.cellexplorers.com) to primary classrooms. After an introductory presentation on cells and DNA, pupils (8-12 years old) extract DNA from a banana in small groups of six. Each group is led by a scientist facilitator who demonstrates each step to the children, who then repeat it individually themselves. Two key steps in the experimental protocol will be discussed in this paper: 1) when pupils create a funnel from filter paper and filtrate a mixture of banana and saline and 2) when they use a pipette to add 1 ml of liquid soap to the resulting filtrate.

The participating school

The participating school was a primary school, with mixed-sex pupils (i.e. boys and girls). It was also a Gaelscoil, which means that all areas of the curriculum (including science) are taught through Irish. There are 8 classes (i.e. grades) in Irish primary schools. Sixth class is the final year and pupils are typically between 11-12 years old. The participating school had two sixth classes, each taught by a different teacher (one male and one female teacher). Each class had approximately 25 pupils, which is within the average range for primary classes in Ireland.

Participant details

Four participants were selected for the case study analysis: Oliver, Sarah, Owen and Lily (Table 2). They were selected based on their response variation in their post-test questionnaire to the pre-test questionnaire for the item ‘How confident are you that you could Learn Science?’. At least one participant was selected for each of these possibilities: increase, decrease or no change in their response score for the ‘learn science’ item. Participants were selected to come from the same school, received the intervention on the same day and to have an even number of boys and girls.

Table 2. Participant details in the case study. Learn science score variation refers to the changes in participant’s responses to the item ‘how confident are you that you could learn science’ between their pre-test questionnaire and post-test questionnaire.

Pseudonym	Variation in ‘Learn Science’	Gender	Age	Class	Scientist facilitator
Oliver	Increase	Male	12	1	Bethany
Sarah	Decrease	Female	12	1	Susan
Owen	Decrease	Male	12	2	Susan
Lily	None	Female	11	2	Bethany

Participant-observer details: the scientist facilitators

The scientist facilitators acted as participant-observers; they were guiding the children in the experiment during the session and took note of the children’s behaviour and interactions. Three scientist facilitators featured in this case study: Bethany, Susan and Evelyn (Table 3). Bethany was the scientist that guided Oliver and Lily in their experiment and Susan guided Sarah and Owen (Table 2). Evelyn acted as ‘Team Leader’. She supervised the intervention and sometimes offered support to other scientists, interacting with the children in their group in this way. All scientist facilitators completed the same training prior to the intervention.

Table 3. Details of the scientist facilitators (participant-observers). ‘Undergraduate’ course refers to the course they were studying at the time of the intervention. ‘Years of experience’ refers to the years spent volunteering with the outreach program.

Pseudonym	Role	Age	Gender	Undergraduate Course	Years of experience
Evelyn	Team Leader	21	Female	Microbiology	3
Bethany	Facilitator	19	Female	Biomedical science	1
Susan	Facilitator	21	Female	Biomedical science	2

DATA ANALYSIS

Quantitative analysis

Participant’s (N=4) responses to pre-test and post-test versions of the IS-SEC-Q were input directly into SPSS version 24. Some items were reverse-coded due to their negative wording.

Qualitative analysis

Interviews, video and audio recordings were transcribed verbatim. NVivo was used as a data analytical tool and transcripts were imported as internal sources (Figure 2). Steps in the qualitative data analysis were similar to those used in 'selective coding'(Cohen, Manion, & Morrison, 2007).

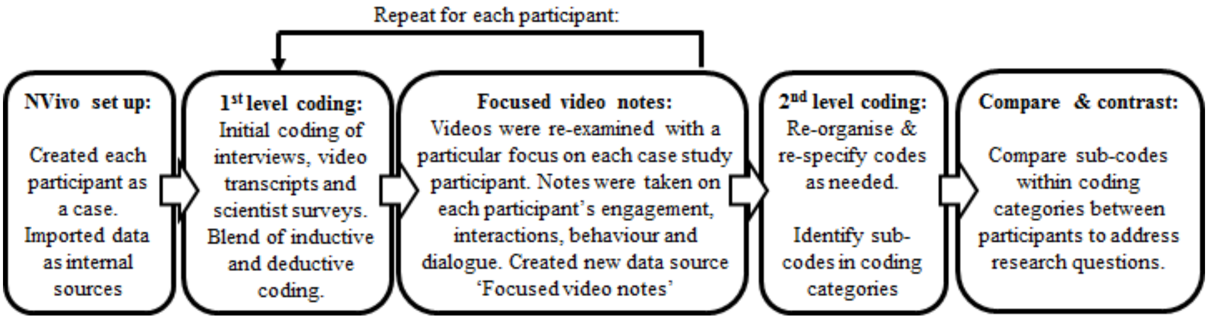

Figure 2. Steps in the qualitative data analysis.

First-level coding was guided by self-efficacy theory, current literature and the research questions. Data sources were reviewed to look for references to (i) the four sources of self-efficacy (mastery experience, vicarious experience, verbal persuasion and emotional state), (ii) interactions between the scientists and the children, (iii) interactions between the children and their peers at the group, (iv) engagement during the session and (v) descriptions of the scientists. These codes formed the 'core categories' (Cohen et al., 2007). In addition to the transcribed video and audio recordings, 'focused video notes' were also created, by re-examining the recordings with a sole focus on the actions and experiences of each participant. The second-level coding involved "…relating categories at the level of the dimensions identified" (Cohen et al., 2007, p. 562). Finally, a comparative analysis of participants looked for convergent and divergent findings to the research questions.

RESULTS

The 4 participants perceived the scientists to be competent, friendly & helpful

Verbal persuasion is most effective when the performer perceives the individual providing the praise to be credibly competent in the task at hand (Bandura, 1997). Therefore, before investigating whether the scientist facilitators affected participant's SSE beliefs, it was important to ascertain whether they perceived the scientists to be credibly competent. Nearly all the participants rated their scientists positively across the five items in the 'perceived competence of scientist' scale in the IS-SEC-Q (Figure 3). They agreed that their scientist facilitators were friendly, clever, well trained, encouraged them in the activities and felt that they got on well with them. Their perceptions of the scientists were further explored in the interviews. The core category 'descriptions of scientists' was divided into three sub-codes (Table 4). The first two sub-codes, 'competent in science' and 'friendly and nice' strongly complement participant's responses to the scale in the IS-SEC-Q (Figure 3). This indicates that participants perceived the scientists to be credibly competent, which makes them good potential candidates to act as providers of verbal persuasion. The third sub-code "helpful & supportive" was unexpected and came through strongly in the interviews. Both Lily and Sarah emphasised that their scientist facilitator helped them through explaining concepts and tasks in a simple and supportive manner.

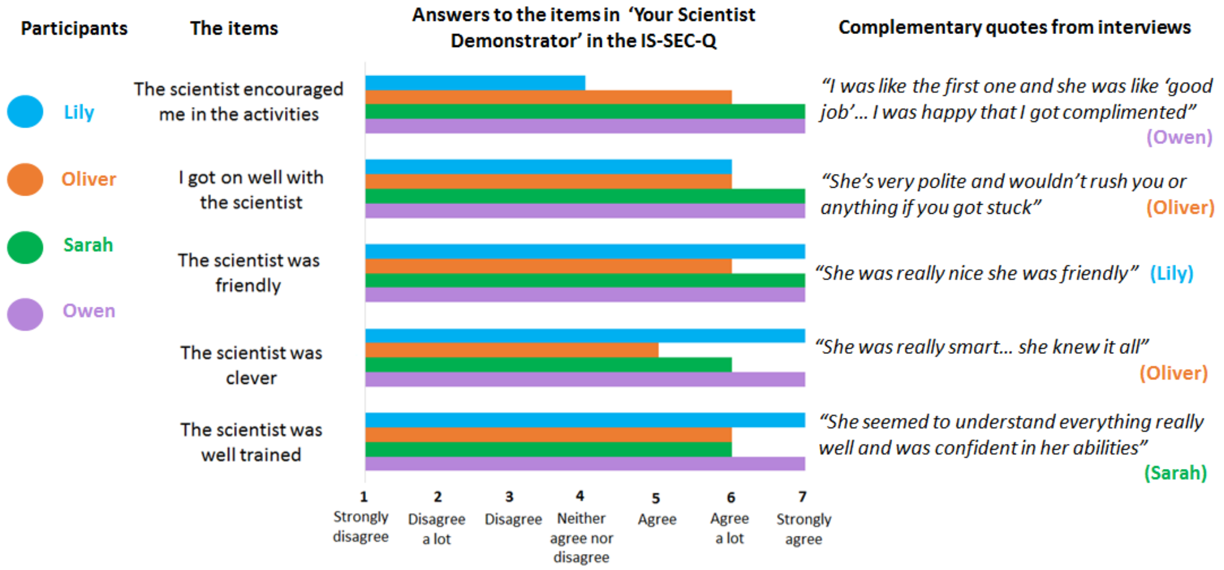

Figure 3. Case study Participant's perceptions of the competence and friendliness of their scientist facilitator. Each participant's answers to the five items (left) in the scale are presented (middle) combined with corroborating quotes from the interview (right).

Table 4. Case study participant's descriptions of the scientist facilitators from interviews. Tabulated are sub-codes and exemplifying quotes from the 'Scientist description' core category of the interview analysis.

Subcode	Exemplifying quotes
Competent in science	*"understand everything really well"* (Sarah) *"she was really smart"* (Lily) *"she knew her stuff"* (Oliver)
Friendly & Nice	*"really nice"* (Sarah) *"really friendly"* (Lily) *"very polite"* (Oliver) *"nice"* (Owen)
Helpful & Supportive	*"she just like explained everything really slowly and carefully so we could understand it"* (Sarah) *"when things are hard she can explain stuff in an easy way"* (Lily) *"she wouldn't rush you or anything"* (Oliver)

Participation did not greatly change the 4 participant's self-efficacy to 'Learn Science'

Changes to case study participant's SSE beliefs were explored through a combination of their responses in the IS-SEC-Q, their interviews and how their video observations. As participants were selected for this case study based on their pre-/post-intervention changes to the item 'How confident are you that you could learn science?', this was the first SSE variable that was examined. Although only one out of the 4 selected participants (Oliver) had an increase in their "Learn Science" score (Tables 2 and 5), all participants reported to feeling more confident in science after the intervention in the interviews (below).

Lily said, "*I've always wanted to do science…it boosted my confidence even more to do it*". Lily postulates that the reason her questionnaire changes did not reflect this increase is due to her low efficacy in maths (i.e. mathematics). Lily marked herself at a 1 (Terribly) in maths at both pre- and post-test. She explained that because she sees maths as such an important aspect of science, even though she felt more confident in science after the intervention, it was not enough to overcome her perceived shortcomings in maths.

"I marked myself the same because I'm not that confident with doing like the maths in science and stuff but em I think I was pretty good at the science" (Lily)

Table 5. Pre- and post-test responses from 4 case study participants for 3 SSE items in the IS-SEC-Q. Variables are assessed by single items in the IS-SEC-Q.

SSE variable	Lily		Owen		Sarah		Oliver	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Learn Science	5.00	5.00	5.00	4.00	6.00	5.00	5.00	6.00
Filter a mixture	6.00	7.00	5.00	3.00	4.00	7.00	5.00	6.00
Pipette 1 ml of liquid	4.00	7.00	3.00	3.00	7.00	7.00	3.00	6.00

Sarah also said that the session increased her science self-efficacy, *"I think just doing one* [of the sessions] *made me feel a lot more confident"*. In fact, it was her second time doing the session as she had done it previously with a youth group outside of school. Sarah suggested that her questionnaire indicated a decrease instead of an increase because she over-estimated her confidence in the pre-test questionnaire and then did not perform as she predicted she would.

"…I was a bit more confident in my abilities than I was actually able to do so then I just kinda did more accurately the second time after I did it" (Sarah)

Owen could not explain why his questionnaire did not indicate an increase in his science confidence, despite feeling more confident after the intervention.

"I felt good that I did it, well I've never really done science before so when I done that I kinda felt good that I did the DNA extraction" (Owen)

Intervention did increase case study children's self-efficacy to perform related skills

Whilst an increase in SSE is not much indicated by the changes in responses to the item 'Learn Science', it is reflected in participants responses to the items pertaining to the specific skills that they performed during the interview: filtering a mixture and pipetting 1 ml of liquid (Table 4). Lily, Oliver and Sarah reported an increase in their self-efficacy to perform at least two of these skills. This increase in self-efficacy in these skills was also corroborated by their responses in interviews and how they were observed to perform the skills in the videos.

For example, Lily reported a +1 increase in her self-efficacy to filter a mixture successfully (Table 4). When asked about it in her interview she said that she felt more confident in filtering a mixture, even though she *"…needed help doing the funnel*". This was supported by her focused video notes, as it was observed that Lily did in fact struggle with creating the funnel with the filter paper. Once her scientist facilitator gave her some further guidance and praised her on completing it, Lily proceeded to filter the mixture with no further struggle. According to his questionnaire, Owen's self-efficacy in these skills was not increased (Table 4). From his questionnaire, he seemed to have become less confident about filtering a mixture (-2, from 'well' to 'not well') and his efficacy about using a pipette remained low (at 3, 'not well'). In his interview Owen describes how he struggled with the filtration step, that he "*…wasn't really good at it"* and "*was struggling a small bit but then got the hang of it*". This combined with his questionnaire would suggest that he had struggled considerably at this step. However, in the video he appeared to complete this step with ease, needing no additional guidance and did so at a rate equal to his peers.

Case study participants received little verbal persuasion from scientists

Only two of the four case study participants, Lily and Owen, reported changes to their perceived levels of verbal persuasion from scientists in the questionnaire after the intervention (Figure 4A and 4B).

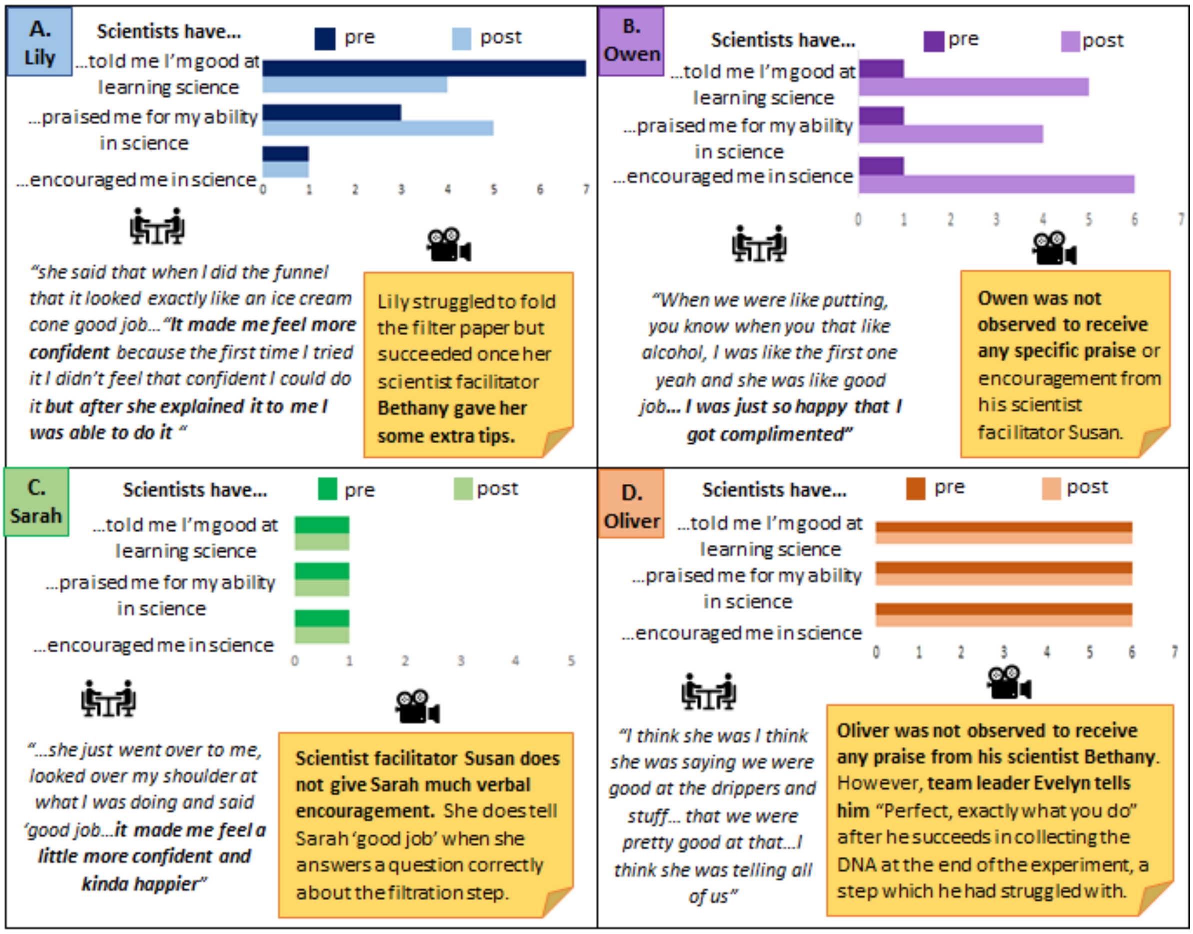

Figure 4. Verbal persuasion from the scientist facilitator. Each panel has a bar chart illustrating each participant's pre-/post-test scores to the three items assessing verbal persuasion from scientists from the IS-SEC-Q, an exemplifying quote in their interviews and excerpts from the videos notes ascertaining whether verbal persuasion from scientists was observed in their recorded session. The x-axis for each bar chart denotes the response range in the 7-point Likert scale used. Each point was labelled as follows (1-7): strongly disagree, disagree a lot, disagree, neither agree nor disagree, agree, agree a lot, strongly agree).

Three items in the IS-SEC-Q assess verbal persuasion from scientists: 'scientists have told me I'm good at learning science', 'scientists have praised me for my ability in science' and 'scientists have encouraged me in science'. Owen reported an increase in all three items (Figure 4B), which was corroborated by his interview. However, Owen was not observed in his video to receive any specific verbal persuasion from his scientist facilitator Susan. It is possible that it was not picked up by the recording device. Lily did receive additional advice and encouragement from her scientist facilitator Bethany (Figure 4A). Lily struggled to correctly fold her filter paper into a funnel before Bethany gave her extra instruction. Once Lily has successfully folded the filter paper, Bethany praised her for making it look like an ice-cream cone, which is how she initially described it. Lily felt that this made her feel more confident about the step (Figure 4A). Neither Oliver nor Sarah were observed to receive specific praise from their scientist facilitator compared to Lily and Owen, nor was this indicated by their questionnaire results (Figure 4C and 4D). However, they both talk about at least one event where their scientist did praise them. For Sarah, the praise was specific to her (4C), whereas Oliver recounted that his scientist facilitator Susan gave general praise to everyone *"I think she was telling all of us"* (Figure 4D). Surprisingly, Oliver did not mention the specific praise he was observed to receive from Team Leader Evelyn. This may be because he was asked about praise he received from his scientist facilitator, and he viewed the two roles differently.

CONCLUSIONS & FUTURE DIRECTIONS

This proceedings paper presents a case study analysis on how scientists delivering hands-on outreach interventions affect upper primary pupil's science self-efficacy beliefs. As a first exploration of related research questions, four participants were selected for analysis. Interviews and responses from the 'perceived scientist competence' scale and descriptions from the interviews supported the hypothesis that participants considered the scientists to be competent in science (RQ1). Although participation in the intervention did not seem to induce great changes to the four children's overall science self-efficacy, all of them reported an increase to their self-efficacy through either the IS-SEC-Q or their interviews in performing the specific skills related to the session: filtering a mixture and pipetting 1 ml of liquid. This supports that children's SSE beliefs are increased after participation in a hands-on science session but are mostly limited to skills practiced during the session (RQ2).

The effect of the scientist facilitators on children's SSE beliefs was explored (RQ3). It was hypothesized the scientists would incur positive changes to children's SSE beliefs through the provision of verbal persuasion. Although the participants perceived the scientist facilitators to be credibly competent, they reported to receiving little verbal persuasion from them during the intervention. It was confirmed through the video analysis that their scientist facilitators did not provide much (if any) verbal praise. Therefore, the hypothesis that the scientist facilitators induces an increase in SSE through verbal persuasion could not be fully examined in this case study. However, three participants (Lily, Owen and Sarah) recounted in interviews that the small amount of verbal persuasion that they recalled in receiving (whether it was observed to occur or not) induced a positive effect, either increased happiness or confidence. This suggests that there could be a relationship between the level of verbal persuasion provided by the scientist facilitator and the amount perceived by the child participant. Therefore, to address RQ3, a future direction of this study will be to attribute a level of verbal persuasion provided by each scientist facilitator and explore its perceived impact for each participant, through a triangulation of IS-SEC-Q responses, interviews and observations.

An unexpected outcome of this case study was the emergence of being 'helpful and supportive' as a strong sub-code in the analysis of children's descriptions of the scientists. By explaining concepts clearly and simply, in a manner that remains informal yet structured, scientists may indirectly contribute to participant's increased SSE through the creation of a positive and supportive atmosphere, thus mediating participants mastery experience. This additional characteristic of the scientist facilitators could provide an alternative explanation to verbal persuasion for how they may have facilitated participant's increase self-efficacy to perform the skills of the session.

Finally, the four participants constituting this case study are part of a larger sample in a quasi-experimental study. Future work will ascertain whether the experiences of these four participants are applicable to a larger cohort and will guide the further investigation of how scientist facilitators delivering hands-on outreach can affect children's SSE beliefs. In particular, the future analysis of the pre- and post-test questionnaires from the quasi-experimental group of 156 participants (N=106 in treatment group, N=50 in control group) will investigate whether there are any statistically significant changes to participant's SSE strengths and sources. Additional analysis of session videos and participant interviews will allow a more comprehensive understanding of the potential role of scientist facilitators in forming children's SSE beliefs in hands-on science sessions. This will be the first step in recommending best practice for scientists in outreach.

ACKNOWLEDGEMENTS

The authors thank the primary pupils, teachers and scientist facilitators for their participation in this study. MG's research group is linked to the activities of Cell EXPLORERS, an educational outreach programme funded by the Science Foundation Ireland strategic Discover awards 16DP4123 and 18DP5772. SC's PhD is funded by a College of Science scholarship. The funders had no role in study, design, data collection and analysis or decision to publish. This research had ethical approval granted by the NUI Galway research ethics committee, reference 17-NOV-02.

REFERENCES

Bandura, A. (1997). *Self-Efficacy: The Exercise of Control*. W.H. Freeman and Company.

Britner, S. L., & Pajares, F. (2006). Sources of science self-efficacy beliefs of middle school students. *Journal of Research in Science Teaching*, *43*(5), 485–499.

Carroll, S., McCauley, S., & Grenon, M. (2020). *Development and validation of the Irish Science Self-Efficacy Children's Questionnaire to assess the short-term influence of scientists facilitator outreach.* Manuscript submitted for publication.

Cohen, L., Manion, L., & Morrison, K. (2007). *Research Methods in Education*. *Education* (Vol. 55).

Jeffers, A. T., Safferman, A. G., & Safferman, S. I. (2004). Understanding K–12 Engineering Outreach Programs. *Journal of Professional Issues in Engineering Education and Practice*, *130*(2), 95–108.

Joët, G., Usher, E. L., & Bressoux, P. (2011). Sources of self-efficacy: An investigation of elementary school students in France. *Journal of Educational Psychology*, *103*(3), 649–663.

Pajares, F. (2015). Current Directions in Self - efficacy Research. In M. Maehr & P. Pintrich (Eds.), *Advances in motivation and achievement* (pp. 1–49). JAI Press.

Stake, E. J. (2006). The Critical Mediating Role of Social Encouragement for Science Motivation and Confidence Among High School Girls and Boys. *Journal of Applied Social Psychology*, *(36)*4, 1017–1045.

The Stem Education Review Group. (2016). *A Report on Science, Technology, Engineering and Mathematics (STEM) Education: Analysis and Recommendations*. Department of Education and Science. Retrieved from: https://www.education.ie/en/Publications/Education-Reports/STEM-Education-in-the-Irish-School-System.pdf

Usher, E. L., & Pajares, F. (2008). Sources of Self-Efficacy in School: Critical Review of the Literature and Future Directions. *Review of Educational Research*, *78*(4), 751–796.

Webb-Williams, J. (2017). Science Self-Efficacy in the Primary Classroom: Using Mixed Methods to Investigate Sources of Self-Efficacy. *Research in Science Education*, 1–23.

Yin, R. K. (2009). *Case Study Research: Design and Methods*. (L. Bickman & J. D. Rog, Eds.) (4th Ed.). California: SAGE Publications Inc.

A SERIOUS GAME TO TEACH EPISTEMIC KNOWLEDGE: THE PLEASURE OF LEARNING TO THINK AND ACT LIKE A SCIENTIST

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Scientific literacy is a perennial objective of science education to adequately prepare all citizens to live in a sustainable world increasingly permeated by science and technology. A component of literacy involves epistemic learning on how science and technology work and how scientists think and act to validate scientific knowledge. Teaching and learning this innovative metacognitive component of literacy is difficult, and especially for primary teachers and students. This paper aims to innovate the initial science training of primary teachers through their involvement in developing and applying some teaching materials with the format of cooperative serious games to teach students an aspect of epistemic knowledge. To this aim, games offer an authentic analogy of the scientific practices, as they replicate complex science epistemological tenets and their cooperative and competitive social aspects that authentically simulate the actual arguments, cooperation and competition among scientists (as sociology of science has posited) and are flexible enough to allow access and evolutionary adaptation to teachers and students. This way, games allow actually training teachers to teach students complex epistemic aspects about thinking and acting like scientists. A real experience to teach students argumentation based on evidence of knowledge validation through a simple serious game with cubes and dices is presented. The results show primary teachers' satisfaction and students' motivation and interest after playing the cubes. The materials and some students' productions (observations, arguments and justifications) will be presented. Finally, the positive results encouraged the teachers to continue their science epistemic by deepening the complexity of the game.

Keywords: epistemic knowledge, primary teacher training, evidence-based argumentation

INTRODUCTION

Science literacy is the perennial objective of science education, which has currently focused on changing the traditional approach of "science for scientists" to a new inclusive "science for all" to adequately prepare citizens for everyday life in a sustainable world increasingly permeated by science and technology (S&T) (Millar, 2006). Besides the cognitive knowledge (traditional S&T concepts, facts, principles, and processes that dominate all textbooks), the key innovative component of science literacy is the knowledge "about" science, which is often called nature of science or epistemic knowledge, as it deals with how science and scientists work to validate their knowledge or intervene in society. Epistemic knowledge involves a set of complex, multifaceted, interdisciplinary, evolving, and changing meta-knowledge about scientific (and technological) practices, which refers to functioning, methods, values, scientific community, science, technology, relationships with society, etc. drawn from history, philosophy and sociology of science (and other disciplines) when they analyse scientific and technological practices (Lederman, 2007; NGSS, 2013; Vázquez & Manassero, 2012).

Teaching and learning epistemic knowledge copes with many difficulties and constitutes a pending innovation in school science. On the methodological hand, recent research suggests that the most effective teaching approaches must involve both explicit and meta-cognitive reflection activities for students (Abd-el-Khalick & Akerson, 2009; Deng, Chen, Tsai & Chai, 2011; García-Carmona, Vázquez & Manassero, 2011; Lederman, 2007). On the other hand, the lack of teacher training and appropriate educational resources for teaching epistemic knowledge contents are the greatest practical hindrances. For instance, Li and Tsai (2013) analysed 31 investigations (2000-2011) based on science digital games and showed that any game addressed the learning of epistemic knowledge topics.

Serious games for epistemic learning

Hence, this communication aims to fill in these gaps by trying an exemplary serious game of cubes as a teaching resource for students learning and teacher training, because games offer an authentic analogy of scientific practices and allow addressing complex epistemic aspects by emulating scientists' behaviour and thinking skills. Hattie's (2009) meta-analysis on visible learning assigns to interactive games and videos a good mean effect size (0.50 and 0.52) on learning and they justify the game's good impact on learning. Furthermore, several studies suggest that serious games are also effective to produce behavioural, cognitive and meta-cognitive changes and convey educational advantages: students do not usually need prior knowledge to play, the contents can be flexibly designed to fit students' needs (age, level, subject, etc.) and their activities can be planned for cooperative learning (McGonigal, 2011).

The use of games as teaching resource addresses those difficulties, especially in primary science education, as playing the game explicitly enhances teachers training and develops students' motivation and interest to learn that contribute to overcome the difficulties. Educational games deploy an authentic analogy of scientific practices that explicitly simulates cooperation and competition among scientists when researching and replicates some scientific epistemic tenets. Further, game design is flexible enough to allow developmental adaptation to students' grade and needs. Overall, games allow teaching students complex epistemic aspects about actually thinking and acting like scientists (Gee, 2007).

The rationale for trying the cube game stems from the ability to address the former difficulties and adding the primary science education context (training elementary teachers and teaching elementary students), a less frequent context of studies on teaching epistemic knowledge.

Teacher training and student learning: development of scientific (critical) thinking

Research points out another important drawback of effective teaching of epistemic topics: teachers do not usually have an adequate training. Thus, this study also deals with improving teacher training on epistemic through games, which is twofold: on the one hand, teachers' pedagogic appropriation of the games, as an innovative resource to teach epistemic knowledge; on the other hand, the development of teachers' scientific (critical) thinking skills to help students' reflective learning activities. This aims unfolds around the following ideas:

- Scientific knowledge assumes order and consistency in the natural systems.
- Scientific research uses a variety of methods.
- Scientific knowledge is based on empirical evidence.
- Scientific knowledge is open to review based on new evidence (change).

- The laws, mechanisms, models and scientific theories explain natural phenomena.

The development of critical (scientific) thinking skills in primary teachers and students involves actively practising these skills, which are relevant for both epistemic science education and everyday life. Some of these thinking skills may be the following:

- Asking questions and defining problems
- Analysing and interpreting data
- Building explanations and designing solutions
- Participating in evidence-based argumentation
- Developing and using models
- Planning and conducting research
- Obtaining, evaluating and communicating information

Thus, a real experience to train teachers in teaching students some epistemic knowledge through a serious game of cube is presented. The game grants students the scientist's role and introduces the scientific method as a generic protocol for problem solving, which has different components: reflective, interactive and cooperative. The objective is to provide opportunities to generate ideas and models, as this is the best way to stimulate students' creative and argumentative thinking to behave like a scientist. The general research question here is: is a serious cube game an appropriate tool to effectively teach epistemic contents in primary science?

METHODOLOGY

Instruments

The criteria for choosing the cube game were that it should explicitly address a topic on epistemic knowledge and allow students' cooperative and reflective thinking (like scientists) about elaborating learning (Vázquez & Manassero, 2012). Some authors were tracked, searching for games that fulfil the former inclusion criteria through puzzles, cubes, scenarios, dice, cards, etc., and digital games were purposefully overlooked as most of them do not meet these conditions (Vázquez & Manassero, 2017).

A simple cube (a dice with each face numbered 1 – 6 or with words) ware selected for the activity on training teachers and teaching students epistemic topics; one face of the cube is hidden from the students, as the aim of cube activity is to predict the content of the concealed face based on the observations and regularities identified in the visible faces. Students work in small groups to respond to the question: what is on the hidden side of the cube? Along the search for answers, students are gently introduced to the main aspects of practices carried out by scientists to validate knowledge (Figure 1).

Students' activities try to discover, verify and argue about the regularities observed through group discussion, solving objections and anomalies, making a prediction about the content of the hidden face of the cube, and verifying that the prediction is compatible with the observations. Only answers that are accompanied by some reasoning about evidence are allowed. The main advantage of this game is that the designs of the observable data on the visible faces can be adapted to various levels of difficulty to adjust to students' needs; for instance, a verbal cube was used in one group as a second activity (figure 1).

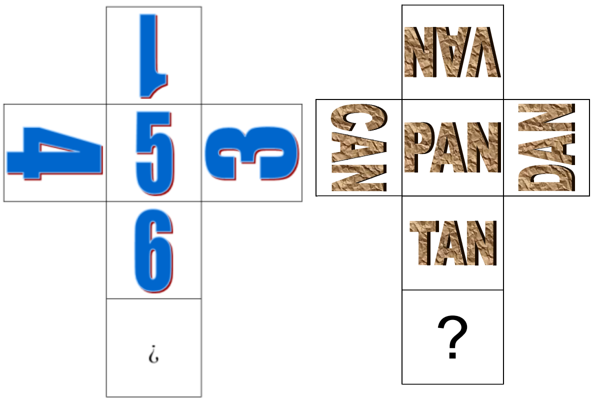


Figure 1. Two exemplary cubes used by students to predict the content of the face with the question mark. A traditional dice with the (1-6) numbers and a verbal cube with letters on its faces.

Procedure

The teachers prepare the lesson plan for the cube game, adapt its epistemic knowledge contents to teaching their groups of students, lead the teaching within the classroom, collect the students' reflections and arguments through organizers and help the students to draw conclusions about the epistemic knowledge involved.

The students observe the cube, look for evidence and reason about the evidence to reach conclusions based on valid reasoning about the accepted evidence. The general learning objectives for teaching the cube game to the students are the following: to practice/engage in accountable and constructive discussion with each other, share content understanding, build understanding on each other's observational data, drive each other to address misconceptions and misinterpretations, and encourage and model the skills of scientific inquiry that characterise scientific practice, such as thinking and argumentation, curiosity, scepticism, and openness to new ideas and data. At the beginning of the activity, the main difficulty was to curb the students' impulsiveness to give a quick response to the number on the hidden face, as everyone knew it, because they were familiar with the numbered dice, which are frequently used in Spain. The teacher insists on the task being to look for data and logical interpretations of data that lead arguably to a valid prediction about the number on the hidden face.

To complete teacher training on epistemic knowledge, the teachers share their experiences on teaching about the cube in a final joint session, to reflect on and analyse the activities carried out and the results achieved by their students.

The students try to respond to the initial question by developing some individual, whole-class and small-group activities, such as exploring the cube, writing down the observed data, looking for evidence, reasoning about data and evidence, proposing hypotheses and explanations, elaborating and discussing explanations supporting the data, reaching and arguing conclusions. A final whole-class activity may discuss all the answers to agree on some conclusions.

Participants

Six Spanish teachers (3 men) prepared and applied the cube game to their 6th grade (12-year-olds) students, which involved about one hundred students. None of the teachers held a major in Science, yet they all taught the subject Science to their students. The rationale of the implementation stems from the development of the Spanish Primary Science school curriculum content Block #1 (the activity of scientists), where the cube activity can be infused.

RESULTS

The first product of teacher training was teachers' design of the teaching-learning sequence (TLS) following the didactic model of the 7E's (elicit, engage, explore, explain, elaborate, evaluate and extend) to apply within the classroom; teachers' tasks involve the adaptation of the dice game lesson plan, the contents and the pedagogy to their students. The most important elements of the TLS on cubes include the general description, the learning standards, the relations of the game with the curriculum contents, the logical connection between evidence, scientific explanation, and theoretical models, and the students' activities.

The students respond initially to questions (How do scientists work? How would you describe a scientific investigation?) and develop some individual, group-class and small-group activities, such as exploring the cube, writing down the observed data, proposing explanations, elaborating and discussing explanations and supporting data, and arguing conclusions. In a final group-class activity, all the answers are discussed to reach a final conclusion.

The justification and general description of the sequence follows: science differs from other forms of knowledge through the use of empirical standards, logical arguments, and scepticism, as scientists struggle for the best possible explanation of things in the natural world. In the first part of the activity, the teacher uses a dice (a cube numbered 1-6) to engage the students in answering the question (what is on the concealed face?) The students propose explanations based on their observations. Optionally, the teacher may present a second cube and asks the students to propose an explanation of what is on the hidden face from the available evidence.

The objectives and learning standards related to epistemic topics of this TLS on the dice are the following:

- To identify issues that can be answered through scientific research
- To design and carry out a scientific research
- To collect, analyse and interpret data using appropriate tools and techniques
- To develop descriptions, explanations, predictions and models using evidence
- To think critically and logically to establish relationships between evidence and explanations
- To recognize and analyse alternative explanations and predictions
- To communicate scientific procedures and explanations.

The dice game relates to the following topics of Block 1 of Spanish Primary Education Science curriculum contents: scientific explanations emphasize evidence, develop logically consistent arguments and conclusions, and use scientific principles, models, and theories. The most important scientific literacy competence developed in this TLS is the logical connection between evidence, explanations and conclusions.

Table 1. Development of the teaching-learning sequence about the cubes, structured according to the didactic model of de 7E's (elicit, engage, explore, explain, elaborate, evaluate and extend).

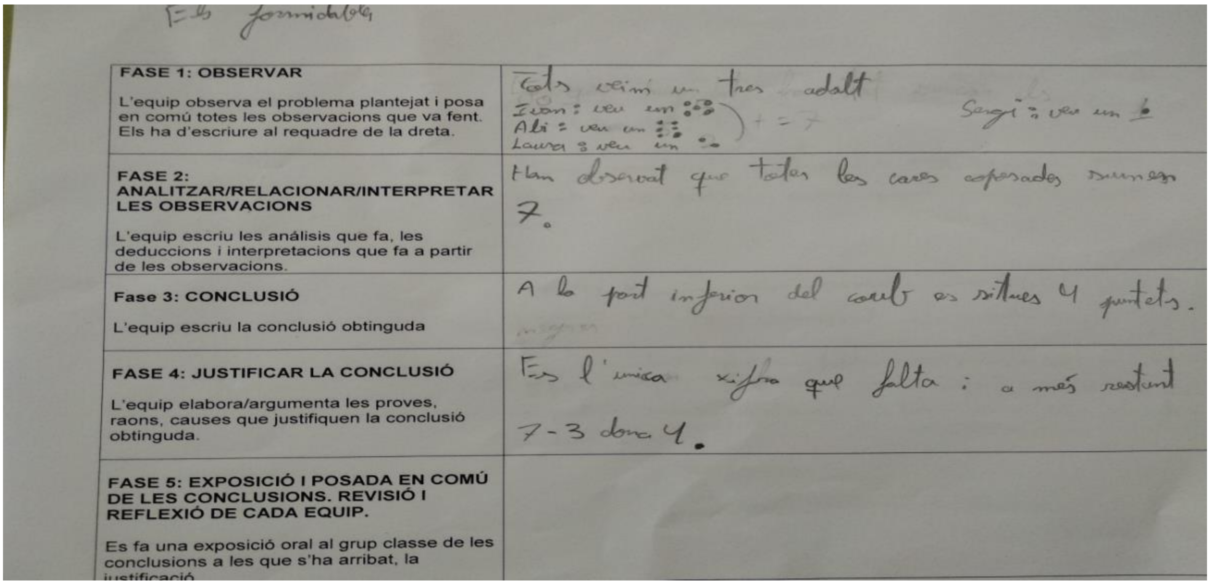
Time (min)	ACTIVITIES (Student / Teacher)	Methodology / organization	Resources
15	ENGAGEMENT Introduction-motivation Respond (write on the blackboard) / How do scientists work?	Whole class group	Verbal
15	ELICIT Previous knowledge Respond (write on the blackboard) / How would you describe a scientific investigation?	Whole class group	Verbal
	Development activities		
5	EXPLAIN/EXPLORE Content Explore dice to answer the question / What is on the bottom face of the dice?	Students in groups of 4	Dice, organizers
10	EXPLAIN/EXPLORE Procedures Write down observed data of dice / Supervise	Students in groups of 4	Dice, organizers
15	EXPLAIN/EXPLORE Attitudes Each student proposes explanations / Supervise The group elaborates its list of explanations / Regulates discussions	Students in groups of 4	Dice, organizers
50	ELABORATE Consolidation Each group presents data, explanations and argues its answer / Differentiates evidence-based explanations from non-based ones Ask and listen / Answer and explanations	Whole class	Dice, organizers
	EVALUATION Students' writings on organizer sheets Students' contributions (oral)	Whole class	
	EXTEND Transfer to verbal cube activity		Verbal cube, organizers
	TEACHER'S REFLECTION ON THE TEACHING PRACTICE (obstacles, facilitators, incidents, etc. the teacher completes pedagogical content knowledge questionnaires)		

Additional questions worth being asked to students may include the following:

- What questions do you have about the cube?
- What do we mean by evidence?
- How do you think an explanation based on evidence is different from other explanations?
- How is your investigation of the cube similar to a scientific investigation?
- May different scientific investigations require different approaches?

Students' observations about the dice will likely include many of the following:

- The numbers are black.
- The dice has five exposed sides.
- The dice has six sides.
- The exposed sides have the numbers 1, 3, 4, 5, and 6.
- The numbers on opposite sides add up to 7.
- The even-numbered sides are shaded.
- The odd-numbered sides are not shaded…



FASE 1: OBSERVAR L'equip observa el problema plantejat i posa en comú totes les observacions que va fent. Els ha d'escriure al requadre de la dreta.	Tots veiem un tres adalt Izan: veu un Abi: veu un Laura: veu un Sergi: veu un
FASE 2: ANALITZAR/RELACIONAR/INTERPRETAR LES OBSERVACIONS L'equip escriu les anàlisis que fa, les deduccions i interpretacions que fa a partir de les observacions.	Hem observat que totes les cares oposades sumen 7.
Fase 3: CONCLUSIÓ L'equip escriu la conclusió obtinguda	A la part inferior del cub es situen 4 puntets.
FASE 4: JUSTIFICAR LA CONCLUSIÓ L'equip elabora/argumenta les proves, raons, causes que justifiquen la conclusió obtinguda.	És l'única xifra que falta: a més restant 7-3 dona 4.
FASE 5: EXPOSICIÓ I POSADA EN COMÚ DE LES CONCLUSIONS. REVISIÓ I REFLEXIÓ DE CADA EQUIP. Es fa una exposició oral al grup classe de les conclusions a les que s'ha arribat, la justificació	

The organizer of Figure 2 contains some comments of a group of students, who reasoned this way on the data recorded on their organizer to find their answer:

Phase 1. Observe. “We all see a 3 above; Izan sees a 5; Abi sees a six; Laura sees a 2; Sergi sees a 1.” (The dice faces are represented by dots on the organizer, because the students' working dice was a classic black-dot dice).

Phase 2. Interpret the observations. “We have observed that all the opposite sides add up to 7"

Phase 3. Conclusion. "There must be 4 dots in the bottom face of the dice."

Phase 4. Justification. It is the only number that is missing, and also if you subtract 7 – 3, you get 4.

Figure 2. Two small groups of students playing with dice and the organizer at the table; the left group observes a numbered dice and the second group is using a verbal cube.

Some students’ verbal contributions and discussions during activities were recorded by teachers. Two exemplary excerpts of these discussions follow: the first excerpt accounts for the (synthetized) argumentative flow within a small cooperative group:

Group 5

- ✓ S1: “The numbers on the opposite sides of the dice are even and odd ...

- ✓ S2: And on top (on the upper face), we have a 2 ...
- ✓ S3: And on the left side, we have a 4 and a 6, which are even numbers, and on the right of the odd numbers are number 3 and number 1 …
- ✓ S4: … mmm… that means that on the bottom, there must be an odd number, and when discarding the known numbers, it has to be 5. The number of the invisible face is 5."

The second excerpt shows a boy's oral account to the class; his Spanish speech is particularly relevant for its simplicity, precision, clarity, coherence, language quality and eloquence.

> Group 4. A boy's speech accounting for the argumentation of his cooperative group to the whole class:
>
> "The parallel faces of the cube always add up to 7. You can check that number 3, which is on this side, plus the 4, which is on the opposite side, add up to 7; further, you can add the 2, which is on this side, plus the 5, which is in the other side, also add up to 7. If you have the 6 on top and subtract it from 7, you get 1, so number 1 is on the bottom."

To complete the primary teacher training on epistemic knowledge, the teachers shared their experiences on the application of the teaching-learning sequence about dice in a reflective joint session, where the teachers assessed the activities and the results achieved by their students. All the teachers were satisfied with the experience, as these two excerpts show:

- T2. "I must mention that working on credible activities of the same style/level we face at specific moments and situations in daily life is one of the things I have found most stimulating and interesting."
- T5. "The experience as a whole ... I found it very positive, as it has shown the value of little, simple activities that can be much more useful tools than they seem at first sight."

The researchers asked the teacher to agree on drawing much more specific conclusions from the experience on teaching the TLS on dice to their students. The teachers' conclusions reflect some students' behaviours that teachers unexpectedly found good enough to be emphasized:

- The students spontaneously accepted all opinions, in spite of being corrected or discarded later on.
- The students did not fight or quarrel to impose their personal views; rather, they accepted and tried to reach a consensus in spite of having quite different ideas.
- The students tried to change and adjust their views to the facts, especially when new evidence arose through the cooperative exchanges and argumentations.
- Students' initial acritical high impulsivity to use the first idea springing to mind was progressively reduced by increasing reflectivity on the evidence.

All in all, teachers' conclusions reveal a progressive awareness and action on self-regulation and meta-cognition processes that contributed to increase the students' self-control throughout their cooperative work along the cube activities.

DISCUSSION AND CONCLUSIONS

The innovative experience of teacher training and student learning about epistemic knowledge presented herein should be contextualized bearing in mind that it was the first innovative step toward including epistemic knowledge in science education of the primary teachers, who do not have specific training in science and much less in epistemic topics. Given that the main difficulty with epistemic knowledge is the lack of resources and teachers' lack of training and their reluctance to teach it, the satisfaction of teachers and students with the simple dice activity developed in the classroom shows that the aims of this study for teachers' training and students' learning were met. Teachers considered the experience with a serious dice game effective to teach epistemic contents and they appreciated the merits of the game: its flexibility to adapt to different topics and students' interests, needs and age, thus fostering students' motivation and interest in playing to learn complex topics (Abd-el-Khalick & Akerson, 2009).

Further, the experience of dice is deliberately simple to allow the teachers to achieve a balanced and calm training on these innovative and complex epistemic issues, so that they can sustainably increase the complexity of their future professional development on epistemic issues, through the experience of more complex games. In fact, the teachers expressed satisfaction and were encouraged to extend the teaching of epistemic contents through new games for the next step of training (Vázquez-Alonso & Manassero-Mas, 2017).

Further, playing dice games manifestly promotes transversal skills for general competences, namely, scientific and critical thinking skills, such as asking (and answering) questions, seeking data, making decisions, creating hypotheses, predicting outcomes, sharing ideas, arguing on evidence, discussing results, and communicating conclusions (NGSS, 2013).

As games contribute to overcome the complexities of epistemic knowledge by means of analogical simplification, they may display a limited image of scientific practices, and it might be argued that games do not perfectly represent the original epistemic content in scientific practice. However, the satisfaction and rationale of this study go beyond the relative limitation of their representativeness; first, the power of games for making complex epistemic knowledge accessible to teachers and students widely compensates these caveats; second, gamification allows teachers and students to draw on key epistemic knowledge for developing a relevant approach to scientific thinking, which is key for competent science literacy; third, the games make the epistemic content affordable, useful and practical to encourage novice teachers and challenge students. Thus, when considering the generation of students' motivation and participation in gamified learning, and teachers' satisfaction and confidence to maintain the epistemic contents in their classroom, the counterbalance to the potential imperfection of games is quite positive. Thus, teachers' and students' engagement with games may set up an inflection point for the omission tradition for epistemic teaching, as most literature reflects (Abd-el-Khalick & Akerson, 2009; Deng et al. 2011; García-Carmona et al. 2011; Lederman, 2007).

All in all, the originality of this study is its sustainability, as it allows systematically self-development of different games that can satisfy multiple adaptations to teach different epistemic topics at different educational levels without external help or previous knowledge. This feature also helps the teachers to deepen their training on these resources, which may encourage them to keep teaching these topics with confidence and excitement (Vázquez-Alonso & Manassero-Mas, 2017, 2018).

ACKNOWLEDGEMENTS

Project EDU2015-64642-R (AEI/FEDER, UE) funded by the Spanish State Research Agency and the European Regional Development Fund.

REFERENCES

Abd-el-Khalick, F., & Akerson, V. (2009). The influence of metacognitive training on preservice elementary teachers' conceptions of nature of science. *International Journal of Science Education, 31*, 2161-2184.

Deng, F., Chen, D.-T., Tsai, C-C, & Chai, C.-S. (2011). Students' views of the nature of science: A critical review of research. *Science Education*, 95, 961–999.

García-Carmona, A., Vázquez, A., & Manassero, M. A. (2011). Estado actual y perspectivas de la enseñanza de la naturaleza de la ciencia: una revisión de las creencias y obstáculos del profesorado. *Enseñanza de las Ciencias*, 28, 403–412.

Gee, J. P. (2007). What video games have to teach us about learning and literacy. New York: Palgrave Macmillan.

Hattie, J. (2009). *Visible learning: A synthesis of over 800 meta-analyses relating to achievement*. London: Routledge.

Lederman, N. G. (2007). Nature of science: Past, present, and future. In S. K. Abell & N. G. Lederman (Eds.), Handbook of research on science education (pp. 831–879). Mahwah, NJ: Lawrence Erlbaum Associates.

Li, M-C., & Tsai, C-C. (2013). Game-based learning in science education: A review of relevant research. *Journal of Science Education and Technology, 22*(6), 877-898.

McGonigal, J. (2011). *Reality is broken: Why games make us better and how they can change the world*. New York, NY: Penguin.

Millar, R. (2006). Twenty-first century science: Insights from the design and implementation of a scientific literacy approach in school science. *International Journal of Science Education*, 28(13), 1499-1521.

NGSS Lead States (2013). *Next generation science standards: For states, by state*s. Washington, DC: The National Academies Press.

Vázquez, A., & Manassero, M. A (2012). La selección de contenidos para enseñar naturaleza de la ciencia y tecnología (parte 1): Una revisión de las aportaciones de la investigación didáctica [The selection of contents to teach the nature of science and technology (part 1): A review of the contributions of didactic research]. *Revista Eureka sobre Enseñanza y Divulgación de las Ciencias, 9*(1), 2–31.

Vázquez-Alonso, A. ,& Manassero-Mas, M.A. (2017). Juegos para enseñar la naturaleza del conocimiento científico y tecnológico [Games to teach the nature of scientific and technological knowledge]. *Educar*, *53*(1), 149-170.

Vázquez-Alonso, Á., & Manassero-Mas, M. A. (2018). Más allá de la comprensión científica: educación científica para desarrollar el pensamiento [Beyond scientific understanding: Science education to develop thinking]. *Revista Electrónica de Enseñanza de las Ciencias*, 17(2), 309-336.

USING PHILOSOPHY-INSPIRED CATEGORIZATION STRATEGIES TO DESIGN A LEARNING ENVIRONMENT ABOUT BIOLOGICAL CLASSIFICATION: A CASE STUDY WITH 4TH GRADERS

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This paper reports on the second case study that has been performed in the first cycle of a design research, which aims at designing a learning environment about biological classification by drawing on philosophical theories of 'concept formation' or 'categorization'. Philosophy can provide theories that suggest different mechanisms of categorization. Family resemblance-inspired theories suggest that we categorize by relying on examples of the concept or on lists of the examples' shared features. Moreover, classical theory suggests that we categorize by articulating concepts' definitions. Considering the above theories, we developed a three-part, learning environment that aims at supporting primary school students in constructing the biological concepts of fish, amphibian, reptile, bird, and mammal, and in enhancing their categorization skills. The first version of the learning environment consists of seven teaching-learning activities that encourage students to use different types of reasoning in order to categorize vertebrate animals into their biological classes. Students are expected to collaborate in small groups in order to classify vertebrate animals into their classes, by (a) observing different examples of each vertebrate class, (b) making lists of the features the members of each class share ('shared features lists'), (c) deducing some key features of each class from the corresponding 'shared features list', and (d) using these key features to articulate definition-like reasoning strands about vertebrates. Analyzing the pre/post responses of the 21 conveniently selected 4th graders who took part in this case study, showed an improvement in their reasoning about the target biological concepts. The results are thoroughly discussed in the paper.

Keywords: Conceptual understanding, science education, reasoning

INTRODUCTION

Organizing human experience into mental categories (that is, concepts like chair, insect, etc.), allows us to store information efficiently, as well as to have theories about the world and reason with them (Ergazaki, Gasparatou, & Valanidou, 2015; Gelman & Meyer, 2011). In everyday life, people seem to categorize in many different ways, depending on the task they deal with (Murphy, 2002). When it comes to biology education however, it is important to familiarize children with *biologically* informed classifications of concepts like plants or animals (Ergazaki, Gasparatou, & Valanidou, 2018).

Biology education research then, is significantly concerned with the ways children classify living things (Allen, 2015; Anderson, Ellis, & Jones, 2014; Martinez-Losada, Garcia-Barros,

& Garrido, 2014; Papadopoulou & Athanasiou, 2015; Patrick et al., 2013; Prokop, Tolarovičová, Camerik, & Peterková, 2010; Rybska, Tunnicliffe, & Sajkowska, 2014; Tao, 2016), as well as with designing learning environments to help them shift to biological classifications in particular (Koliopoulos, Gouskou, & Arapaki 2012; Kos, Šuperger, & Jerman, 2015; Lorenzi, Labrell, Ronchi, Tatano, & Perucchini, 2013; Marulcu, 2014; Randler, 2009; Ronchi, Labrell, Lorenzi, Tatano, & Perucchini, 2012; So & Ching, 2015). Research shows that children have rather naive ideas about animals and their groupings (Marulcu, 2014), and that these ideas are rather resistant to teaching (Kattmann, 2001). For example, children tend to classify bats as birds, dolphins as fish (Natadze, 1963), and sea turtles and crocodiles as amphibians, even after biology instruction (Yen, Yao, & Chiu, 2004).

Since typical biology teaching does not always seem to work adequately, we thought it would be interesting to design an alternative learning environment by drawing on general theories of concept formation. Philosophy can provide us with such theories and suggest different reasoning strategies that may be involved in categorization (Gasparatou & Ergazaki, 2016). More specifically, classical theory claims that we categorize individual fish, for instance, under the concept fish, by articulating a fish definition. Family resemblance-inspired theories on the other hand, imply that we categorize individual fish under the concept fish, by exploring different examples of fish and intuitively grasping common fish-features.

Thus, our study addresses the question of whether it is feasible to use these philosophical theories in order to design a learning environment that could facilitate primary school students in constructing the biological concepts of fish, amphibian, reptile, bird, and mammal. In this paper, we are concerned with evaluating the first version of our philosophy-inspired learning environment by identifying students' ideas before and after taking part in it. So, the research question here is: 'How do primary school students of 4th grade reason about the biological concepts of fish, amphibian, reptile, bird, and mammal, before and after their participation in the first version of our philosophy-inspired learning environment?'. More specifically, 'do they group vertebrate animals in class-groups?', 'how do they justify their groupings?', and 'how they use the quantifiers 'all' or 'some' when reasoning about specific features of vertebrates classes?'.

METHODS

The overview of the study

This paper reports on the second case study of the first research cycle of a design research (Akker, Gravenmeijer, McKenney, & Nieveen, 2006) that aims at designing a philosophy-inspired learning environment about the classes of vertebrate animals. The learning environment is addressed to primary school students, and in this particular case study we implemented and evaluated its first version with fourth graders. The implementation was carried out with three, 1-1.5 hour sessions in three consecutive school days. Before and after implementing our learning environment, we performed a pre/post test, using an open-ended questionnaire that students had to fill in individually. The questionnaire was first piloted with students of similar profile with that of our participants, and the feedback was used for elaborating the initial phrasing and format of the items.

The participants

The participants of the case study were 21 4th graders (12 girls/9 boys, age 9-10), attending a public school in a semi-urban area of Patras with medium/high socio-economic status. Students were selected conveniently: their teacher volunteered to facilitate our study. According to her, students were familiar with group-work, as well as with some basics about animals. Before carrying out the pre-test, the first author visited children's class to meet them, inform them about the study, and ask for their own assent to participate.

The learning environment

Having in mind the mechanisms of concept formation suggested by relevant philosophical theories such as the family resemblance inspired theories or the classical theory (Gasparatou & Ergazaki, 2016; Murphy, 2002), we designed the first version of a constructivist learning environment. This consists of seven teaching-learning activities that aim at actively engaging students in class-based groupings of vertebrates. Using the strategies suggested by the family resemblance inspired theories, students were encouraged to think about vertebrates (a) by comparing new items with examples of each vertebrate class (*session 1*), and (b) by making lists of family resemblances for each vertebrate class *(session 2)*. Then, using the strategies that *classical theory* implies, children were encouraged (c) to make inferences about which of these resemblances are more usual and/or important for each vertebrate class (*session 2*), and (d) deduce the classes' 'key features' in order to differentiate between them (*session 3*). In sum, children had the chance to employ different categorization strategies throughout the sessions, like philosophers suggest we do in everyday life.

In more detail, the participants were divided into five mixed-level groups of 3-6 members and collaborated in all three sessions. In s*ession 1* (activity 1.1) students worked on a scenario about five small suitcases, each corresponding to one vertebrate class. Presumably, suitcases fell open, and the cards that were inside them fell off and got mixed; only two cards per suitcase remained in place. Each suitcase was assigned to one peer-group. Students were shown one by one the cards that fell off all the suitcases, and were asked to compare them to the two cards still inside their group's suitcase, in order to decide whether each card belonged to their suitcase and why.

In *session 2,* suitcases were assigned to different peer-groups, this time along with a *'features' list'* of the corresponding class. Students now had to identify how many members of the class had these features, by using the options *'all', 'some',* or *'none' (activity 2.1).* Then *(activity 2.2),* peer-groups exchanged suitcases again, were given 'animal-cards', 'features-cards' and *'all'*-/*'some'*-/*'none'*-cards, and they were asked to use them for creating *true* phrases about the depicted animals (e.g. *'some mammals fly'*; '*no bird has gills'*). Finally, they were presented with new animal cards and had to recognize which card belongs to which suitcase once more, but this time *not* by '*comparing to the class's examples'* like before*,* but by using *'features' lists' (activity 2.3).*

In *session 3,* students were asked to compare the lists of the five vertebrate classes and reject the features these lists had in common. Thus, they came up with the *'key features'* of each class *(activity 3.1).* Then *(activity 3.2)* students were asked to play a 'guessing' game. They were given lists of key or non-key features of unidentified animals and asked to guess to which vertebrate class these animals belonged. Finally, they were asked to create 'suitcase-tags' by articulating definition-like reasoning strands (e.g. *'If it has fur and is breastfed when young, it is a mammal'*), that could help put the cards back in place in case of another accident *(activity 3.3)*.

The pre/post questionnaire

The pre/post questionnaire included six open-ended items. Here we will present just three. The first two aimed at exploring how students' vertebrate groups may differ from the biological ones and why. Both these items relied on a scenario about a five-hall museum, with two animal exhibits of the same vertebrate class in each hall (hall 1: fox, squirrel; hall 2: eagle, sparrow; hall 3: snake, lizard; hall 4: frog, toad; hall 5: sea bream, sole). Someone supposedly donated sixteen new animal exhibits (bear, tiger, koala, dolphin, whale, bat, peacock, ostrich, penguin, crocodile, salamander, ray, seahorse, shark, swordfish and eel) to the museum. Students, having pictures of the animals at their disposal, were asked to distribute all new exhibits to the five halls (item 1) and justify *why* they chose to configure the halls as they did (item 2). Item 3 was designed to test students' ability to distinguish between features that characterize *all* the members of a vertebrate class from features that characterize only *some*. Students were given 10 propositions, two per vertebrate class, and they had to fill them in with a suitable quantifier (*'all'* or *'some')*. For instance, *'...... reptiles have scales'*, *'...... mammals lay eggs'* and so forth.

The analytic procedure

Students' responses to the items of the pre/post questionnaire were coded in *NVivo* as follows. Item 1 responses about the configuration of the museum halls with the new exhibits, were coded according to whether each hall was configured as a *'class-hall'* or not. So, we created an 'NVivo-attribute' per hall, we gave it the 'values' *'class-hall configuration: yes'* or *'class-hall configuration: no'* and we coded accordingly. In order for the first 'value' to be attributed to a response, students should have configured the hall by displaying in it (a) *all* the new exhibits that belong to the same class with the two already there, and (b) *no*ne that belongs to a different class. Responses that did not meet these two requirements *at the same time*, were given the value *'class-hall configuration: no'*.

Item 2 responses about *why* students chose to configure each hall as they did, were coded as *'naive', 'transitional'* and *'informed*'. Responses that justified the configuration of the museum-halls by appealing to the animals' class (e.g. '*They should go together because this will be the bird room')* and/or the class's key features (e.g. *'They are put here because they all have gills'*), were coded as *'informed'*. Responses that did not appeal to anything of the above were coded as *'naive' (e.g. 'They go together because they fly').* Finally, responses with *both* an *'informed' and* a *'naive'* part, were coded as *'transitional' (e.g. 'I've put them together because they give birth to babies and they breastfeed them)*.

Item 3 responses were coded with regard to how many propositions per vertebrate class were filled in with the appropriate quantifier *('all' or 'some')*. So, we created an 'NVivo-attribute' for each vertebrate class which we called *'correct quantifier'* (in short *'CQ'*), and since children had to fill in *two* 'same class'-propositions, we gave the attribute the three 'values' *'CQ_0', 'CQ_1', 'CQ_2',* and we coded accordingly. The coding of all items' responses was performed independently by two of the authors with a satisfactory agreement.

RESULTS

Configuration of the museum halls - Item 1

Analyzing students' pre/post responses about how they would configure the five museum halls by distributing the new animal exhibits to them showed that they made progress. In the post-test, the number of students who came up with *'class-halls'* (*'class-hall configuration: yes'* or *'CHC_yes'* in short) was always higher than in the pre-test; and so the number of students who did not come up with *'class-halls'* (*'class-hall configuration: no'* or *'CHC_no')* was always lower than in the pre-test (Figure 1).

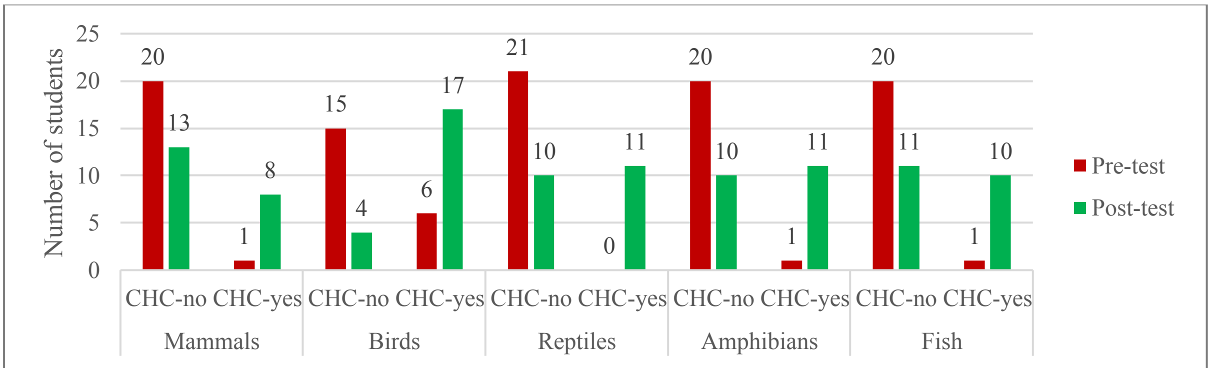

Figure 1. Class-hall ('CHC_yes') and non class-hall ('CHC_no') configurations - Item 1

More specifically, in the case of birds, the number of students with *'CHC_yes'* in the post-test (17/21) was much higher than the number of students with *'CHC_yes'* in the pre-test (6/21) (Figure 1). The results about mammals, reptiles, amphibians and fish were slightly different. The number of students with *'CHC_yes'* in the post-test was once more higher than the number of students with *'CHC_yes'* in the pre-test (mammals: 8/21 *vs.* 1/21, reptiles: 11/21 *vs.* 0/21, amphibians: 11/21 *vs.* 1/21, fish: 10/21 *vs.* 1/21); however, the number of students with *'CHC_no'* in the post-test, despite being reduced, it still remained rather high (mammals: 13/21, reptiles: 10/21, amphibians: 10/21, fish: 11/21) (Figure 1). Misclassifications revealed in non-class configurations of the halls concern whales (misclassified as fish), sharks (misclassified as mammals), penguins (misclassified as fish).

Justifications about the configuration of the museum halls - Item 2

The analysis of students' pre/post justifications about how they would configure the museum halls by distributing the new animal exhibits, showed progress as well. In the post-test, only a few students with class-hall configurations provided 'naïve' justifications for what they did (mammals: 0/8, birds: 3/17, reptiles: 2/11, amphibians: 3/11, fish: 3/10), whereas most of them provided *'informed' and 'transitional'* justifications (mammals: 8/8, birds: 14/17, reptiles: 9/11, amphibians: 8/11, fish: 7/10) (Figure 2). For instance, students configured 'hall 2' by distributing all the new bird-exhibits and none non-bird-exhibit to it *'because this is the group of birds'* ('informed' post-response); '*because they are all birds and because they all have wings'* ('transitional' pre-response); '*because they can fly'* ('naïve' pre-response).

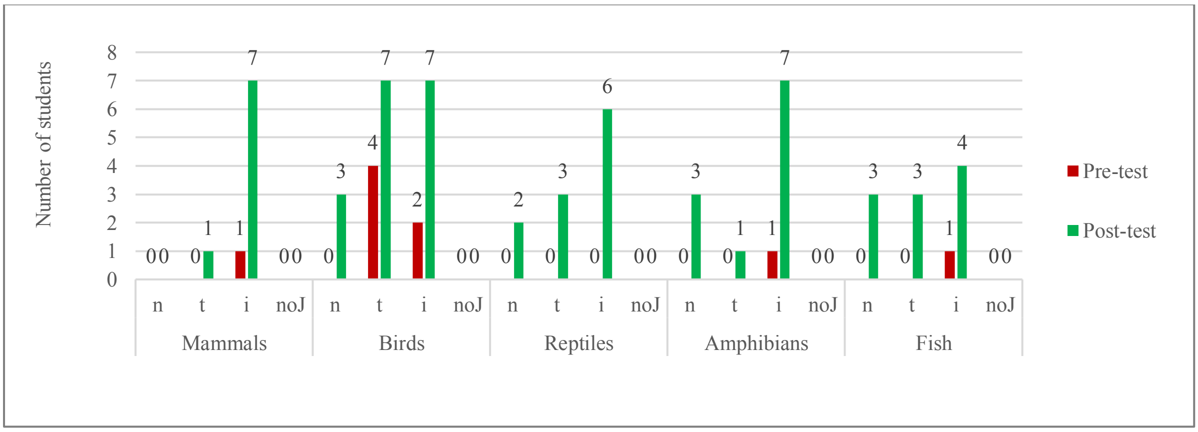

Figure 2. Justifying class-hall configurations ('CHC_yes') - Item 2

Moreover, all students with non-class-configurations (*'CHC_no')* in the post-test, gave much more *'informed'* and *'transitional'* justifications than *'naive'* ones: mammals: 13/13 vs 0/13; birds: 3/4 vs 1/4; reptiles: 7/10 vs 2/10; amphibians: 6/10 vs 1/10; fish: 8/11 vs 3/11) (Figure 3). The common mistake in *'CHC_no'* post-responses was including all the members of a class in the class hall together with a non-member, or, in some cases, leaving just one member of the class out of the hall. However, when they tried to justify their decisions, they would use 'informed' justifications. For instance, students configured 'hall 5' including the ray, the seahorse, the shark, the swordfish, the eel *and the dolphin* '*because these are the fish group'*. In other words, they did draw on the class of the animals in order to group them together, even though they had the misconception that dolphins are fish.

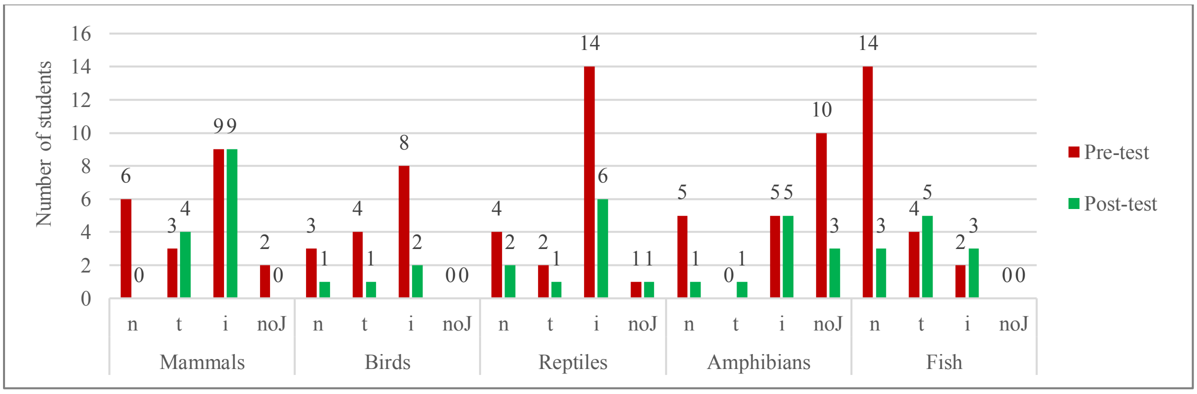

Figure 3. Justifying non class-hall configurations ('CHC_no') - Item 2

Use of the quantifiers 'all' and 'some'- Item 3

The analysis of students' pre/post-use of the quantifiers *'all'* or *'some'* with regard to the members of vertebrate classes, indicates progress as well (Figure 4).

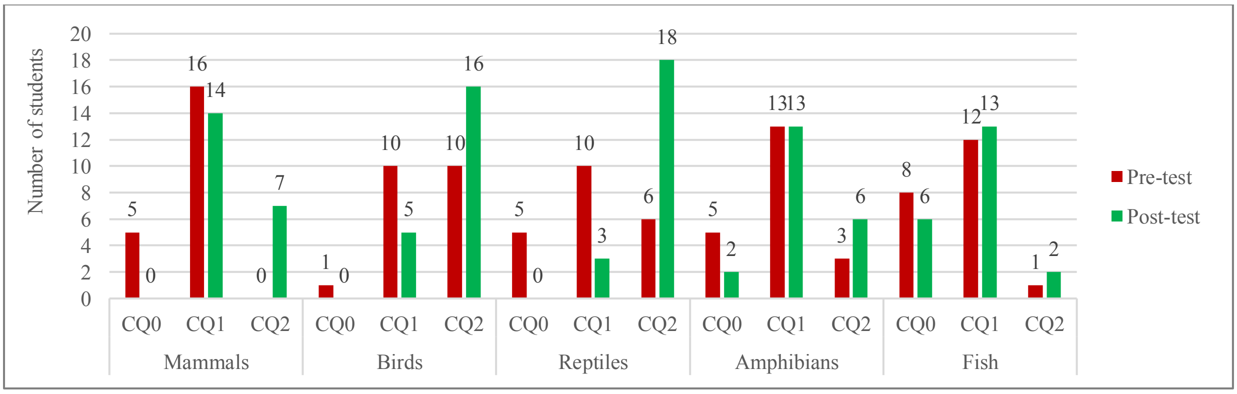

Figure 4. Use of the quantifiers 'all' and 'some' - Item 3

In the case of reptiles, the number of students who used the appropriate quantifier in *both* propositions *('CQ_2)*, increased quite remarkably in the post-test (18/21 *vs.* 6/21). In the case of mammals as well as in the case of birds, the number of students who used the appropriate quantifier in *both* propositions (*'CQ_2')* increased significantly (mammals: 7/21 *vs.* 0/21; birds: 16/21 *vs.* 10/21). On the other hand, in the case of amphibians, the number of '*CQ_2'* post-responses increased slightly (6/21 *vs.* 3/21), whereas fish seemed to trouble students even more: only two students used the appropriate quantifier in both propositions in the post-test (*'CQ_2'*: 2/21 *vs.* 1/19) (Figure 4).

DISCUSSION

According to the results, students made progress in grouping vertebrate animals in *class*-groups. After the implementation of the learning environment, class-groupings within the five-hall museum scenario became much more frequent. However, many students did not configure all their halls as class-halls. When justifying their configurations, most students in the post-test provided *'informed'* or *'transitional'* justifications, whereas only a few provided *'naïve'*. More interestingly, even children who came up with non class-groupings mostly provided *'informed'* or *'transitional'* justifications; that is, they appealed to the animals' class and/or the class' key features. So, even though they did not come up with *fully* class-configured halls, their justifications may indicate that they *did* wish to do so but they missed the correct information about specific animals. For example, they may have added one or two mammals in the hall they identified as the *fish* hall, because they did not know they were mammals; or they may have left one or two mammals out of the hall that they did identify as the *mammal* hall, just for the same reason. In other words, it seems that children grasped the overall idea of using biology-informed categorization strategies that involve class identifications or 'key-features' justifications, but they were unable to perform it adequately yet. Finally, students also improved their use of specific quantifiers (*'all', 'some'*) when reasoning about vertebrates classes. In the case of reptiles, mammals and birds, the number of students who used the appropriate quantifier in *both* propositions, increased quite remarkably. In the case of amphibians and fish, there was a slight increase, but results seemed less promising.

In sum, the first version of our learning environment worked quite well, not only with 5th graders as reported elsewhere (Valanidou, Ergazaki, & Gasparatou, 2019), but with 4th graders, too. It seems however, that there is still room for improvement. So, since the rationale of having students practice philosophy-inspired reasoning strategies in order to categorize seemed to pay off, we are considering extending our learning environment with more educational activities that could further promote students' understanding of biological classification.

ACKNOWLEDGEMENT

This research was supported by Grant (E667) from the Research Committee of the University of Patras via "K. Karatheodori" program.

REFERENCES

Akker, J.V.D., Gravenmeijer, K., McKenney, S., & Nieveen, N. (Eds.). (2006). *Educational Design Research*. Oxon, England: Routledge.

Allen, M. (2015). Preschool children's taxonomic knowledge of animal species. *Journal of Research in Science Teaching, 52*, 107-134.

Anderson, J. L., Ellis, J. P., & Jones, A. M. (2014). Understanding early elementary children's conceptual knowledge of plant structure and function through drawings. *CBE-Life Sciences Education*, *13*, 375-386.

Ergazaki, M., Gasparatou, R. & Valanidou, E. (2015). Tracing preschoolers' ability to form and use categories. *Educational Journal of the University of Patras UNESCO Chair*, *2*, 84-95.

Ergazaki, M., Gasparatou, R. & Valanidou, E. (2018). *Young children's reasoning when sorting pictures and objects.* In N. Gericke & M. Grace (Eds.), *Volume of selected from ERIDOB 2016: Challenges in Biology Education Research* (pp. 199-215). University of Karlstad, Sweden.

Gasparatou, R. & Ergazaki, M. (2016). Could philosophy inform biology education? *Educational Journal of the University of Patras UNESCO Chair, 3,* 29-35.

Gelman, S. A., & Meyer, M. (2011). Child categorization. *Wiley Interdisciplinary Reviews: Cognitive Science, 2*, 95-105.

Kattmann, U. (2001). Aquatics, Flyers, Creepers and Terrestrials—students' conceptions of animal classification. *Journal of Biological Education, 35*, 141-147.

Koliopoulos, D., Gouskou, E., & Arapaki, X. (2012). Organizing principles of a school-museum teaching intervention for pre-school children. In *Colloque Siest Mediterranee Tunis 2012* (p. 21).

Kos, M., Šuperger, B., & Jerman, J. (2015). Early Science Outdoors: Learning about Trees in the Preschool Period. *Problems of Education in the 21st Century*, *1*, 24-37.

Lorenzi, C., Labrell, F., Ronchi, C., Tatano, C. M., & Perucchini, P. (2013). Children's conceptions about animals, plants and nonliving things before and after instruction. In *Conference Proceedings New Perspectives in Science Education edited by Pixel* (pp. 211-214).

Martinez-Losada, C., Garcia-Barros, S., & Garrido, M. (2014). How children characterize living beings and the activities in which they engage. *Journal of Biological Education, 48*, 201-210.

Marulcu, I. (2014). Teaching habitat and animal classification to fourth graders using an engineering-design model. *Research in Science & Technological Education*, *32*, 135-161.

Murphy, G. L. (2002). *The big book of concepts.* MIT press.

Natadze, R. G. (1963). The mastery of scientific concepts in school. *Educational Psychology in the USSR*, 192-197.

Papadopoulou, P., & Athanasiou, K. (2015). Children Ideas for "Animal" Compared to Teachers' Conceptions. *International Journal of Innovation and Research in Educational Sciences, 2*, 462-471.

Patrick, P., Byrne, J., Tunnicliffe, S. D., Asunta, T., Carvalho, G. S., Havu-Nuutinen, S., Sigurjónsdóttir, H., Óskarsdóttir, G. & Tracana, R. B. (2013). Students (ages 6, 10, and 15 years) in six countries knowledge of animals. *Nordic Studies in Science Education*, *9*, 18-32.

Prokop, P., Tolarovičová, A., Camerik, A. M., & Peterková, V. (2010). High school students' attitudes towards spiders: a cross-cultural comparison. *International Journal of Science Education*, *32*, 1665-1688.

Randler, C. (2009). Learning about bird species on the primary level. *Journal of Science Education and Technology*, *18*, 138-145.

Ronchi, C., Labrell, F., Lorenzi, C., Tatano, M.-C. & Perucchini, P. (2012). Children's Biological Conceptions before and after Instruction. In C. Bruguière, A. Tiberghien & P. Clément (Eds.), *E-Book Proceedings of the ESERA 2011 Conference: Science learning and Citizenship,* Part 1 (co-ed. R. Pinto & K. Niebert), (pp. 72-78). Lyon, France: European Science Education Research Association.

Rybska, E., Tunnicliffe, S. D., & Sajkowska, Z. A. (2014). Young Children's Ideas αbout Snail Internal Anatomy. *Journal of Baltic Science Education, 13*, 828-838.

So, W. W. M., & Ching, F. N. Y. (2015). A study of the internet resource-based e-learning environments in Hong Kong: Animal classification in a primary school. In *Science Education in East Asia* (pp. 317-337). Springer, Cham.

Tao, Y. (2016). Young Chinese children's justifications of plants as living things. *Early Education and Development*, *27*, 1159-1174.

Valanidou, E., Ergazaki, M., & Gasparatou, R. (2019). Towards a philosophy-inspired learning environment about biological classification: Insights from the 1st cycle of a design research. *Educational Journal of the University of Patras UNESCO Chair, 6*, 61-70.

Yen, C. F., Yao, T. W., & Chiu, Y. C. (2004). Alternative conceptions in animal classification focusing on amphibians and reptiles: A cross-age study. *International Journal of Science and Mathematics Education, 2*, 159-174.

REINFORCEMENT OF KNOWLEDGE ABOUT GERMINATION AND PLANT GROWTH: A CASE STUDY OF A LEARNING SUPPORT SYSTEM BASED ON FULL-BODY INTERACTION AND COLLABORATION

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Through experiential learning, students not only obtain knowledge but also acquire the ability to solve problems; the former is necessary for the latter to be effective. However, most teaching relies on passive methods of learning, which has a negative effect on both student motivation and learning itself. Active learning methods can improve the impact of experiential learning. To this end, in this study we develop a prototype system that supports learning using collaboration and full-body interaction. We then apply it to a lesson at a primary school in Chiba, Japan, where multiple students learn about plant germination and growth conditions through quizzes and evaluate its effect. Our evaluation suggests that this system reinforces learners' knowledge of germination and plant growth conditions and that it is an effective tool for furthering students' learning.

Keywords: Active Learning, Collaboration, Primary School

INTRODUCTION

Experiential learning is vital to science education (Kolb & Kolb, 2005; Uitto & Nordström, 2017). For example, garden-based learning can help students acquire both knowledge and problem-solving skills (Robinson & Zajicek, 2005). To develop the latter, students must first identify problems through their own experiences. However, it is difficult to determine a problem simply through experience with no knowledge. Therefore, student learning is furthered when students first obtain any necessary knowledge and then deepen their understanding through hands-on experience (Rickinson, 2004).

Current approaches to teaching knowledge before experiential learning rely on watching videos and providing explanations: both of these methods involve explaining concepts to all students at once (Palmárová & Lovászová, 2012). However, since these are both passive methods, differences in student motivation result in differences in learning (Nicol, 2010). This may decrease the impact of experiential learning and must be addressed to ensure this tool's effectiveness. As one of the support methods, there is a learning support system for teaching knowledge before experiential learning (Fuse et al., 2003). This system reproduces the learning location on a computer. Students simulate experiential learning on a computer. Thereby, students learn the knowledge for experiential learning. However, in this system, since students use different computers, it is difficult to reduce the difference in student motivation. In addition, there is a problem that operation is difficult for students who have never used a computer.

Student discuss and learn effectively through collaboration with multiple people (Grabinger & Dunlap, 1995). Research shows that learning improves when body movement is incorporated into lessons (Norris et al., 2015). Therefore, we develop a prototype system that supports learning using collaboration and full-body interaction. We expect this system will help learners acquire knowledge actively and effectively.

In this paper, we describe developed learning support system using collaboration and full-body interaction and evaluate this system. In this system, students learn about germination conditions and plant growth condition. In order to evaluate this system's promotion of collaboration and full-body interaction, we conduced follow-up questionnaire. We also conducted the same tests before and after the system experience to evaluate improvement in knowledge of germination and plant growth conditions.

METHODS

Experiential Learning Model

Our model allows multiple students to simultaneously learn about germination and plant growth conditions using full-body interaction and collaboration. Figure 1 shows the system setup; it is comprised of two screens (one on the wall and the other on the ground), two projectors, a Kinect sensor, and a control PC. Three learners collaborate and discuss quiz questions about germination and growth conditions and answer using body movements. The system displays areas for answering each question and a plant seed or seedling on the wall screen. The floor screen, meanwhile, shows nine answer choices. Participants select three germination conditions (sunlight, water, moderate temperature) for seeds displayed on the wall screen from nine choices on the floor screen.

This system enables learning using bodily movements and collaboration by including an answer selection function to the floor screen through the use of a Kinect sensor. Kinect sensors acquire human skeleton coordinates as three-dimensional coordinates (Alabbasi et al., 2015). When the user stands on his or her choice of answer on the floor screen, the sensor obtains his or her position and compares it with the position of the answer choice and displays the user's response on the wall screen. If the user moves back and forth, new answers will display on the wall screen.

To foster collaborative learning, quiz answers are shared among participants. Nine answer choices are displayed on the floor screen in a 3x3 grid. Each participant selects one answer from three choices in a 1x3 grid. If each participant choices are correct, the quiz is correct. That is, participants need to collaborate, discuss, and find three correct answers to the quiz. Also, participants had time to discuss the quiz correct answers before answering the quiz.

When participants decide on their answers and step on the response, the wall screen displays whether students' answers are correct or incorrect. When all answers are correct, the seed image of the wall screen changes to the germinated seed image. When studying growth conditions, the seedling image changes the grown plant image. In the case of an incorrect answer, participants try again until they answer correctly. Visually presenting the answer, whether correct or incorrect, allows participants to feel a sense of accomplishment and to better remember their mistakes.

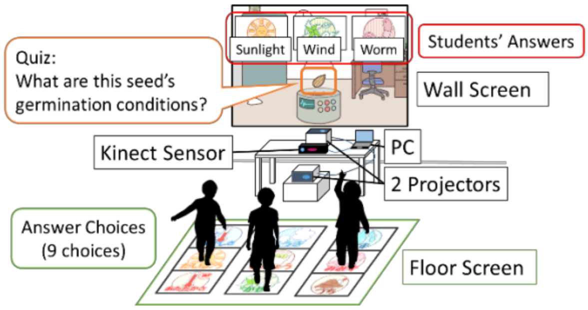

Figure 1. System setup

Figure 2. Lesson participants

Case Study

Participants

The participants were 45 sixth-grade students at Yamazaki Primary School in Chiba, Japan. We targeted all sixth-grade students at Yamazaki Primary School. We consulted with primary school and received permission, and we conducted an evaluation experiment. The evaluation experiment took place on October 12, 2018.

Study methods

First, we divided participants into 15 groups of three. Next, the participants experienced the developed system one group at a time. Students first took a quiz about germination conditions of a carrot. If they answered correctly, they had another quiz about carrot growth conditions.

We evaluated this system using a test and questionnaire. Participants answered the same six-question test before and after experiencing the system. Questions 1 to 3 asked about plant germination conditions and Questions 4 to 6 asked about plant growth conditions. Students were asked to select three out of nine choices: the same as those displayed in the experiential learning system. Students then received one point per correct choice. This allowed us to evaluate changes in knowledge.

We also created a questionnaire about the developed system based on the social presence module, a GEQ (Game Experience Questionnaire) that measures engagement in the game experience (De Kort et al., 2007; IJsselsteijn et al., 2013) (Table 5). We examined participants' involvement in psychological and behavioral games from three perspectives: psychological involvement-empathy, psychological involvement-negative feeling, and behavioral involvement.

The psychological involvement-empathy section included the following eight items: "I empathized with my friends," "During the quiz, I felt connected to my friends," "I found it enjoyable to do the quiz with my friends," "When I had fun, I think my friends also had fun," "When my friends seemed to have fun, I also had fun," "Taking the quiz together influenced my friends' feelings," and "My friends' emotions influenced my feelings," "I admired my friends." The psychological involvement-negative feelings section included the following three items: "This quiz game is fun," "I got angry with my friends," and "I was glad if my friends made mistakes or couldn't answer." The behavioral involvement measurement included the following six items: "During the quiz, I moved based on my friends' opinions," "During the quiz, my friends moved based on my opinions," "During the quiz, my friends paid close attention to me," "During the quiz, I paid close attention to my friends," "During the quiz, my friends' opinions influenced my movements," and "During the quiz, my opinion influenced my friends' movements." Answers were graded using a five-step Likert scale.

RESULTS

Tables 1 and 2 show the mean, median, and mode test scores of the quizzes conducted before and after our experiential learning activity. Tables 3 and 4 show the distribution of scores before and after the activity. Using a sign test, we investigated the bias between the number of participants whose score improved and the number of participants whose score decreased. We found a significant difference for both germination and plant growth conditions.

Tables 3 show participant responses to our questionnaire. We classify participants' replies into positive responses ("strongly agree," or "agree") and neutral or negative responses ("no strong opinion," "disagree," or "strongly disagree"). We then analyzed the differences between the number of positive, neutral, and negative replies for each item using a 1x2 Fisher's exact test.

All eight items of the psychological involvement-empathy section show more positive than neutral or negative responses. There is a significant difference between the number of positive responses and neutral or negative responses. This indicates that empathy occurred during social game play.

All three items of the psychological involvement-negative feelings section show more neutral or negative answers than positive answers. There is a significant difference between the number of neutral or negative responses and positive responses. This indicates that participants have no negative feelings toward one another during social game play.

Finally, all size items in the behavioral involvement section show more positive responses than neutral or negative responses. There is a significant difference between the number of positive responses and neutral or negative responses. This indicates that all participants showed active behavioral involvement during social game play.

Table 1. Change in quiz score after experiential learning (germination conditions)

	Before learning activity	After learning activity
Mean	5.09	7.09
Median	5	7
Mode	6	7

Table 2. Change in quiz score after experiential learning (plant growth conditions)

	Before learning activity	After learning activity
Mean	8.30	8.93
Median	9	9
Mode	9	9

Table 3. Distribution of participants' quiz scores (germination conditions)

Score	Before learning activity	After learning activity
9	4	6
8	2	7
7	3	21
6	11	8
5	7	2
4	5	1
3	10	0
2	2	0
1	1	0
0	0	0

Table 4. Distribution of participants' quiz scores (plant growth conditions)

Score	Before learning activity	After learning activity
9	31	44
8	3	0
7	5	0
6	6	1
5	0	0
4	0	0
3	0	0
2	0	0
1	0	0
0	0	0

Table 5. Questionnaire items

	Item	SA	A	N	D	SD
(1)	This quiz game is fun. **	41	4	0	0	0
(2)	I empathized with my friends. **	25	14	4	1	1
(3)	During the quiz, I moved based on my friends' opinions. **	41	3	0	0	1
(4)	During the quiz, my friends moved based on my opinions. **	32	11	1	0	1
(5)	During the quiz, I felt connected to my friends. **	22	17	4	2	0
(6)	During the quiz, my friends paid close attention to me. **	22	19	3	1	0
(7)	During the quiz, I paid close attention to my friends. **	31	10	1	2	1
(8)	I found it enjoyable to do the quiz with my friends. **	40	2	1	1	1
(9)	When I had fun, I think my friends also had fun. **	35	6	2	2	0
(10)	When my friends seemed to have fun, I also had fun. **	39	4	0	1	1
(11)	Taking the quiz together influenced my friends' feelings. **	24	18	1	1	1
(12)	My friends' emotions influenced my feelings. **	28	14	1	1	1
(13)	I admired my friends. **	28	13	3	0	1
(14)	During the quiz, my friends' opinions influenced my movements. **	32	10	1	1	1
(15)	During the quiz, my opinion influenced my friends' movements. **	27	15	2	0	1
(16)	I got angry with my friends. **	1	2	0	2	40
(17)	I was glad if a friend made a mistake or couldn't answer. **	2	0	3	1	39

N=45 $p^{**}<.01$, $p^{*}<.05$, $^{n.s.}$: not significant; SA: Strongly agree A: Agree; N: No strong option D: Disagree SD: Strongly disagree.

CONCLUSION

In this study, we developed a learning support system based on full-body interaction and collaboration and evaluated it using a case study. Participants learned germination and plant growth conditions using this system. We evaluated this system using follow-up questionnaire and tests about germination and plant growth conditions. As results of follow-up questionnaire, we confirmed that participants experienced this system using collaboration and body movements. As results of tests about germination and plant growth conditions, we confirmed that Participants' scores improved before and after the system experience. This suggests that this system reinforces participants' knowledge of germination and plant growth conditions using collaboration and full-body interaction. We conducted this experiment for only sixth-grade students in primary school. In the future research, we will evaluate this system for other grade students in primary school.

ACKNOWLEDGMENTS

This research was supported by JSPS Grant-in-Aid for Scientific Research (B) Grant Number 17H02002. This evaluation experiment was supported by Yamazaki Primary School, Chiba.

REFERENCES

Kolb, A.Y., & Kolb, D.A. (2005). Learning styles and learning spaces: Enhancing experiential learning in higher education. *Academy of Management Learning & Education*, *4*(2), 193–212. Retrieved from http://www.jstor.org/stable/40214287

Uitto, A., & Nordström, T. (2017). Inquiry in outdoor education - A case study in primary school science. *12th Conference of the European Science Education Research Association* (ESERA '17), *Stand 9: Environmental, health and outdoor science education*, 1314-1320.

Robinson, C.W., & Zajicek, J.M. (2005). Growing minds: The effects of a one-year school garden program on six constructs of life skills of elementary school children. *HortTechnology*, *15*(3), 453–457. doi: 10.21273/HORTTECH.15.3.0453

Rickinson, M., Dillon, J., Teamey, K., Morris, M., Choi, M. Y., Sanders, D. & Benefield, P. (2004). *A Review of Research on Outdoor Learning.* London: National Foundation for Educational Research.

Fuse, M., Ohkawara, R., Yokoyama, D., Minato, A., Ozawa, S., Maciewicz, E. K., & Mor, K. (2003). Development of" Detective Learning" System by Using Virtual Reality Technique–An Application for Virtual Museum–. Computer and Advanced Technology in Education, 624-627.

Palmárová, V., & Lovászová, G. (2012). Mobile technology used in an adventurous outdoor learning activity: A Case Study. *Problems of Education in the 21st Century*, 44(6), 64-71.

Nicol, D. (2010). From monologue to dialogue: improving written feedback processes in mass higher education. *Assessment & Evaluation in Higher Education*, *35*(5), 501-517.

Grabinger, R.S., & Dunlap, J.C. (1995). Rich environments for active learning: A definition. *ALT-J*, *3*(2), 5–34. doi: 10.1080/0968776950030202

Norris, E., Shelton, N., Dunsmuir, S., Duke-Williams, O., & Stamatakis, E. (2015). Physically active lessons as physical activity and educational interventions: a systematic review of methods and results. *Preventive Medicine*, *72*, 116–125. doi: 10.1016/j.ypmed.2014.12.027

Alabbasi, H., Gradinaru, A., Moldoveanu, F., & Moldoveanu, A. (2015). Human motion tracking & evaluation using Kinect V2 sensor. *2015 E-Health and Bioengineering Conference,* IEEE, 1-4.

IJsselsteijn, W. A., De Kort, Y. A. W., & Poels, K. (2013). The game experience questionnaire. *Eindhoven: Technische Universiteit Eindhoven,* 3-9.

De Kort, Y. A., IJsselsteijn, W. A., & Poels, K. (2007). Digital games as social presence technology: Development of the Social Presence in Gaming Questionnaire (SPGQ). *Proceedings of PRESENCE*, *195203,* 1-9.

SCIENTIFIC COMPETENCY AND HUMAN NUTRITION IN PRIMARY SCHOOL TEXTBOOK IN SPAIN AND PORTUGAL

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A total of 671 activities on human nutrition included in Primary education school texts in Spain and Portugal, produced by six different widely spread publishers, are analysed. The purpose of this paper is to learn to what extent these activities promote scientific competency. In order to collect the necessary data, an analysis dossier was elaborated, taking the abilities associated with scientific competencies determined by PISA 2015 (OECD 2016) as its reference. Furthermore, the basic cognitive abilities related to acquiring scientific knowledge which were identified in the activities are also added. Four types of ability were defined to undertake this analysis, and their respective sub-categories were likewise established. The findings show that chiefly basic cognitive abilities (type I) were included in both countries. On the other hand, the Portuguese textbooks, in their activities, include a greater number of specific abilities requiring scientific literacy (types II, III and IV)) than the Spanish, although they focus on those that are less demanding in terms of cognitive requirements. Besides, the activities of both publishers mostly promote one type of abilities. Schoolbook text writers ought to take these findings into account so as to be able to improve their texts. Moreover, these data are a wake-up call to those in charge of teacher training, as such training should enable teachers to have the capacity to select those activities aligning the most with the guidelines for scientific competency.

Keywords: Primary School, Scientific Competences, International Studies in Education.

INTRODUCTION

Furthering scientific competency is crucial to young people's education and training, as they will find themselves facing situations and issues stemming from the globalised high-tech world they live in (Pedrinaci, 2012). In this sense, the latest report from PISA (OECD, 2016) defines scientific literacy as the ability to interact with socio-scientific issues and Science itself as a reflective citizen. Furthering such skills entails acquiring knowledge, skills or attitudes (OECD, 2002) i.e., specific competencies requiring scientific literacy: explaining phenomena scientifically; assessing and designing scientific enquiring; interpreting data and evidence scientifically (OECD, 2016). It is also common to foster other basic cognitive abilities related to acquiring specific basic contents - identifying features, comparing...

Likewise, research has emphasised the relevance of applying different abilities to both personally and socially relevant contexts (Blanco & Lupión, 2015). In addition, science knowledge must be useful//serve//allow to explain scientific phenomena as well as promote a responsible behavior (Cañal, García-Carmona & Cruz-Guzmán, 2016). In this sense, a topic of special importance is human nutrition (en inglés probablemente se pondría al revés). Such a topic is included repeatedly across throughout compulsory education, highlighting the importance of addressing its study from an early age (Alburquerque, Pontes & Osório, 2013). Therefore, the study of human nutrition shall contribute, among other aspects, to the development of nourishment competency (Cabello, España & Blanco, 2016). Developing this competency goes beyond the academic knowledge and enters the personal and social needs of the citizenship (Rivadulla, García & Martínez, 2017).

Furthering scientific competency hinges on how teachers promote it in their classrooms (Blanco-López, España-Ramos, González-García & Franco-Mariscal, 2015; Lupión-Cobos, López-Castilla & Blanco-López, 2017) and on the quality of the teaching materials they use. In this respect, schoolbook texts are the most commonly used material among teachers in Spain and Portugal (Rivadulla, García & Martínez, 2017), as well as internationally (Yun & Park, 2018). In this regard, teachers trust and use textbooks to plan their lessons and their experimental activities in the classroom. Likewise, textbooks are the most convenient source of information for students to read and complete their school tasks (Enero Upahi, Ramnarain & Saheed Ishola, 2018).

On the other hand, research has consistently demonstrated how science textbooks tend to dictate - to a great extent - the content to be taught (including the activities to be developed as well as the discourse finally delivered in most science classrooms) (Abd-El-Khalick, Myers, Summers, Brunner, Waight, Wahbeh, Zeineddin & Belarmino, 2017). It has also been shown that in recent decades an array of activities labeled as inquiry, exploring and/or research tasks have been incorporated to textbooks, although they remain scarce (Yang, Liu & Liu, 2019).

So it is that this paper endeavours to find out to what extent Primary education textbooks from Spain and Portugal promote acquiring scientific competency amongst pupils. The analysis is focused on the activities included in those books, since scientific competency is shown by action (Sanmartí & Márquez, 2017). To narrow down our study, the issue of human nutrition was chosen, which facilitates explaining facts/phenomena in an integral way as well as making justified decisions with regard to personal behaviour (Rivadulla et al., 2017).

METHODOLOGY

The activities about human nutrition included in year 6 textbooks (11-12 years) pertaining to three widely used publishers in Primary Education in Spain– Anaya, Santillana and SM (henceforth referred to as A, B and C respectively) – and in Portugal were considered –Areal Editores; Porto Editora y Lisboa Editora (D, E and F respectively). 671 activities were analysed: 226 taken from the Spanish publishers and 445 from the Portuguese ones.

A dossier taking four types of ability into account was elaborated, based on what is taken into consideration in our introduction. Three of them (II, II and IV) are related to scientific competency (OECD, 2016), and another one is related to basic cognitive abilities (I). For each one of them, relevant sub-categories were established:

- Type I: basic cognitive abilities (identifying features, establishing relationships, comparing/ordering and defining or conceptualising what something is).

- Type II: abilities related to using knowledge in specific (describing what is happening, explaining phenomena scientifically and justifying by means of theories why it is happening).
- Type III: abilities related to assessing and designing scientific research (observing, searching for information from different sources, putting forth hypothesis and designing strategies performing experiments to obtain data).
- Type IV: abilities associated with interpreting data and evidence in a scientific manner (analysing data, reaching evidence-based conclusions, arguing in favour or against them).

In table 1 some examples of activities from different publishers associated to each ability are presented.

Table 1. Examples of activities associated to the different abilities.

	Abilities	Activity examples
Type I	Identifying features	Identify and locate the main organs involved in carrying out the life functions in the human body (Spanish publisher). Among the following variety of foods, select those ones that could be part of a healthy menu for your lunchtime... (Portuguese publisher).
	Establishing relationships	Match different daily life practices with an appropriate functioning of the body... (Spanish publisher). Establish relationships between the numbers contained in the diagram (showing the main functions of nutrients) and the following terms: lipids, carbohydrates, proteins… (Portuguese publisher).
	Comparing / Ordering	What is the difference between urine and sweat? What do they have in common? (Spanish publisher). Put in order the words in the sentences so that you describe chronologically the phenomena that take place in the oral cavity… (Portuguese publisher).
	Defining	Define the following terms: a) blood circulation; b) excretion (Spanish publisher). What is a healthy food? (Portuguese publisher).
Type II	Describing facts/phenomena	Describe the main characteristics of two systems involved in nutrition (Spanish publisher). What are the additional benefits of the product referred in the text *(vegetables)*? (Portuguese Publisher).
	Explaining	Tell the reason why during systole, blood does not flow backward from the ventricle to the atrium (Spanish publisher). What would happen to nutrition if any of these systems failed? A) excretory system; b) respiratory system (Portuguese publisher).
	Justifying	Why is it better to breathe through the nose than through the mouth? (Spanish publisher). When we run, we breathe faster than when we are still. Why does this happen? (Portuguese publisher).
Type III	Observing	Observe the diagram and write down a brief summary of the factors that have an influence on our health (Spanish publisher). Observe attentively the label from a soft drink and answer the following questions… (Portuguese publisher).
	Searching for information	Using ICTs, search how much air lungs can hold (Spanish publisher). Search information about how many children in Portugal are overweight… (Portuguese Publisher).
	Designing evidence	No examples in Spanish publishers' textbooks have been found. Using a spirometer, we can know how much air can be hold in our lungs. Build a spirometer using a bowl, a water bottle and a piece of hose (see photo). How much water was drained when you blew into the bottle? (Portuguese publisher).
	Experimenting	Researching. Building a model of a lung (Spanish publisher). Which food contains starch? Carry out the following experiment... (Portuguese publisher).
T	Analysing data	Read the following document and explain what a transfusion is (Spanish Publisher).

		Record in a table the results from measuring the pulsations. Explain how pulsations change throughout the experiment (Portuguese publisher).
	Elaborating conclusions	Evaluate the table elaborated by your classmate to check it agrees with the requirements of a healthy diet (Spanish Publisher). Taking into account what you know about nutrition and circulation, explain why we obtained those results (Portuguese publisher).
	Arguing	Imagine you are participating in a television debate about the convenience of having emergency services for all citizens. Prepare your arguments and discuss them in classroom (Spanish publisher). Write down three reasons you would give a smoker to quit (Portuguese Publisher).

FINDINGS

Our findings show that, in Spain, Type I abilities predominate in the activities provided by all the publishers (82.3%), the second most common abilities being Type II (39.8%). In Portugal Type I abilities prevail (60.4%) and II (57.3%), yet in a more balanced way, though there is a certain difference between the publishers, as D and F promote Type I abilities (70.1% and 60.3% respectively) to a larger extent, whereas E promotes Type II activities (62.9%). Type III and IV abilities are used to a lesser degree, being slightly more numerous in Portugal (30.1% and 29% respectively) than in Spain (2.7% and 14.6%). In connection with these two abilities, there are hardly any differences between the publishers in Spain, whereas Type IV abilities are more frequently found in Portugal in publisher l D (53.3%) (Table 2).

More specifically, identifying features is the most frequently found Type I abilities in both countries (60.2% in Spain versus 39.6% in Portugal). As far as Type II abilities are concerned, differences between Spain and Portugal clearly noted. The Portuguese publishers especially promote *describing* (41.3%), whereas the Spanish ones, exception for publisher A, further the three Type II abilities in a more balanced way. Within the Type III abilities, *observing* (20.9%) prevails in Portugal as opposed to *searching for information* (4.7%), whereas both abilities are virtually equal in Spain (10.6% y 10.2% respectively). *Designing evidences* and *experimenting* are scarcely included in the activities found in both countries. Within the Type IV abilities, *analysing information* is the most usual one, especially in Portugal (24.3% versus 9.3% in Spain), and in texts by publisher D in particular. *Elaborating conclusions* and *arguing* represent rarely promoted abilities, the latter being found somewhat more often in Spain (5.3%) than in Portugal (0.9%).

Table 2. Percentage of capacities demanded by the activities from the different publishers.

	Abilities	Spanish publishers				Portuguese publishers			
		A (n=40)	B (n=81)	C (n=105)	*Total (n=226)*	D (n=107)	E (n=178)	F (n=160)	*Total (n=445)*
Type I	Identifying features	22 55%	36 44.4%	78 74.3%	*136* *60.2%*	48 48.9%	65 36.5%	63 39.4%	*176* *39.6%*
Type I	Establishing relationships	5 12.5%	13 16%	23 21.9%	*41* *18.1%*	31 29%	17 9.6%	13 8.1%	*61* *13.7%*
Type I	Comparing / Ordering	3 7.5%	9 11.1%	14 13.3%	*26* *11.5%*	9 8.4%	9 5.1%	11 6.9%	*29* *6.5%*
Type I	Defining	6 15%	21 25.9%	17 16.2%	*44* *19.5%*	2 1.9%	17 7.9%	28 17.5%	*47* *10.6%*
Type I	*Total**	*32*	*63*	*91*	*186*	*75*	*88*	*106*	*269*

		80%	*77.8%*	*86.7%*	*82.3%*	*70.1%*	*49.4%*	*66.3%*	*60.4%*
Type II	Describing facts/phenomena	13 32.5%	12 14.8%	18 17.1%	*43* *19%*	37 34.6%	87 48.9%	60 37.5%	*184* *41.3%*
	Explaining	6 15%	9 11.1%	18 17.1%	*33* *14.6%*	18 16.8%	31 17.4%	23 14.4%	*72* *16.2%*
	Justifying	-	11 13.6%	11 10.5%	*22* *9.7%*	14 13.1%	11 6.2%	18 11.3%	*43* *9.7%*
	*Total**	*17* *42.5%*	*29* *35.8%*	*44* *41.9%*	*90* *39.8%*	*56* *52.3%*	*112* *62.9%*	*87* *54.4%*	*255* *57.3%*
Type III	Observing	3 7.5%	10 12.3%	11 10.5%	*24* *10.6%*	21 19.6%	49 27.5%	23 14.4%	*93* *20.9%*
	Searching for information	4 10%	10 12.3%	9 8.6%	*23* *10.2%*	3 2.8%	5 2.8%	13 8.1%	*21* *4.7%*
	Designing evidence	-	-	-	-	3 2.8%	2 1.1%	-	*5* *1.1%*
	Experimenting	5 12.5%	7 8.6%	1 1%	*13* *5.8%*	12 11.2%	12 6.7%	8 5%	*32* *7.2%*
	*Total**	*8* *20%*	*21* *25.9%*	*20* *19%*	*49* *21.7%*	*33* *30.8%*	*54* *30.3%*	*47* *29.4%*	*134* *30.1%*
Type IV	Analysing data	3 7.5%	4 4.9%	14 13.3%	*21* *9.3%*	51 47.7%	28 15.7%	29 18.1%	*108* *24.3%*
	Elaborating conclusions	1 2.5%	3 3.7%	3 2.9%	*7* *3.1%*	6 5.6%	10 5.6%	5 3.1%	*21* *4.7%*
	Arguing	2 5%	7 8.6%	3 2.9%	*12* *5.3%*	1 0.9%	3 1.7%	-	*4* *0.9%*
	*Total**	*7* *17.5%*	*9* *11.1%*	*17* *16.2%*	*33* *14.6%*	*57* *53.3%*	*38* *21.3%*	*34* *21.3%*	*129* *29%*

* % of activities including some ability of that Type

When analysing each activity individually, we observed that all publishers, either Spanish or Portuguese, tend to address just one type of ability per activity (figure 1). The number of activities where two types of abilities are worked on is clearly inferior. In this case, there are differences between the Spanish and the Portuguese textbooks, having detected this sort of activities to a greater extent in the former (between 20% and 30.9%) than in the latter (between 13.5% and 27.1%). On the contrary, Portuguese publishers include more activities where three types of abilities are covered (between 17.5% and 27.1%) compared to the Spanish ones (between 4.9% and 10.5%). Publishers that incorporate activities involving the use of the four types of abilities are a minority in both countries (5.3% in total in Spain and 6.7% in Portugal).

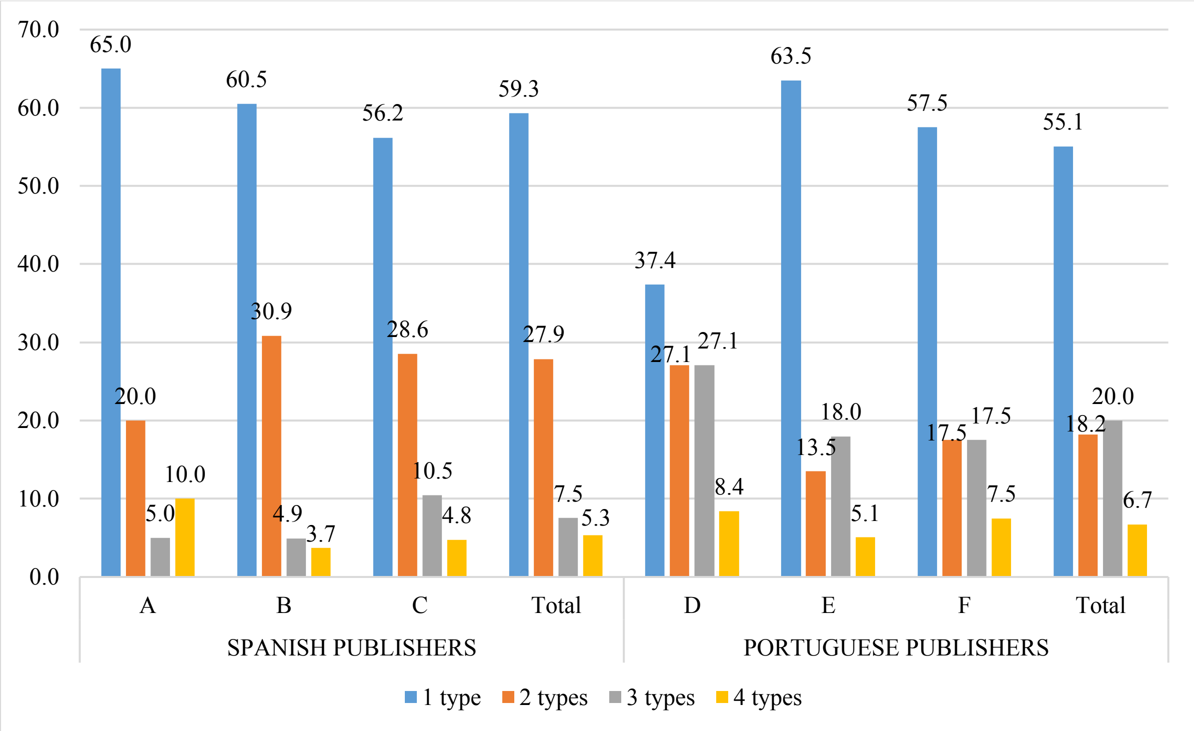

Figure 1. Percentage (%) of activities found in books by publishers where one or more types of skill are dealt with.

CONCLUSIONS

The publishers from Spain and Portugal promote different types of ability through the activities in their textbooks, where not only similarities but also differences are detected. The publishers from both countries, and the Spanish ones in particular, mainly further basic cognitive abilities in their activities, i.e. Type I, related to scientific knowledge itself. The Portuguese ones include more Type II, III and IV abilities (associated with scientific competencies) in their activities than their Spanish counterparts, Spain, although the Type III and IV ones are less seldom practised. The publishers from both countries tend to further those abilities found in each Type which are less demanding from a cognitive point of view, and the Portuguese ones more so than the Spanish.

In general, most of the activities from the publishers from both countries promote just one type of ability. Activities involving two or three types of abilities are less frequent and very few activities address all the four types of abilities.

Despite the differences between the two countries, a deficit is noted, in both countries, in the field of furthering the abilities related to assessing and designing scientific enquiry as well as to interpreting data and evidence scientifically, whereas acquiring scientific knowledge and using it to explain phenomena scientifically is favoured. These data constitute a wake-up call to textbook authors, as well as to those in charge of teacher training, since they are the people responsible for deciding what types of activity children are to do in order to achieve solid scientific training as early as Primary School.

ACKNOWLEDGEMENT

This study is part of the project EDU2016-79563-R

REFERENCES

Abd-El-Khalick, F., Myers, J.Y., Summers, R., Brunner, J., Waight, N., Wahbeh, N., Zeineddin, A.A. & Belarmino, J. (2017). A Longitudinal Analysis of the Extent and Manner of Representations of Nature of Science in U.S. High School Biology and Physics Textbooks. *International of Research in Science Teaching, 54*(1), 82-120.

Alburquerque, A., Pontes, C. & Osório, M. (2013). Knowledge of educators and dieticians on food and nutrition education in the school environment. *Revista de Nutrição, 26* (3), pp. 291-300. DOI: https://doi.org/10.1590/S1415-52732013000300004

Blanco-López, A., España-Ramos, E., González-García, F. J. & Franco-Mariscal, A.J. (2015). Key Aspects of Scienti fic Competence for Citizenship: A Delphi Study of the Expert Community in Spain. *Journal of Research in Science Teaching* 52 (2): 164–198.

Blanco, A. y Lupión, T. (2015). *La competencia científica en las aulas.* Santiago de Compostela: Andavira editora.

Cabello, A., España, E. & Blanco, A. (2016). *La competencia en alimentación*. Barcelona: Octaedro.

Cañal, P., García-Carmona, A. & Cruz-Guzmán, M. (2016). *Didáctica de las Ciencias Experimentales en Educación Primaria*. Madrid: Paraninfo.

Enero Upahi, J., Ramnarain, U. & Saheed Ishola, I. (2018). The Nature of Science as Represented in Chemistry textbooks used in Nigeria. *Research in Science Education*. DOI: https://doi.org/10.1007/s11165-018-9734-7

Lupión-Cobos, T., López-Castilla, R. & Blanco-López, Á. (2017). What do science teachers think about developing scientific competences through contextbased teaching? A case study. *International Journal of Science Education, 39*(7), 937-963.

OECD (2002). *Definition and Selection of Competencies: Theoretical and Conceptual Foundations (DeSeCo)*. Online: http://www.oecd.org/education/skills-beyond-school/41529556.pdf

OECD (2016). PISA 2015 *Assessment and Analytical Framework: Science, Reading, Mathematic and Financial Literacy*. París: PISA OECD Publishing. Online: https://bit.ly/2F5pjge

Rivadulla, J.C., García, S. & Martínez, C. (2017). Qué enseña y evalúa sobre nutrición humana un grupo de profesores españoles y portugueses de educación primaria. *Enseñanza de las Ciencias, 35*(3), 69-87.

Pedrinaci, E. (coord.) (2012). *11 Ideas clave. El desarrollo de la competencia científica*. Barcelona: Graó.

Sanmartí, N. y Márquez, C. (2017). Aprendizaje de las ciencias basado en proyectos: del contexto a la acción. *Ápice. Revista de Educación Científica,* 1(1), 3-16.

Yang, W., Liu, C. & Liu, E. (2019). Content analysis of inquiry-based tasks in high school biology textbooks in Mainland China. *International Journal of Science Education, 41* (6), 827-845.

Yun, E. & Park, Y. (2018). Extraction of scientific semantic networks from science textbooks and comparison with science teachers' spoken language by text network analysis. *International Journal of Science Education, 40* (7), 2118-2136.

THE PROJECT-BASED LEARNING: IMPACT ON LEARNING OF GEOLOGY BY SYRIAN REFUGEE GRADE 6 STUDENTS

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The war in Syria has an impact on the entire population in general and especially on young people. Indeed, young Syrian refugees who have experienced the war are in a state of trauma that hinders their normal development, be it physical, emotional, behavioral or even at school level (concentration problems and/or learning, school delays due to long stays in refugee camps ...).

Geology is, therefore, a difficult field to address for both students and teachers. In order to familiarize primary school students (grade 6) with this theme, we have set up and realized a pedagogical project at the "Janah" educational center that deals with Syrian refugee students enrolled in public schools in Lebanon.

Working geology with refugee students has been a challenge for us given the double complexity of the topic on one hand and the population concerned on the other. We integrated project-based learning (PBL) into teaching in order to introduce grade 6 students to some basics in geology. We also sought by this approach to develop the motivation and autonomy of these students. Several tests were conducted before and after our intervention in order to study the effect of project-based learning on the motivation, autonomy, and success of the students. The results show that the PBL develops students' motivation and involves them more in learning situations while starting from their interests and promoting their cognitive engagement. In addition, PBL promotes their autonomy, awakens their sense of responsibility by integrating them into teams where they collaborate and communicate in order to solve problems or achieve a product. Our work has also shown a marked improvement in the acquisition of knowledge.

Keywords: Project-based learning, Primary school, Motivation

1- INTRODUCTION

Education today must aim to develop the communication and interpersonal skills of the students by submitting them to team work that promotes cooperation and collaboration between different members of the same team. In order to meet these needs and requirements and to achieve what education advocates for developing in students, different teaching methodologies are implemented. Among these promising methodologies, we particularly distinguish the project based learning (PBL). This approach puts students in situations of choice based on their interests, communication, teamwork, unsupervised work time and responsibility. Throughout the stages of the realization of the project, the pupil acquires knowledge, know-how and well-being. He then masters new knowledge and new attitudes (Belagra et al., 2014). As a result, the student becomes an actor of his / her learning, which consequently promotes the development of his / her autonomy. In addition, this approach allows more students to access learning and thus develop their potential in order to take charge, in the future, of the roles they have in society, whether in relation narrow with citizenship, work, family, learning, etc. (Gregoire et al., 1998, 2001). Indeed, for Huber (2005), "by developing analytical skills and a methodology of action, the young person will use his skills in his professional project and in his life project. This pedagogy then enables the young person to develop skills and knowledge that help him to structure and organize the situations he will face in his future life.

The war in Syria has an impact on the entire population in general and on young people who are between 12 and 14 years old. Young Syrian refugees experienced the war. Therefore, they are in a state of trauma that hinders their normal development, whether physical (sleep disorders, eating disorders ...), emotional (anxiety, dependencies ...), behavioral (hyper vigilance, irritability ...) or at school level (problems of concentration and / or learning, school delays related to long stays in refugee camps ...). All this influences the psychological development of the child and, consequently, his level of learning. "The personal and psychosocial responses that each refugee child draws from his memories and experience do not go away when he walks through the door of the school. He brings with him this emotional and social baggage and educators must take this into account. (Meyers M. 1993, cited in Azdouz 2003). As a result, these students find themselves behind school and - when they are re-enrolled in public schools in Lebanon - have to deal with a demotion at a class level or at a level that does not correspond to them. This causes a loss of interest and motivation for any activity and causes a feeling of rejection and failure at home.

The teaching of geology is confronted with several obstacles that hinder the acquisition of learning in this theme, whether at the epistemological, didactic, ideological, etc ... and which present difficulties for both students and teachers. This science is an important part of French and Lebanese school programs in the different school cycles. It is also very useful at the cultural level, because it explains most of the natural phenomena that occur around us, on the surface of the earth and at the level of deeper layers. Students find many difficulties and become demotivated and disinterested during geology lessons because this knowledge is not included in their daily lives and represent for them something virtual. This leaves a negative impact on their academic achievement. The use of new pedagogical approaches is thus necessary.

Working geology with refugee students is a challenge for us given the dual complexity of the topic on the one hand and the population concerned on the other. Our job is to integrate PBL into the teaching of geology. In order to introduce grade 6 students, going to the complementary cycle, to the geology part, and to familiarize them with these future learning. We also seek by this approach to develop motivation and autonomy of the student to acquire learning objectives in this part. This leads us to ask ourselves: Can PBL develop the autonomy and motivation of refugee students and, subsequently, ensure that they acquire better learning objectives in geology? The results of our research will identify, verify and confirm to what extent the PBL contributes and leads to the development of motivation and autonomy, as well as to the appropriation of the notions of geology by refugee students. This will promote the integration of project pedagogy into the systems and schools that deal with pupils requiring specific support.

2- METHODOLOGY

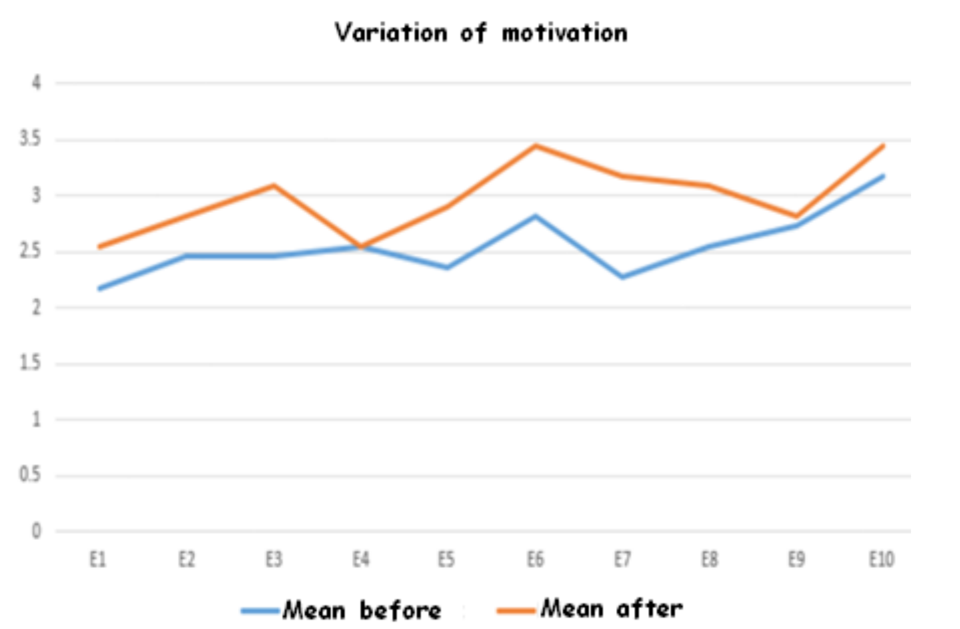
Our research aims to study the impact of project pedagogy on the motivation and autonomy of refugee students on the one hand and the acquisition of learning objectives in geology on the other hand. Our study was supported by the French organization "Semeurs d'avenir". This NGO is part of the IECD (European Institute of Coordination and Development) organization which supports the educational project that supports children and young people who come from vulnerable families (Lebanese and refugees). The educational center Janah, in which we work, is associated with the organization "Semeurs d'avenir". This center is interested in Syrian refugee students. It welcomes immigrant students who are enrolled in public schools and helps them to overcome the obstacles they face, on the one hand psychologically and socially and on the other hand, at the educational level. The sample consists of ten students of grade 6 class (three boys and seven girls), belonging to the same age group (12-14 years). Two hours a week are devoted to design, implement and evaluate the project, during the summer period (July-August 2018). Data collection was done through tests of knowledge, motivation and autonomy (one test at the beginning of the project and a second at the end).

3- RESULTS AND DISCUSSION

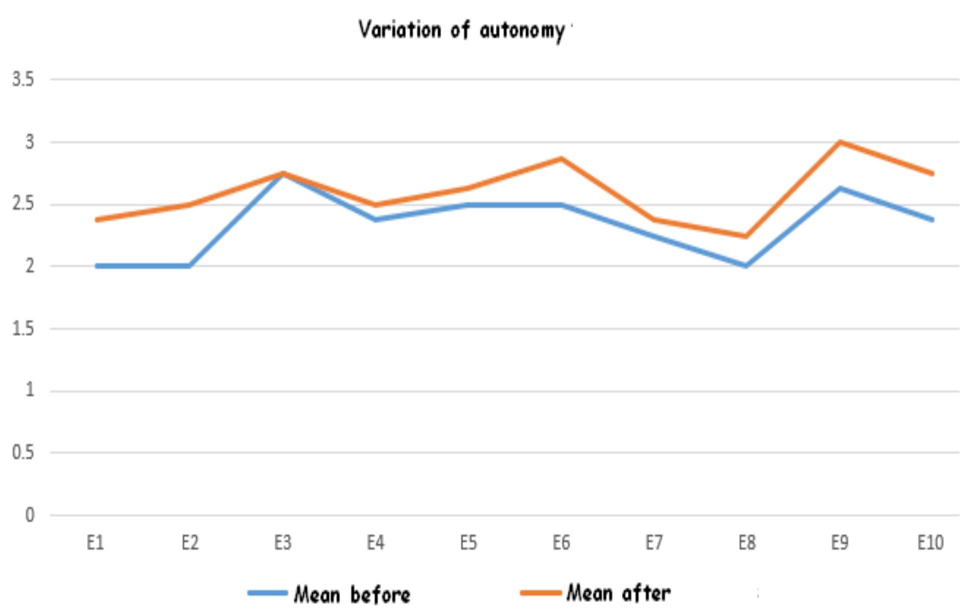
Our research enabled us to put 10 refugee students of the EB6 class, in a situation of introduction to geology through project pedagogy. Students were invited to work together and conduct research to learn and acquire the concepts, design a final product, the result of their learning and introduce it to others.

3.1- Analysis of test results assessing motivation and autonomy before and after the intervention of the PBL:

The particularity of our work is in testing the impact of project pedagogy on refugee students with psychological, social and academic difficulties. Indeed, the project pedagogy has stimulated the motivation of Syrian refugee students who have overall academic difficulties, to learn geology, considered one of the most rigid, difficult and incomprehensible topics for students and teachers, while promoting their autonomy. Comparing the results also allowed us to reveal the change in our students' motivation (graph 1) and autonomy (graph 2).



Graph 1: Variation in means of student motivation before and after application of PBL.



Graph 2: Mean Change in the autonomy of the students before and after the implementation of PBL.

Graphs 1 and 2, above, show that the average motivation and autonomy of the majority of students has increased after the application of PBL. But this increase is not the same for all students.

PBL seems to have a positive impact on the motivation and autonomy of refugee students. This impact seems to be associated with other factors to be defined.

3.2- Analysis of achievement test scores:

Graph 3: Variation of average marks of students in the achievement tests before and after the application of the PBL.

Graph 3 above shows a variation of the averages of the different tests done with the pupils, before and after the implementation of the project. We observe a significant increase of the average of 6.5 / 20 in the 1st prerequisite test carried out before the application of the project, to reach approximately 17/20 at the 3rd test level, final test carried out at the end of the project for test the notions acquired by the students.

This shows that the PBL approach has favored the acquisition of the notions of geology in refugee students.

Our results on motivation are consistent with the work of Genest and Pellaton (2012), where student motivation increased after the project was completed, but this increase was subject to fluctuations. It is raised at the beginning of the apprenticeship, and then drops in the middle of the project, so that it increases again during the implementation of the final product. Talbi et al. (2007) did not notice a development at the level of autonomy, which is contrary to our results. In fact, we had an increase in the level of autonomy itself that this increase was low. Our results also showed a clear improvement in knowledge following the implementation of project pedagogy. From the results obtained, we note that project pedagogy has a positive impact on the acquisition of targeted learning in geology. This is manifested by the remarkable increase in student marks in knowledge tests. These results are consistent with those of Lebrun (2002) who claims that PBL allows students to acquire knowledge better. Similarly Huber (2005) states that the student is mobilized during the implementation of the project, and that the resolution of problems encountered during this realization will promote the production and mobilization of new skills and knowledge. We were also able to confirm this statement thanks to the recovered results of the notes and the public presentation of the final product. Despite all the limitations we faced in carrying out our project, we find that this approach has greatly influenced the motivation of refugee students who have enough difficulties at school level than at the psychological level. It has stimulated and stimulated their desires and interests towards the theme while giving them the chance to take the initiative in their work and to be autonomous. This active role of the students, their cognitive engagement and responsibility, make the learning sound and help to memorize it in the long term, because the students have not just studied notions that are passed on to them but they have even learned and deeply understood these notions. They played their true role, the role of the "learner".

REFERENCES

Azdouz, R. (2003). L'intégration des enfants touchés par la guerre dans les écoles de Montréal. Guide à l'intention du personnel enseignant et non enseignant. Comité de gestion de la taxe scolaire de l'île de Montréal. ISBN 2-89506-099-1

Belagra, M., Benachaiba, C. et Draoui, B. (2014). Quel impact de la pédagogie par projet sur la motivation des étudiants ? Cas des étudiants de 2eme année licence en informatique. Université de Béchar, Algérie. Formation et profession, 23(1), p. 36-51. doi.org/10.18162/fp.2015.85

Genest, O. & Pellaton, C. (2012). L'impact de la pédagogie de projet sur la motivation, le sens et le développement des compétences transversales. Haute École Pédagogique de Lausanne.

Grégoire, R. & Laferrière, T. (1998/2001). Apprendre ensemble par projet avec l'ordinateur en réseau. Guide à l'intention des enseignants et des enseignantes. Réseau scolaire Canadien (RESCOL).

Huber, M. (2005). Conduire un projet-élèves. Hachette Education, Paris.

Lebrun, M. (2002). Théories et méthodes pédagogiques pour enseigner et apprendre. Bruxelles : De Boeck Université.

Talbi, M., E. Benichou, M. Kabbaj, B. Gourja et S. Abouhanifa (2007). Compétence : encadrement des projets de production des élèves du collège. Le palimpeste revue de l'éducation et de formation, Maroc.

A TEACHING APPROACH ABOUT NANOSCALE SCIENCE AND TECHNOLOGY CONTENT: EVALUATION OF PRIMARY SCHOOL STUDENTS' LEARNING

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Many researchers support the need for incorporating Nanoscale Science and Technology (NST) concepts in all levels of education. However, the related research in primary school is in its infancy. In this paper, we present a pilot teaching approach about NST content addressing to primary students (6th grade). The teaching approach included three components of NST: concepts, phenomena and applications. Our research aimed to investigate to what extent did students improve their ideas concerning the NST content after the implementation of the teaching approach. The data were collected via pre and post written questionnaires and analyzed qualitatively in order to create levels of understanding for primary students' ideas. The Wilcoxon test showed that students improved their conceptualization of the term nanotechnology, the concept of size and the lotus effect.

Keywords: primary school, conceptual understanding, science education

INTRODUCTION

Nanoscale Science and Technology (NST) is an interdisciplinary research field focusing on the manipulation of matter as well as on the exploitation of the unique materials' properties, in the nanoscale (1-100 nm) (Lin, Wu, Cho & Chen, 2015). The incorporation of NST concepts in all levels of education is supported by many researchers (Blonder & Sakhnini, 2016; Manou, Spyrtou, Hatzikraniotis & Kariotoglou, 2018; Stevens, Sutherland & Krajcik, 2009). Since students already use NST products, the need to develop a new aspect of their science and technological literacy, called nanoliteracy, has emerged (Laherto, 2010; Manou et al., 2018). School science curricula are focused on a macro or/and atomic scale to explain abstract concepts such as density (Wiser & Smith, 2008). However, in order to explain phenomena and applications such as superhydrophobic textiles, there is a need to use the nanoscale. This intermediate gap (the neglection of nanoscale between macro and atomic-scale) deprives students form the development of an explanatory model consistent to the scientific view about the non-observable causes that explain how a phenomenon works (Vosniadou, 2013). Moreover, the interdisciplinary nature of NST, the "mysterious" phenomena and the related applications have the potential to increase students' interest towards NST carriers. It is argued that elementary students may constitute the future workforce to be occupied in nano-related fields (Lin et al. 2015).

In this paper, we present a pilot teaching approach about NST topic as well as its impact on students' learning. The research question was the following: To what extent did primary students improve their ideas concerning NST concepts and phenomena after the implementation of the approach?

METHOD

Participants

The participants were 22 primary school students (aged 11-12), attending an urban public primary school.

The units of the teaching approach

In the teaching approach, we introduced five essential concepts qualitatively: (i) Size, (ii) Tools, (iii) NST Applications, (iv) Size-dependent Properties-Lotus effect, and (v) Models (Blonder & Sakhnini, 2016; Manou et al., 2018; Stevens et al., 2009). The teaching approach aimed to enhance students' understanding of how nanoworld affects macroworld. The cycles and the branches of Figure 1 represent the essential concepts and the specific content respectively that were included in the teaching approach. For example, in the case of the "NST Applications", we comprised in the approach the hydrophobic surfaces e.g. self-cleaning textiles and the nano-filter water purification systems.

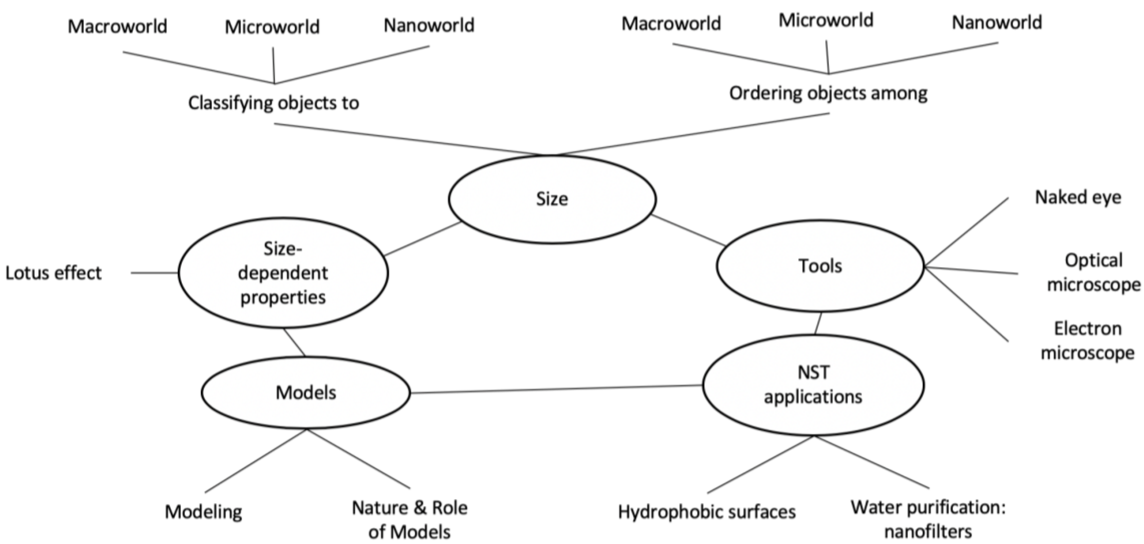


Figure 1. The essential concepts of the teaching approach.

We designed six units of two-hours duration each, in a way that that the five essential concepts were gradually introduced. The activities that were included were inspired by related literature in non-formal education settings (e.g. Filipponi & Sutherland, 2009) and corresponding online resources such as presented in nisenet.org. Table 1 presents the units of the approach and the intended learning outcomes.

Table 1. The units of the teaching approach and the intended learning outcomes.

The units of the teaching approach	Intended learning outcomes *Students will be able to*:
1. Macroworld 2. Microworld 3. Nanoworld	(a) Classify various sizes objects into the macro, micro and nanoworld based on the observation tool (naked eye, optical microscope, electron microscope), and (b) order macro, micro and nanoworld objects based on the qualitative criterion "which object is part of the other or fits into the other". (Essential Concepts: Size, Tools, Models).
4. The case of viral infection	Describe how nanoworld affects the macroworld in the case of viral infection using concepts as virus, cells, the human body. (Essential Concepts: Size, Tools, Models).
5. The Lotus effect	(a) Explain the phenomenon using the concept of leaf's nanostructure (nanobumps) or the hydrophobicity, and (b) recognise commercial products that mimic the lotus effect. (Essential Concepts: Size, Tools, Size-dependent Properties, NST Applications, Models).
6. Water purification using nano-filters	(a) Explain the filtration mechanism using the concept of the nanopore, and (b) recognise how NST contributes to the solution of the potable water shortage problem. (Essential Concepts: Size, Tools, NST Applications, Models).

The first unit included inquiry-based activities about macroworld, namely the human-world. Specifically, students collected small visible objects from the schoolyard, which they compared them according to their size. Also, they created models of the collected objects using playdoh and presented them into the class. Then, the teacher introduced aspects about the nature and role of models (e.g. the models focus on specific aspects of the objects) (Schwarz et al., 2009) and the students reflected about their designs. It is pointed out that a scaffolding instruction about the nature and role of models was adopted (Zoupidis, Pnevmatikos, Spyrtou, & Kariotoglou, 2016). So, in each unit, new aspects were introduced, or reflective discussions were conducted. Afterwards, the students placed their models in the first part of a classification poster, which was named "macroworld" (Figure 2, left part). In the end, they discussed the observation tool of the macroworld objects, namely the naked eye.

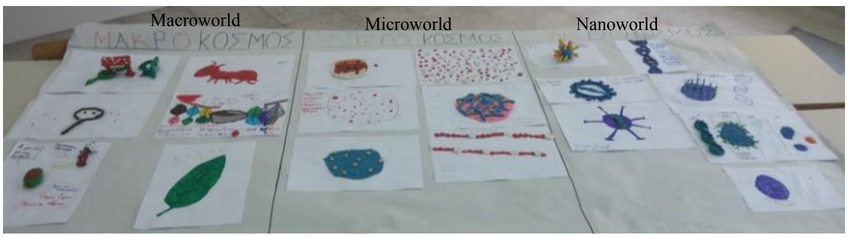


Figure 2. Classification poster created by the students.

In the second unit, the inadequacy of the naked eye for seeing an object smaller than a strand of hair triggered discussions that oriented towards microworld. Students studied onion cells and red blood cells using optical microscopes (Figure 3), guided by appropriate worksheets. They also searched for information about them within printed recourses, and they created models of onion cells, their nucleus and the red blood cells. Then the models were placed on the second part of the classification poster, the microworld (Figure 2, middle part). The optical microscope was established as a criterion for classifying objects to the category of the microworld. Moreover, the criterion "which object is part of the other or fits into the other" was introduced for ordering objects of the microworld; for instance, "the cell's nucleus is smaller than the cell because it is part of the cell".

Figure 3. Students handle the optical microscope.

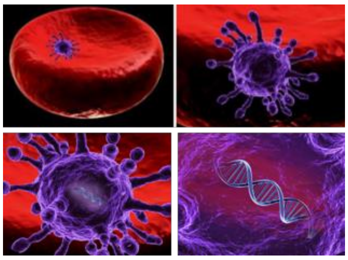


Figure 4. Print screen of the educational software.

The transition to the nanoworld happened similarly, as in the second unit. Namely, the inadequacy of the optical microscope for observing objects smaller than the cell's nuclei served as the entryway to nanoworld. The electron microscope was introduced via educational software (created by the researchers) which demonstrated its basic features. Students using this software "handled" an electron microscope to study models of a virus and DNA (Figure 4). They collected additional information by supplementary videos, and they created models of the above objects. Moreover, the electron microscope was used as a criterion for classifying objects to the category of the nanoworld. The same criterion with the second unit (which object is part of the other or fits into the other) was discussed for ordering the nanoworld objects by their size. The students created models of the nanoworld objects, and they placed them into the third part of the poster (Figure 2, right part).

The fourth unit included viral infection. The viral infection is considered to be relevant and meaningful to students' life (Delgado, Stevens, Shin, & Krajcik, 2015). We selected viral infection as a context to assign students to apply their knowledge about size, identifying the interaction of the three worlds as well. The students collected additional information by videos and printed images and created models in order to represent how the nanoword (a virus) affects the microworld (the cells) and the macroworld (the human body) in the case of viral infection.

In unit five, students were engaged in experimental activities about the lotus effect. They were assigned to pour some water droplets on the surface of four materials and to record the shape and behavior of the droplets (Figure 5). The materials were natural or artificial hydrophobic (cabbage leaf and textile respectively) and natural or artificial hydrophilic materials (lettuce leaf and textile respectively), Students collected information concerning the nanostructure of the lotus leaf's surface by videos and a poster. In addition, they were informed about several related commercial applications that mimic the lotus effect, such as athletic shoes. In the end, they created their models to describe this phenomenon.

Figure 5. Experimental activity for the lotus effect.

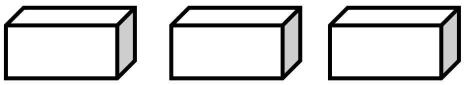
Figure 6. Experimental activity for the filtration.

The final sixth unit was about the contribution of nanotechnology to water purification. Students were motivated by a related video that demonstrated the problem and the consequent health issues arising from the contaminant water. Students were engaged in experimental activities trying to purify water using filters with a different pore size (Figure 6). Moreover, they collected information from videos about the nanostructure of the nanofilters. The last learning task was the creation of models that represented the water purification process by nanofilters.

Data collection tool

A written pre-post questionnaire was used to evaluate students' learning. The design of the first four items was based on suggestions of NST related literature (e.g. Castellini et al. 2007; Delgado, 2009; Delgado et al., 2015; Magana, Brophy, & Bryan, 2012), and the fifth item was designed by the researchers (Table 2). A pilot questionnaire was tested in a small number of primary school students (Peikos et al. 2017).

Table 2. The items of the questionnaire.

1. A student read on the internet the term nanotechnology and wondered what it means. How would you explain to him/her what is nanotechnology?
2. Name the smallest object you think that exists.
3. Classify the following objects to the boxes based on their size (ant, soccer ball, onion cell, red blood cell, human, DNA, virus, cell's nucleus). Explain your reasoning for each box. 
4. Order the following objects from the biggest to the smallest: onion cell, DNA, the grain of salt, soccer ball, virus, cell's nucleus.
5. Two brothers washed some cabbage leaves for the salad and noticed that the water on the leaves beads up forming spherical droplets. Why do you think this happened? 

Data analysis

Based on both inductive and deductive qualitative methods, students' answers were grouped in categories and then were classified hierarchically in levels of understanding (Ls) from irrelevant and non-answers to more sophisticated (coded from L0 to L3), in respect to the expected learning outcomes. Specifically, concerning Items 1 and 5 (Table 2), the coding was inductive since no categories were retrieved from the literature. Regarding the Items 2, 3, and 4 the coding was both deductive and inductive as we retrieved categories from the literature that were modified and enriched (Delgado, 2009; Delgado et al., 2015; Magana et al. 2012). Following a deductive approach, new categories emerged to include data that did not fit the categories that were retrieved from the literature. The first author of this paper coded all the students' answers. Then two independent researchers, with experience in science education, coded the sum of the material too. The inter-rater agreement was high (Cohen's kappa > .80). All differences were settled by discussion. Table 3 presents the levels of understanding for each item.

Table 3. Coding rubric: The levels of understanding (Ls) per Item.

Items	L3	L2	L1	L0
I1: Meaning of NST	Nanoliteracy terms, e.g. nanoscopic objects, electron microscope	Terms concerning small size, microworld or optical microscope	No nanoliteracy terms or consider nanotechnology in anthropocentric terms	Do not know statements
I2: The smallest object	Nano or atomic world objects	Microworld objects	Macroworld object	Generalities/do not know statements
I3: Classification	Correct observation tool (OT) for the macro, micro and nanoworld objects and correct classification	Correct OT for the macro, micro and nanoworld objects and one mistake in classification	Correct OT for the macro, micro and nanoworld objects and two mistakes in classification	One or more mistakes in OT or more than two mistakes in classification
I4: Ordering	Correct ordering of macro, micro, nanoworld objects	Correct ordering of macro and microworld objects	Correct ordering of macroworld objects	Wrong ordering of macroworld objects
I5: Lotus effect	Reasoning based on the leaf's surface nanostructure (nanobumps) or the hydrophobicity	Reasoning based on the invisible features of the leaf (no reference to the nanostructure)	Reasoning based on perceptual based features of the leaf, e.g. the leaf is hard	Generalities/not know statements

RESULTS

Table 4 presents the percentage of primary students' answers in the Ls based on the pre-post questionnaire. Before the instruction, most of the students' answers were grouped in L0 or L1, while after that, most of their answers were moved in L2 and L3. A Wilcoxon test was used to examine whether, after the instruction, students increased their nanoliteracy significantly.

Table 4. Pre-post students' answers percentage (%) for each level of understanding.

	L0		L1		L2		L3	
Items	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**
I1: Meaning of NST	27.3	0	31.8	13.6	36.4	22.7	4.5	63.6
I2: The smallest object	4.5	0	31.8	9.1	40.9	4.5	22.7	86.4
I3: Classification	100	18.2	0	18.2	0	31.8	0	31.8
I4: Ordering	59.1	18.2	18.2	4.5	9.1	0	13.6	77.3
I5: Lotus effect	77.3	9.1	18.2	9.1	4.5	9.1	0	72.7

Figure 7 displays the mean of students' score (0-3) based on the pre and post questionnaire and the corresponding standard error (SE) of the mean. The difference in the pre-post results was statistically significant for all the items (all *z* scores of the Wilcoxon test were greater than 3.11 and all the *p*s < 0.05).

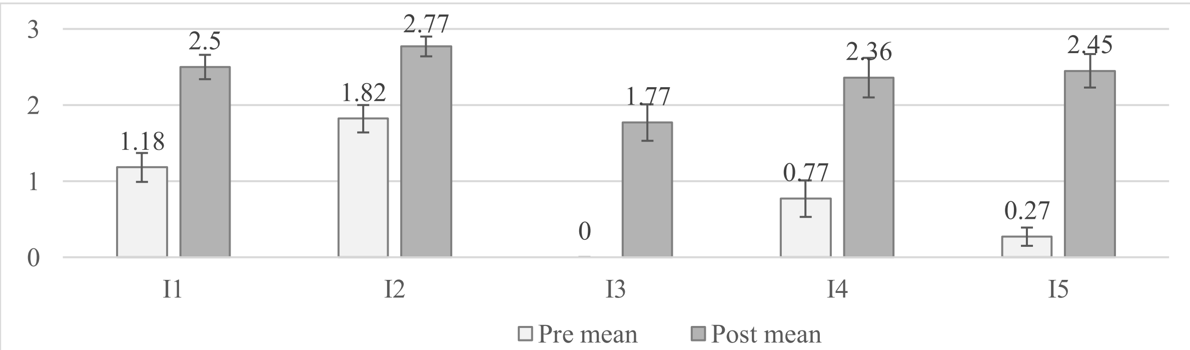


Figure 7. Mean and SE for the pre-post scores of the student's answers.

Concerning the "Meaning of NST" (Item 1) before the implementation of the teaching approach, most of the responses were categorized in L2 and L1. Indicative answers were *"There are some scientists who study small objects"* (L2) and, *"I think it is a technology for dwarfs"* (L1). After the intervention, most of the answers included nanoliteracy terms and were coded as L3. For example, a student mentioned *"Nanotechnology concerns nanoworld objects like a virus and the DNA. We can see these objects only with the electron microscope"*.

As regards "The smallest object" (Item 2), in the initial assessment, the highest percentage of the answers comprised microworld objects (L2), e.g. a cell and macroworld objects (L1), e.g. an ant. Interestingly, 22.7% of the students mentioned nanoworld objects e.g. *"a virus"* or subatomic particles e.g. *"electrons"*. In the post-assessment, most of the students' responses were coded as L3 since they included nanoworld objects such as *"the DNA"*.

Concerning the "Classification" (Item 3) before the instruction, no one student could classify all the objects correctly in the boxes by implementing the criterion of the corresponding observation tool, so all responses were categorized in the L0. After the instruction, 31,8 % of the students succeeded in categorizing all the objects according to the observation tools (L3). The same percentage of students made a single mistake in object categorization (L2).

As far as the "Ordering" in the pre-assessment most of the students ordered the macroworld objects (L0) inappropriately. However, in the post-assessment, a significant percentage of students succeeded in ordering all the macro, micro and nanoworld objects (L3) correctly. For example, a student responded *"soccer ball > grain of salt > onion's cell > cell's nucleus > virus > DNA"*.

Regarding the "Lotus effect" before the educational intervention, most of the students provided general answers or "do not know" statements (L0) while a small percentage expressed perceptual based explanations (L1). For instance, a student mentioned, *"Because the cabbage has a little gluey surface"*. After the implementation, a significant percentage of students explained the phenomenon using terms of nanoliteracy (L3). An indicative answer was *"Cabbage leaves have very small things on its surface which are called nanobumps. Nanobumps don't allow the water to break up and enter the leaf. Leaves that absorb or break up the droplets are called hydrophilic, while these which don't absorb and don't break up the droplets are called hydrophobic"*.

CONCLUSION

As expected, the teaching approach supported students to improve their nanoliteracy.

As regards the meaning of the term nanotechnology, results show that before the implementation, a significant percentage of students thought that nanotechnology concerns something small. One possible explanation for this finding is that the prefix "nano" is a Greek word which means "small" or "dwarf". Greek children in their everyday communication use this prefix. In literature, we find similar examples of people trying to approach the term nanotechnology etymologically (Waldron et al. 2006). After the educational intervention, most of the students used terms of nanoliteracy such as the electron microscope and the nanoworld objects. Among the five NST essential concepts (Figure 1), we found that "Tools" and "Size" were the dominant concepts that the students used to describe this new field. We argue that this finding is attributed to the content of the teaching approach since these concepts were evident in all the units of the intervention (Table 1).

The content of the "Size" is associated with the awareness of landmark objects of the three words, the skill of classification and the ordering from the biggest to the smallest. Results indicate that students achieved significant gains regarding the particular content. Before the implementation, most of the students referred to the non-visible objects as the smallest objects they could think of. The highest percentage of the answers regarded microworld objects and a small percentage included nanoworld or atomic world objects. Similar findings have been reported in previous studies (Castellini et al. 2007, Waldron et al. 2006). We argue that this knowledge may originate from the school textbooks that include units about non-visible objects such as the cells. After the intervention, students enriched their knowledge mentioning nanoscale objects (DNA, virus). Also, they improved their ordering and classification skills. However, the most challenging item after the intervention seems to be the classification of objects into macro micro and nanoworld. For the particular item, we identified that approximately only the 1/3 of the students' answers were coded as L3 after the intervention. In contrast, concerning all the other items, approximately the 2/3 of the students' responses were categorized in L3. This finding indicates the need to refine our approach regarding the development of students' classification criteria.

For the "Size Dependent Properties" aspect, we introduced the Lotus effect. Before the implementation of the teaching approach, most students either could not explain the phenomenon, or they explained the phenomenon using terms related to the macroscale physical features of the leaf. This finding is aligned with literature concerning the explanation of counter-intuitive phenomena (Vosniadou 2014). For instance, phenomena related to the particulate nature of matter are explained based on students' visual everyday experience (Wiser & Smith, 2008). After the implementation, most of the students described the Lotus effect using the newly acquired category of nanosize, and in terms of the leaf's nanostructure or the hydrophobicity.

Next step of this research is to refine the educational approach and to implement it in a larger number of primary school students. Moreover, we aim to enrich the data collection process by pre and post semi-structured interviews (Cohen, Manion, & Morrison, 2007) in order to provide in-depth qualitative data concerning students learning of the NST concepts.

REFERENCES

Blonder, R., & Sakhnini, S. (2016). What Are the Basic Concepts of Nanoscale Science and Technology (NST) that Should Be Included in NST Educational Programs? In K. Winkelmann & B. Bhushan (Eds.), *Global Perspectives -of Nanoscience and Engineering Education, Science Policy Reports* (pp. 117-127). Switzerland: Springer.

Castellini, O.M., Walejko, G.K., Holladay, C.E., Theim, T.J., Zenner, G.M., & Crone W.C. (2007). Nanotechnology and the Public: Effectively Nanoscale Science and Engineering Concepts. *Journal of Nanoparticle Research, 9*, 183-189. doi:10.1007/s11051-006-9160-z.

Cohen, L., Manion, L., & Morrison, K. (2007). *Research Methods in Education*. Abingdon: Routledge.

Delgado, C. (2009). *Development of a research-based learning progress in for middle school through undergraduate students' conceptual understanding of size and scale* (Doctoral dissertation). Retrieved from https://umich.edu.

Delgado, C., Stevens, S., Shin, N., & Krajcik, J. (2015). A middle school instructional unit for size and scale contextualized in nanotechnology. *Nanotechnology Reviews, 4*, 51-69. doi: https://doi.org/10.1515/ntrev-2014-0023.

Filipponi, L., & Sutherland, D. (2010). *Introduction to Nanoscience and Nanotechnologies. Chapter 1.* Retrieved from http://nanoyou.eu.

Laherto, A. (2010). An Analysis of the Educational Significance of Nanoscience and Nanotechnology in Scientific and Technological Literacy. *Science Education International, 21*, 160-175. Retrieved from http://www.icaseonline.net/seiweb/.

Lin, S.Y., Wu, M.T., Cho, Y.I., & Chen, H.H. (2015). The effectiveness of a popular science promotion program on nanotechnology for elementary school students in I-Lan City. *Research in Science & Technological Education, 33*, 22-37. doi: 10.1080/02635143.2014.971733.

Magana, A., Brophy, S., Bryan, L. (2012). An Integrated Knowledge Framework to Characterize and Scaffold Size and Scale Cognition (FS2C). *International Journal of Science Education, 34,* 2181-2203. doi: 10.1080/09500693.2012.715316.

Manou, L., Spyrtou, A., Hatzikraniotis, E., & Kariotoglou, P. (2018). Content transformation for experimental teaching nanoscale science and engineering to primary teachers. *In Journal of Physics: Conference Series 1076*, 012006. doi :10.1088/1742-6596/1076/1/012006.

Mayring, P. (2014). *Qualitative content analysis: theoretical foundation, basic procedures and software solution*. Retrieved from https://www.ssoar.info/ssoar/.

Peikos, G., Manou, L., Spyrtou, A., & Papadopoulou, C. (2017). Study of the Evolution of Primary Students' Ideas about Nanoscience-Nanotechnology. In B.C. Dimov (Ed.) *Third International Conference: Education across Borders*, (pp.459-467). Bitola: University St. Kliment Ohridski.

Schwarz, C.V., Reiser, B.J., Davis, E.A., Kenyon, L., Achér, A., Fortus, D., Shwartz, Y., Hug, B., & Krajcik, J. (2009). Developing a learning progression for scientific modeling: Making scientific modeling accessible and meaningful for learners. *Journal of Research in Science Teaching, 46,* 632- 654. doi:10.1002/tea.20311.

Stevens, S., Sutherland, L., & Krajcik, J. (2009). *Big ideas of nanoscale science and engineering: A guidebook for secondary teachers*. Arlington, VA: NSTA Press.

Vosniadou, S. (2013). Model-based reasoning and the learning of counter-intuitive science concepts. *Infancia y Aprendizaje*, *36*, 5-33. doi: 10.1174/021037013804826519.

Vosniadou, S. (2014). Examining cognitive development from a conceptual change point of view: The framework theory approach. *European Journal of Developmental Psychology, 11*, 645-661. doi: 10.1080/17405629.2014.921153. ISBN: 0-203-87481-1.

Waldron, A.M., Spencer, D., & Batt, C.A. (2006). The current state of public understanding of nanotechnology. *Journal of Nanoparticle Research, 8,* 569-575. doi: 10.1007/s11051-006-9112-7.

Wiser, M. & Smith, C. L. (2008). Learning and teaching about matter in grades K-8: When should the atomic molecular theory be introduced? In S. Vosniadou (Ed.), *International handbook of research on conceptual change* (pp. 205–239). New York, NY: Routledge.

Zoupidis, A., Pnevmatikos, D., Spyrtou, A., & Kariotoglou, P. (2016). The impact of procedural and epistemological knowledge on conceptual understanding: the case of density and floating–sinking phenomena. *Instructional Science, 44*(4), 315-334. doi:10.1007/s11251-016-9375-z

ACKNOWLEDGEMENT

This research is co-financed by Greece and the European Union (European Social Fund- ESF) through the Operational Programme «Human Resources Development, Education and Lifelong Learning» in the context of the project "Strengthening Human Resources Research Potential via Doctorate Research" (MIS-5000432), implemented by the State Scholarships Foundation (IKY).

HORIZON 2020 NEWTON PROJECT EARTH COURSE: LEARNER MOTIVATION CASE STUDY IN STEM EDUCATION TECHNOLOGY ENHANCED LEARNING

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This paper presents a Technology Enhanced Learning science, technology, engineering and maths (STEM) education case study, Earth Course, carried out in two primary schools in Dublin, Ireland as part of the European Horizon 2020 NEWTON Project. The presented Earth Course provides learners with educational content on the following main topics: Biosphere, Geosphere, Astronomy and Physics using digital applications developed as part of the NEWTON Project, employing technology enhanced learning (TEL) solutions. Two 5th classes participated in each school. One of the classes in each school interacted with the NEWTON approach as an introductory tool, with 30 boys in one school and 30 girls in the other school. The second class in each school used NEWTON lessons as a revision tool following the usual instruction by their teacher, with 30 boys in the first school and 27 girls in the second. This paper is focused on the assessment of learner motivation and affective state following the Earth Course case study. Most students found the Earth Course interesting and they would like to use similar lessons in other science classes. Students were extremely positive about the use of technology in the classroom, seeing it as a supporting tool for their teacher.

Keywords: Technology Enhanced Learning, STEM education, Technology in education and Training, Primary School

INTRODUCTION AND BACKGROUND

Technology Enhanced Learning (TEL) is one of the proposed solutions to enhance learners' engagement with STEM subjects, particularly when reduced interest in these subjects has been observed recently (Henriksen, 2016). Beneficial impacts of TEL have been noted in various research papers, such as (Ibáñez, Serio, Villarán, & Kloos, 2014), where Augmented Reality (AR) was evaluated in terms of its benefits on knowledge acquisition and improving learners' flow state when employed in teaching of Electromagnetism in a secondary school and was associated with very positive results. AR was also demonstrated as a valuable teaching tool in (Yipa, Wonga, Yicka, Chanb, & Wong, 2019) when used as support for teaching complex threading tasks.

Virtual Reality (VR) teaching environments were investigated in (Ruppa, et al., 2019). The authors showed that the increased sense of immersion provided by this technology improved learner experience and interest in the taught subjects as well as being beneficial to students' learning outcomes. VR technology was also employed in (Akbulut, Catal, & Yıldız, 2018) for software engineering teaching, where experimental group students exhibited higher knowledge gain compared to the control group, which employed traditional methods. In (Ak & Kutlu, 2017) it was shown that even 2D game-based learning environments improved university students' knowledge gain and were perceived by students as more valuable compared to the traditional approach. Virtual Laboratories were employed in conjunction with traditional-based methods in (Daineko, Dmitriyev, & Ipalakova, 2017) for teaching physics in universities, exhibiting significant enhancement of learning outcome and learning experience.

This paper presents the results of a primary school Horizon 2020 NEWTON Project STEM case study, *Earth Course*, where various technologies were used in a set of lessons in two schools, one girls only and one boys only. First, a description of the NEWTON Project is presented. This is followed by the overview of the *Earth Course* case study set-up, educational applications employed, its participants and assessment procedure which was focused on participating students' motivation and affective state. This is then completed by the results obtained during the evaluation and case-study conclusions

Horizon 2020 NEWTON Project

Horizon 2020 NEWTON Project has the objective of increasing learner quality of experience and learner engagement at the same time maintaining or increasing the learning outcomes in STEM subjects. It is focused on all levels of education, starting with primary level when learners are more open to new approaches, followed by secondary and tertiary institutions.

In order to achieve its objective, NEWTON project employs a variety of TEL approaches and various pedagogies, including **multimedia** and **multiple sensorial media** (Bi, et al., 2018), (Bi, Silva, Ghinea, & Muntean, 2018), (Bi, Zou, Maddi, Rozinaj, & Gabriel-Miro Muntean, 2019), **personalisation**, Virtual Labs (VL) (Lynch & Ghergulescu, 2018), (Ghergulescu, Moldovan, Muntean, & Muntean, 2019), (Ghergulescu, Zhao, Muntean, & Muntean, 2019), **gamification** (Lynch, et al., 2018), (Zhao, Muntean, & Muntean, Enhancing Students Learning Experience in Software Development by Employing Gamification,, 2019), **fabrication labs** (Togou, et al., 2018), (Togou, Lorenzo, Cornetta, & Muntean, 2019), **AR** and **VR** (Bogusevschi, et al., 2018), (Bogusevschi, Muntean, & Muntean, Earth Course: Knowledge Acquisition in Technology Enhanced Learning STEM Education in Primary School, 2019), **problem-based**, **game-based** and **self-directed learning** (El Mawas, et al., 2018), (Zhao, Bogusevschi, & Muntean, 2018), (Ghergulescu, Moldovan, Muntean, & Muntean, Interactive Personalised STEM Virtual Lab Based on Self-Directed Learning and Self-Efficacy, 2019).

All NEWTON Technologies and its Gamification Portal are embedded on the **NEWTON TEL P**latform (NEWTELP)[1] (Bogusevschi D. , Muntean, Gorji, & Muntean, 2018), which hosts all NEWTON project educational applications and technologies as well as its assessment procedure. NEWTELP can be used by teachers, for creating and personalising courses as well as evaluating knowledge gain and affective state following TEL approach lessons, and by students, for interacting with the educational content.

EARTH COURSE

The *Earth Course* case study was set up to assess the effect of NEWTON technologies, such as Virtual environments, including VLs, game-based learning, gamification and of the

[1] Developed by SIVECO, Bucharest, Romania (siveco.ro)

NEWTON Project platform, NEWTELP, on primary school learners' motivation and affective state, knowledge gain and usability of NEWTELP as well as of individual technologies and pedagogical approaches. Table 6 provides an overview of the topics within the *Earth Course* and specific applications within each topic (Bogusevschi, et al., 2018), (Bogusevschi D. , Muntean, Gorji, & Muntean, 2018), (Zhao, Bogusevschi, & Muntean, Improving Future STEM Education with an Innovative Learning Management System and Technology-Enhanced Learning Materials, 2018), (Bogusevschi, Muntean, & Muntean, Earth Course: Knowledge Acquisition in Technology Enhanced Learning STEM Education in Primary School, 2019), (Bogusevschi & Muntean, Water Cycle in Nature – An innovative Virtual Reality and Virtual Lab: Improving Learning Experience of Primary School Students, 2019). It also includes the main technology used and a brief description of the learner activities within each application. Applications *Wildlife*, *Sea-Life* and *Water Cycle in Nature* were developed by NEWTON consortium partner SIVECO, Romania. *Final Frontier* was developed by consortium partner National College of Ireland (NCI). *Geography* application was developed by consortium partner Slovak University of technology in Bratislava, Slovakia (STUBA).

Table 6 *Earth Course* Case Study Applications

Topic	Application	Technology	Description
Biosphere	Wildlife I Wildlife II[1]	VR, VL, gamification	Learners explore a nature environment collecting gas-cans in a forest and finding terrestrial animals, which are then explored in a VL. Quick quizzes are provided in order to reach the bonus level.
	Sea-life I[1] Sea-Life II[1]	VR, VL, gamification	Learners explore a nature environment collecting star-fish in an ocean and finding aquatic animals, which are then explored in a VL. Quick quizzes are provided in order to reach the bonus level.
Geosphere	Geography[2]	AR, VR	Learners need to familiarise with digital educational content focused on UK and the Republic of Ireland where images of monuments with enabled AR/VR functionality are provided. A Virtual Map is then employed for assessing learners' geographical knowledges.
Astronomy	Final Frontier I[3]	Gamification game-based learning	Game with an avatar on a spaceship which focuses on Rocky Planets, allowing for an exploration of virtual planets, where learners need to collect meteorites and answer quizzes.
	Final Frontier II[3]	Virtual library	Virtual library that exists on the spaceship and provides educational information about the giant Gas Planets and the Rocky planets.
Physics	Water Cycle in Nature[1]	VR, VL	Learners explore a virtual nature environment learning about phenomena participating in precipitation formation and a VL which exhibits relevant physics experiments in a laboratory setting.

The focus of this paper is on students' motivation and affective state with the main research question: What is the impact of NEWTON Technologies and platform on learners' motivation and affective state?

[2] Developed by Slovak University of Technology in Bratislava (STUBA), Slovakia (stuba.sk)
[3] Developed by National College of Ireland (NCI), Dublin, Ireland (ncirl.ie)

Set-up: Participants and Evaluation Procedure

The *Earth Course* case study was carried out in two single sex primary schools, St. Patrick's Boys National School (BNS) and Corpus Christi Girls National School (GNS) in Dublin, Ireland and it meets all ethics requirements. Two 5th class groups participated in each school with learners of 10-11 years of age. Classes A and A' in St. Patrick's BNS and Corpus Christi GNS respectively employed the NEWTON approach as an introductory tool to a topic. Classes B and B' were initially presented the educational content by their usual teacher in a teacher centred approach, following which, 4 to 10 weeks later they interacted with the NEWTON applications to review the previously presented content.

The NEWTON Project Pedagogical Assessment Committee (PAC) Toolkit (Montandon, et al., June 2018) was used to evaluate the intervention, whereby at the beginning of the intervention, two questionnaires were completed by learners - Demographics and Affective State/Motivation Pre questionnaires. Following the completion of the 8 NEWTON learning sessions, learners filled out the Affective State/Motivation Post questionnaire in order to determine students' motivation toward STEM and their engagement following interaction with TEL solutions. Interviews and focus groups were also conducted with learners and teachers, in order to obtain a more informal account of their experience during NEWTON lessons, ensuring that any aspects which might have been missed in the questionnaires were addressed.

EVALUATION OF CASE STUDY IMPLEMENTATION

Following completion of the *Earth Course*, during focus groups and interviews, the majority of learners reported being very engaged in the NEWTON lessons. It was reported quite strongly that they perceived NEWTON as a very useful supporting tool for the teacher. This was especially notable during the focus group, where students reported being very excited about the classes where the content was provided by both the teacher and reinforced by the NEWTON approach. Students reported enjoying the TEL approach together with the teacher for support and direction.

From the data in the Motivation/Affective State Post questionnaires, it can be noted that the majority of students were interested in the relevant subjects, where around 60% of learners in classes B and B' were very or extremely interested (65% of boys and 60% of girls), with an even higher percentage in classes A and A' (85% of boys and 70% of girls). While the majority of all the students responded that they were somewhat or very engaged, the female students responded more positively (90% of girls and 70% of boys). Only one girl in class A' reported boredom.

The implementation of the technology in introducing the topic was considered more favourably by participating students compared to its use as a revision tool (with over 80% of learners in classes A and A' indicating the NEWTON lessons were extremely interesting, and 53% of boys' class B and just over 62% of girls' class B' responding similarly). The students' preference to the use of technology in STEM subjects remains quite stable compared to before the *Earth Course* case study as assessed in the Pre Motivation/Affective State questionnaire, with 85% of boys in class A wanting to use more technology (compared to 92% in the questionnaire prior study), 76% of boys' in class B (compared to 77% prior study), compared to 72% (with 74% prior study) and 64% (with 60% prior study) of girls respectively.

When enquiring on students' preference toward computer-based and teacher-based learning, the majority of students stated that they prefer computer-based teaching: 96% of boys in class A and 76% of boys in class B, compared to 82% of girls in class A' and 62% of girls in class B'. However, it has to be noted that when further discussing this matter during interviews, students noted that they were really positive about computer-based teaching when it is supported by their teacher. They really emphasised that it was very important for them to have the support and the leadership of their usual teacher during TEL lessons.

Following the Post Motivation/Affective State questionnaire, comments obtained from girls include: "I like NEWTON very much […] thank you so much for teaching me about the Earth space and nature" and "I loved learning with NEWTON [,] it was really fun and interesting" in class A'; "I think I preferred doing the game [,] it made it more interesting" and "I enjoyed learning" in class B'. Boys' answers included: "I really enjoyed NEWTON and hope to continue with it in 6th Class" and "I liked the animation" in class A; "Good" and "Games are more fun" in class B. Girls were considerably more detailed in their feedback provided in the Post questionnaires. During interviews and focus groups, both genders were very open to provide their comments and reactions to the novel NEWTON Project TEL solutions.

CONCLUSION

This paper presents the findings of a EU Horizon 2020-funded NEWTON Project case study carried out in two primary schools in Dublin, Ireland, one a boys only school and one a girls only school. Two 5th classes participated in each school, one class assigned as the experimental group employing NEWTON technologies as introduction to a topic and the other class was employing NEWTON technologies a revision to a topic which was previously presented to students by their usual teacher in a classic approach lesson. Students' affective state was evaluated following the TEL NEWTON lessons, exhibiting excellent results. It was shown that the experimental classes employing NEWTON as an introduction tool benefited slightly more in terms of affective state, compared to the revision classes, even though the revision classes benefited more in terms of knowledge gain, as seen in (Bogusevschi, Muntean, & Muntean, Earth Course: Knowledge Acquisition in Technology Enhanced Learning STEM Education in Primary School, 2019). However overall, following NEWTON approach lessons, all groups of students presented increase in motivation, satisfaction and interest in STEM subjects.

Further analysis of the data will probe the learning gains presented by the technologies and the comparison of uses in the different class groups (Bogusevschi, Muntean, & Muntean, Earth Course: Knowledge Acquisition in Technology Enhanced Learning STEM Education in Primary School, 2019). Interview data from teachers will be used to support data analysis (Bogusevschi, Maddi, & Muntean, Teachers' Impact and Feedback Related to Technology Enhanced Learning in STEM Education in Primary and Secondary Schools, 2019). Following the extremely positive outcome of this NEWTON Project case study, access to the NEWTON Project platform, NEWTELP, and to the previously employed *Earth Course* educational content and assessment procedure was provided to both schools for future use in classes both for in-class and after-school activities, as identified more suitable by school teachers.

ACKNOWLEDGEMENT

This research is supported by the NEWTON project (http://www.newtonproject.eu/) funded under the European Union's Horizon 2020 Research and Innovation programme, Grant Agreement no. 688503. The support of the Science Foundation Ireland (SFI) Research Centres Programme Grant Numbers 12/RC/2289 (Insight) and 16/SP/3804 (ENABLE) if gratefully acknowledged.

REFERENCES

Ak, O., & Kutlu, B. (2017). Comparing 2D and 3D game-based learning environments in terms of learning gains and student perceptions. *British Journal of Educational Technology*.

Akbulut, A., Catal, C., & Yıldız, B. (2018). On the effectiveness of virtual reality in the education of software engineering. *Computer Applications in Engineering Education*, 918-927.

Bi, T., Silva, F., Ghinea, G., & Muntean, G.-M. (2018). Improving Learning Experience by Employing DASH-based Mulsemedia Delivery. *IEEE Games, Entertainment, Media Conference (GEM).*

Bi, T., Simiscuka, A., Silva, F., Togou, M., Rozinaj, G., & Muntean, G.-M. (2018). A Study of Learning Experience with a DASH-based Multimedia Delivery System. *10th annual International Conference on Education and New Learning Technologies (EDULEARN).* Palma de Mallorca, Spain.

Bi, T., Zou, L., Maddi, M., Rozinaj, G., & Gabriel-Miro Muntean, G.-M. (2019). Knowledge Acquisition by Employing Adaptive Multimedia in Third Level Technology Enhanced Learning STEM Education. *World Conference on educational Media and Technology (EdMedia).* Amsterdam, Netherlands.

Bogusevschi, D., & Muntean, G.-M. (2019). Water Cycle in Nature – An innovative Virtual Reality and Virtual Lab: Improving Learning Experience of Primary School Students. *11th International Conference on Computer Supported Education (CSEDU).* Greece.

Bogusevschi, D., Maddi, M., & Muntean, G.-M. (2019). Teachers' Impact and Feedback Related to Technology Enhanced Learning in STEM Education in Primary and Secondary Schools. *Ireland International Conference in Education (IICE).* Dublin, Ireland.

Bogusevschi, D., Muntean, C. H., & Muntean, G.-M. (2019). Earth Course: Knowledge Acquisition in Technology Enhanced Learning STEM Education in Primary School. *Proceedings of EdMedia: World Conference on Educational Media and Technology.* Amsterdam, Netherlands.

Bogusevschi, D., Muntean, C. H., Gorji, N. E., & Muntean, G. M. (2018). Earth Course: A Primary School Large-Scale Pilot on STEM Education. *10th annual International Conference on Education and New Learning Technologies (EDULEARN).* Palma de Mallorca, Spain.

Bogusevschi, D., Tal, I., Bratu, M., Gornea, B., Caraman, D., Ghergulescu, I., . . . Muntean, G. (2018). Water Cycle in Nature: Small-Scale STEM Education Pilot. *Proceedings of EdMedia: World Conference on Educational Media and Technology*, (pp. 1496-1505). Amsterdam, Netherlands.

Daineko, Y., Dmitriyev, V., & Ipalakova, M. (2017). Using virtual laboratories in teaching natural sciences: An example of physics courses in university. *Computer Applications in Engineering Education*.

El Mawas, N., Tal, I., Moldovan, A., Bogusevschi, D., Andrews, J., Muntean, G., & Muntean, C. H. (2018). Final Frontier Game: A Case Study on Learner Experience. *Proceedings of the 10th International Conference on Computer Supported Education (CSEDU), .* Madeira, Portugal.

Ghergulescu, I., Moldovan, A.-N., Muntean, C. H., & Muntean, G. (2019). tomic Structure Interactive Personalised Virtual Lab: Results from an Evaluation Study in Secondary Schools. *11th International Conference on Computer Supported Education (CSEDU).* Heraklion, Crete.

Ghergulescu, I., Moldovan, A.-N., Muntean, C. H., & Muntean, G.-M. (2019). Interactive Personalised STEM Virtual Lab Based on Self-Directed Learning and Self-Efficacy. *27th Conference on User Modeling, Adaptation and Personalization (UMAP).* Larnaca, Cyprus.

Ghergulescu, I., Zhao, D., Muntean, G.-M., & Muntean, C. H. (2019). Improving Learning Satisfaction in a Programming Course by Using Course-Level Personalisation with NEWTELP. *27th Conference on User Modelling, Adaptation and Personalization (UMAP).* Larnaca, Cyprus.

Henriksen, E. (2016). *Understanding student participation and choice in science and technology education.* SPRINGER.

Ibáñez, M. B., Serio, Á. D., Villarán, D., & Kloos, C. D. (2014). Experimenting with electromagnetism using augmented reality: Impact on flow student experience and educational effectiveness. *Computers and Education*.

Lynch, T., Playfoot, T., De Nicola, C., Guarino, G., Di Salvadore, F., & Ghergulescu, I. (2018). Gamification elements in STEM subjects – Lessons learned from NEWTON Project. *Ireland International Conference on Education, - IPETeL.* Dublin, Ireland.

Montandon, L., Playfoot, J., Ghergulescu, I., Bratu, M., Bogusevschi, D., El Mawas, N., & Rybarova, R. (June 2018). Multi-dimensional Approach for the Pedagogical Assessment in STEM Technology Enhanced Learning . *EdMedia World Conference on Educational Media and Technology.* Amsterdam, The Netherlands.

Ruppa, M. A., Odetteb, K. L., Kozachuka, J., Michaelisa, J. R., Smithera, J. A., & McConnell, D. S. (2019). Investigating learning outcomes and subjective experiences in 360- degree videos. *Computers & Education, 128*, 256-268.

Togou, M. A., Lorenzo, C., Cornetta, G., & Muntean, G.-M. (2019). NEWTON Fab Lab Initiative: A Small-Scale Pilot for STEM Education. *World Conference on Educational Media and Technology (EdMedia).* Amsterdam, Netherlands.

Yipa, J., Wonga, S.-H., Yicka, K.-L., Chanb, K., & Wong, K.-H. (2019). Improving quality of teaching and learning in classes by using T augmented reality video. *Computers & education, 128*, 88-101.

Zhao, D., Bogusevschi, D., & Muntean, G. (2018). Improving Future STEM Education with an Innovative Learning Management System and Technology-Enhanced Learning Materials. *International Conference on Engaging Pedagogy (ICEP).* Dublin, Ireland.

Zhao, D., Muntean, G.-M., & Muntean, C. H. (2019). Enhancing Students Learning Experience in Software Development by Employing Gamification,. *28th ICDE World Conference on Online Learning (WCOL'19).* Dublin, Ireland.

PART 17: STRAND 17

Science Teaching at the University Level

Co-editors: *Jenaro Guisasola & Paula Heron*

CONTENTS

STRAND 17: INTRODUCTION

INTRODUCTION: TRANSFORMING UNIVERSITY-LEVEL SCIENCE EDUCATION

During the last few decades there have been significant changes in society and in the environment that have driven changes in the teaching of science at all educational levels, including higher education (NRC 2015). New demands in science education frequently challenge the efficacy of traditional teaching at the university level. The scientific community needs to change science and technology teaching to make it effective and relevant to a diverse university student population. The new social needs are very different from those in the past, when the main objective of science education was to train a small number of students to become future scientists. Scientific-technological education at the university level now needs to support and train a diverse student population where the actual use of knowledge, not just memorization, is increasingly important (Report European Commission 2013). Science education research shows that it is necessary to change university instruction in a way that changes the way students think about science, about solving scientific problems, and allows them to practice the scientific skills of the scientific-technical community. (Hake 1998, McDermott 2001).

The "Science Teaching at the University Level" strand (strand 17) focuses on the relationship between research in science education and teaching and learning in higher education. The nine articles that make up strand 17 of the ESERA Conference Proceedings e-book illustrate that inquiry-based teaching is fundamental to the process of university education. The studies are based on data collected with different tools such as questionnaires, surveys and interviews. The results are mainly focused on learning problems, related to conceptual understanding and scientific practices in a wide range of aspects, such as cognitive, affective, and social. The research presented includes the analysis of teaching processes with various purposes. Two articles deal with analyzing the attitudes, behaviors and interests of students towards "Responsible Research" in scientific research (Elster) and on the benefits and challenges of technology-enhanced learning (Roche). Another article focuses on evaluating the results of an educational action focused on proposing authentic research to students in the form of research works (Hougaard and Nielsen). Two articles analyze the improvement of learning evaluation formats considering aspects that range from structural factors, psychological and physical resources, study behavior, study motivation and study performance (B. Paczulla et al.), to evaluation criteria in study program and competences (Flodin and Davidson). Four other articles analyze the conceptual learning and/or scientific skills of students in traditional teaching in lectures (Zuazagoitia et al; Praprotnik and Torkar), in the laboratory (Poensgen and Reiners) and in problem solving (Woitkowski).

The collection of articles included in this section shows the need to investigate science teaching processes using a variety of methodological approaches and in different contexts. The combination of complementary methodological tools and types of analysis can support a systematic analysis of science education practices with the aim of reforming learning and teaching. The "Science Teaching at the University Level" strand was defined for the first time in the 2015 Conference and has remained as a strand in the following congresses in 2017, 2019 and, in the next 2021. The number of contributions has been growing with 16 oral communications in 2015, 25 in 2017 and 34 in 2017. However, the number of studies submitted for the e-book ESERA Conference Proceedings is a low proportion of those submitted.

Consequently, the number selected for the e-book is low. In 2015, 4 papers were published, 8 in 2017 and 9 in 2019. However, research in science education is increasing at the university level, as shown by the large increase in research published in high-impact journals. Thus, it will be necessary to disseminate and share the results of the e-book proceedings with the community of university professors. Having a specific strand on teaching and learning problems at the university is necessary for the discussion and dissemination of advances in science teaching at the university.

Jenaro Guisasola & Paula Heron

References

Hake, R.R. (1998) Interactive-engagement versus traditional methods: A sixthousand-student survey of mechanics test data for introductory physics courses, American Journal of Physics. **66,** 64–74.

McDermott, L.C. (2001). Oersted Medal lecture 2001: Physics Education Research- The key to student learning, American Journal of Physics. **69,** 1127–1137.

NRC-National Research Council. (2015). *Guide to Implementing the Next Generation Science Standards*. Committee on Guidance on Implementing the Next Generation Science Standards. Board on Science Education, Division of Behavioral and Social Sciences and Education, Washington, DC: The National Academies Press.

Report to the European Commission on Improving the quality of teaching and learning in Europe's higher education institutions. (2013) . ISBN 978-92-79-30360-9. In: http://ec.europa.eu/dgs/education_culture/repository/education/
library/reports/modernisation_en.pdf

STARBIOS2 - ENGAGING WITH RESPONSIBLE RESEARCH THROUGH SCIENCE EDUCATION

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The purpose of this theoretical paper is to present and discuss a strategy to implement the concept of Responsible Research and Innovation (RRI) in the Faculty Biology and Chemistry at the University Bremen using science education as a promoter of this process. The project is part of STARBIOS2 (Structural Transformation to Attain Responsible Biosciences), a European project funded in the HORIZON 2020 program Science With And For Society (Swafs) (see http://starbios2.eu). It aims to implement Action Plans to promote RRI in partner institutions of six European countries. Based on the experiences a model and guidelines has been elaborated to facilitate the implementation of RRI in other research institutions.
The University of Bremen is one of the 12 partners of STARBIOS2. The Bremen team develops, conducts and evaluates an Action Plan with Science Education as a trigger for the structural transformation process. The Action Plan aims in the performing of a series of educational building blocks with the goal of raising the awareness of RRI issues. The vision is to implement RRI in the future concept of the Faculty of Biology and Chemistry.

Keywords: Responsible Research, Higher Education, European project

CONTEXT AND RELEVANCE TO SCIENCE EDUCATION

STARBIOS2 – Structural Transformation to Attain Responsible Biosciences - is a European project that has received funding from the Framework Programme HORIZON 2020 (coordinator: Universitá di Roma Tor Vergata, Italy). The goal of STARBIOS2 is to raise the awareness of Responsible Research and Innovation (RRI) and to better align research to the needs of the society. Therefore, structural transformation processes in six European research institutions (in Bulgaria, Germany, Italy, Poland, Slovenia, and United Kingdom) and three non-European entities (in Brazil, South Africa, and United States), all active in the field of biosciences, are initiated and tailored in respect to their culture, rules and procedures. The processes are focussing on the five RRI key issues: Public Engagement, Gender, Education, Open Access, and Ethics (Colizzi et al., 2019).

The University Bremen is a member of the STARBIOS2 consortium. The goal is to raise the awareness of RRI by conducting a transformation process in regard to RRI issues in the Faculty of Biology and Chemistry (one of the 12 faculties of the University Bremen). This process is triggered by the Institute of Science Education with the goal to provide future researchers and teachers with new capacities for attracting children and youth to science and technology (Elster et al., 2016; 2019a,b).

THEORETICAL FRAME

Responsible Research and Innovation (RRI) represents a contemporary view of the connection between science and society. The goal is to create a shared understanding of the appropriate roles of those who have a stake in the processes and products of science and technology, scientists as well as educators and the general public. It is estimated that a shared understanding and mutual trust will lead to safe and effective systems, processes and products of innovation. RRI can be defined as 'a transparent, interactive process by which societal actors and innovators become mutually responsive to each other with a view to the (ethical) acceptability, sustainability and societal desirability of the innovative process and its marketable products (in order to allow a proper embedding of scientific and technological advances in our society)' (Sutcliffe, 2011:19).

In the Horizon 2020 framework RRI is built on the following key dimensions (Von Schomberg & Von Schomberg, 2013):

- *Societal Engagement* and *technology transfer* focus on the promotion of the engagement of all societal actors in the R&I process;
- *Gender* aims at favouring gender equality within research institutions as well as in the Research and Innovation (R&I) content;
- *Science Education* aims to provide future researchers with news capacities for attracting children and youth to science and technology;
- *Open Access* focuses on making research and innovation transparent and accessible through making Open Access a reality; and
- *Ethics* aims in ensuring high quality research results and ethical standards.

This framework of RRI allows research institutions to raise the awareness of current and future scenarios regarding the science and technology advances.

Enhancing Responsible Research in Biosciences

The European project STARBIOS2 aims to contribute to the advancement of the RRI strategy by fostering structural change in biosciences research institutions. The hope is to cope with one of the main risks for European research: its inadequate connection with society by changing the institutional culture, values and procedures in a holistic manner (STARBIOS2 Consortium, 2016; Colizzi et al., 2019).

To reach these goals the project comprises three steps:

In a first step, six European STARBIOS2 partners in Bulgaria, Germany, Italy, Poland, Slovenia, and United Kingdom develop, evaluate and implement six RRI Action Plans (APs) in their research institutions. The experiences about the APs' implementation form the base for the development of new practical knowledge. They are the starting points for the development of tailored APs Based in three non-European entities in Brazil, South Africa and United States.

In a second step, a complex learning process about the implementation of APs is initiated. That that allows the members of the partner institutes to learn from each other. Questions about supporting and hindering structures are reflected. The goal is a better understanding about the different possible ways of the implementation of RRI in biosciences research institutions.

In the third step, the outcome of the learning process results in the development of a sustainable model and a set of guidelines on RRI implementation, aimed at providing recommendations on how to deal with resistances to RRI in research institutions (Declich et al., 2019). As each community of the participating Higher Education Institutes is characterized by its own features, culture, languages, networks, communication means and power dynamics it is important to identify multiple RRI strategies tailored to each research institute (STARBIOS2 Consortium, 2016).

Science Education as a Trigger to Attain Responsible Research

The University of Bremen is a relatively young university with 12 faculties and about 20 000 students. Faculty Biology and Chemistry takes part in the STARBIOS2 project with the goal to develop a tailored AP for the implementation of a RRI mission statement. To reach this goal a whole-institute-approach based on a bottom up – top down is conducted. Therefore, af a Core Team of scientists and science educators as well as an Extended Team with important stakeholders of the faculty (dean, vice dean, member of the quality management) and representatives of the status groups students, doctoral students and researchers has been set up. A central goal is the initiation of a negotiation process of RRI issues (among stakeholders, researchers, students) and the inclusion of RRI in the future concept (mission statement) of the faculty.

To reach these goals a roadmap (fig.1) is set up (Elster et al., 2016; 2019a).

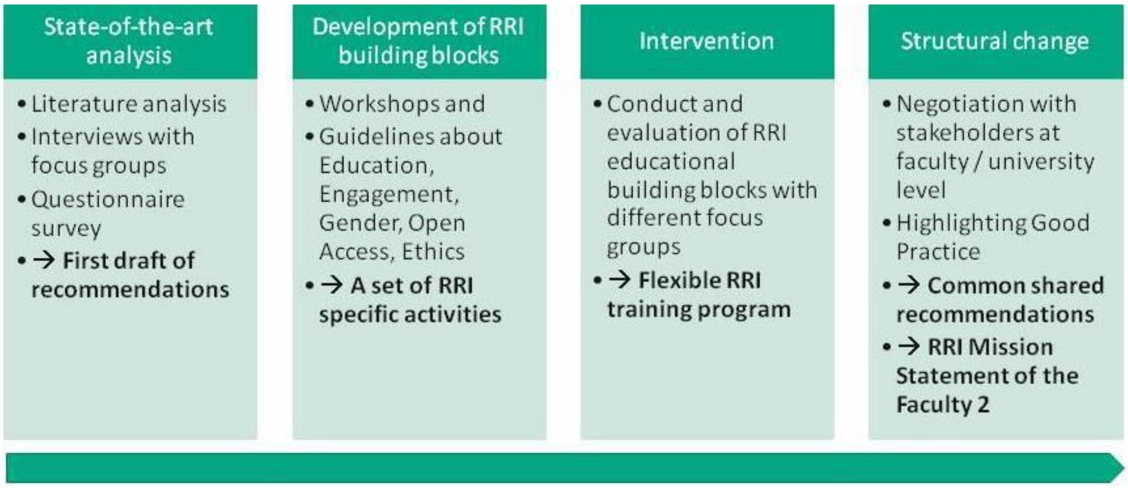

Figure 1. Roadmap for structural change at the University Bremen (Elster et al., 2016).

1) We started with a comprehensive **state-of-the-art analysis** of literature and research programmes. The findings of the analysis built the basis for the development of interview guidelines. The interviews were conducted with different focus group(s) (doctoral students, students, researchers, and/or educators; n=21). Based on the interview results a RRI questionnaire survey was conducted on-line at the faculty (n=163). From the findings of the interviews and the questionnaire survey criteria for the successful promotion of the specific RRI issues were deduced. The criteria formed the basis of a first draft of recommendations.
2) The development of **RRI specific educational building blocks** comprised the development of RRI modules and reflective activities in respect to the RRI keys. These building blocks (5) and reflective activities (6) were conducted and evaluated within the different focus groups or in the outreach lab Backstage Science (with school classes). They formed the base for the educational intervention.

3) The goal of the **RRI educational intervention** was the connection of the key-specific building blocks to a RRI training programme in accordance of the needs and the interest of the specific target group(s). The results contributed to a further development of the RRI recommendations and the RRI future concept of the faculty.
4) **For structural transformation and change** the goal was to foster sensitiveness and awareness in respect to RRI through dialogue with important stakeholder, offer of academic lectures, and transparency by a user-friendly website, good practice examples, and recommendations at the faculty level and at the university level.

EDUCATIONAL CONCEPTS TO PROMOTE RRI IN BREMEN

Science education has an important role to educate the future scientists and university students. What scientists do, how they work, innovate and make decisions are important subjects for contemporary science education. While science and technology develop, science education needs to renew itself and work along with the developments in science and technology. New developments and technologies are very often controversially discussed in society. Therefore, a useful model for the processes of **communication between researchers and the public** is needed. It forms the basis of educational and didactical interventions.

In the case of the University Bremen new educational models should trigger the raising of awareness of RRI issues and an inspiring and fruitful structural change regarding RRI issues. As a consequence, within the Starbios2 project new educational concepts are developed at the level of students' individual training by **RRI reflective activities**, **RRI modules** as inspiring practices, and **RRI in the curricula of academic programmes**.

A Communication Model between Researchers and the Public

Our communication model is based on the Common Ground Theory of Bromme (2000) and the Model for Communication about Biotechnology based on Ben France and John K. Gilbert (2006). In everyday communication, interaction partners encounter different perspectives. The question of how mutual comprehension arises in the case of different perspectives or knowledge especially in the expert and layman communication. The Common Ground Theory postulates that every act of communication presumes a common cognitive frame of reference between the partners of interaction called the common ground. All contributions to the process of mutual understanding serve to establish or ascertain and continually maintain this common ground (Bromme, 2000). 'Two people´s common ground is, in effect, the sum of their mutual, common, or joint knowledge, beliefs, and suppositions.' (Clark, 1996: 3)

Researchers in the field of biosciences face the challenge to persuade 'the public' of the rightness of their case, whilst 'the public' is trying to argue a scepticaly or even contrary case. A model that might be of use in any field where technological controversy takes place was set up by France and Gilbert (2006). They took the idea of a *communicating community*, defined as relatively coherent social group engaging in communication with itself. The authors differentiate in the *biotechnology communities* and the *public communities*. Each of the communities has a certain 'view' on biotechnology that is made up of four 'dimensions': their understanding of the nature of science and biotechnology; understanding of the key concepts and models used in biotechnology; perceptions of the nature of risk; and beliefs and attitudes about biotechnology.

Similar to Bromme´s definition of a 'common ground' (Bromme, 2000) France and Gilbert (2006) define a 'search room' as a virtual arena where the 'views' of the communities of scientists and the public communities are exchanged. 'Where there are elements of the views that are in common to the two, communication is possible. Where there is no commonality, the degrees of understanding reached must be used to construct a mutual understanding that may evolve into an agreement exchange.' (France & Gilbert, 2006: 2).

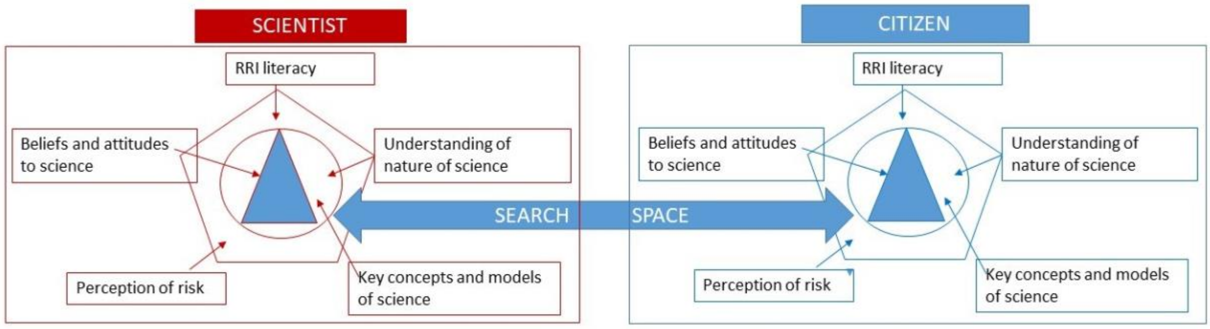

Fig. 2 The inclusive communication model for biosciences (Elster et al, 2019a)

Within our Starbios2 project in Bremen we have to expand this model in respect to the RRI issues. Firstly, we defined a *RRI literate researcher* is a person who 1) perceives sensibly to detect questions related to RRI issues related to societal engagement and technology transfer, gender, ethics, open access publications and science education; 2) who is willing to apply its knowledge of RRI issues; 3) who actively acts to disseminate RRI issues in the context of research and the research institution. Secondly, we expanded France and Gilbert´s four 'dimensions' by a fifth dimension, the RRI literacy. And thirdly, we extended the model which specifically focused on biotechnology to a more comprehensive view on biosciences. Our inclusive communication model is summarized in figure 2.

Promotion by RRI Reflective Activities

The promotion of critical thinking is considered one of the key issues of good scientific RRI education. Students and researchers should be encouraged to critically question about what is responsible and conscientious practice within their scientific domain. They should be aware of societal needs and that research is not oblivious towards societal values.

Reflexive capacities are crucial for understanding the role and responsibilities of research. Therefore, students and researchers should be aware of the interrelationship of their own research with other areas of science. The goal is to open the view to collaborate and coproduce knowledge with researchers as well as professionals outside their own fields and with interested citizens.

Within the Starbios2 project a series of reflective activities in respect to the societal engagement, contextualization of research, publication open access, gender in research, diversity team management, ethics in science communication are developed, tested and evaluated. They are summarized in the RRI toolbox at the local website (https://blogs.uni-bremen.de/starbiosbremenenglish/)

RRI Modules as Inspiring Practices

In the context of Starbios2 at University of Bremen the concept of raising awareness of RRI issues through RRI educational building blocks is based on the Citizen-SIP educational model. The model is based on Problem-based Learning (PBL) in socio-scientific contexts (SSC) and Inquiry-based Science Education (IBSE) with a specific focus on Citizenship Education (CE). Problem-based learning stands for self-determined and discovering learning, action-oriented teaching, interdisciplinary learning and self-evaluation. Participants learn to analyse a topic or question, to find and use suitable sources of information, and finally to compare, select and implement solutions. Socio-scientific issues (SSI) are open-ended, multifaceted social issues with conceptual links to science (Sadler, 2011). PBL in socio-scientific contexts in authentic research projects as ‘real-world scenarios’ offers powerful opportunities to develop critical thinking on the nature of science and its implications (Lederman et al., 2014). IBSE is an appropriate educational instrument to acquire process skills and an adequate view of the Nature of Science (Capps & Crawford, 2013) as well as a meaningful understanding in a societal context. Citizen Education takes into account the moral and social function of education at a socio-political level.

RRI in science education requires that students have creative thinking and problem solving skills. RRI deals with dilemmas and uncertain situations where students’ arguments are as important as the scientific facts. Examples of RRI modules developed at the University of Bremen are ‘Promotion of Risk Literacy in Regard to Nanotechnology’ (Eschweiler & Elster, 2018), ‘Wake up – Sensitisation of adolescents for the stem cell donation for leukaemia patients’ (Holzer & Elster, 2019), and ‘Biodiversity loss and climate change in the Wadden Sea’ (Müller & Elster, 2018). These modules are developed in doctoral and master studies in cooperation of scientists, science educators and teacher candidates. The modules are evaluated in in-service trainings, pre-service education and schools.

RRI in Curricula of the Bachelor´s and Master´s programmes

University students as nascent researchers should acquire knowledge and skills needed to work responsibly during their academic experiences. In their academic development, ideas and concepts of RRI should be fostered and developed throughout the formative process of education. Traditional academic hierarchies should be modified to enhance the voluntary participation and debate among the students. In an atmosphere of openness and trust, students should be encouraged to draw their own conclusions and provide valuable contributions to the debate.

The integration of research and teaching can provide valuable ways of enhancing student learning experiences. Nevertheless, the linking can be challenging and the understanding of a ‘research-based education’ and ‘research-informed teaching’ within and between disciplines is diverse. The ‘nexus’ of research and teaching is influenced by the departmental structural arrangements for organising research and teaching activities, and a potential gap in making connections between staff research outputs and students´ learning when this research is too far ahead of the undergraduate curriculum to be accessible to students (Jenkins, 2004). Graffiths (2004) and Healey (2005) distinguish five ‘Research-informed teaching’ approaches:

- Research-led (RL): Students learning “about” the research of others.
- Research-oriented (RO): Students learning about research processes.
- Research-based (RB): Students learning as researchers.
- Research-tutored (RT): Students learning through critiquing research.
- Scholarship of teaching and learning (STL): Enquiring and reflecting on teaching and learning.

In the bachelor’s biology programme and in the different master’s programmes at the Faculty Biology and Chemistry all five approaches of research-informed teaching are offered. They provide different avenues for RRI learning. Whereas during the bachelor’s programme different concepts, ideas, relevance and aims of research and RRI are discussed (RL and/or RO), the integration in research groups and writing of the bachelor theses offers the possibility of students learning as researcher (RB). That allows them to relate RRI processes in the own field and the role of responsibility in these processes. Especially within the associated modules ‘interdisciplinary key qualifications’ students learn about criteria for good research and ethical issues in scientific writing.

In the master’s programmes of biosciences students focus on the specific topics of their fields of research and research-tutored (RT) learning may be at the core. Science chats and master seminars allow doing and experiencing dialogical reflection on research and innovation (STL) and a perspective with the wider society.

RRI in the curricula of PhD programmes

Most of the reflective activities developed in Starbios2 projects are targeted to PhD students and young researchers. When doing more or less self-reliant research the application of RRI issues is important. The assessment of possible societal impacts of one´s own concrete research activities as well ethical issues of research receive increased importance. The goal is to propose adoptions to better align a research project with societal needs, values and expectations.

A good practice example at the University of Bremen is the Graduate School NanoCompetence – Research, Mediation, Design. This interdisciplinary graduate school combines the expertise of natural sciences and humanities, aiming at enlightening society about the applied aspects of nanotechnology. (https://www.nano.uni-bremen.de/)
Especially in the doctoral programme of Science Education RRI is reflected and RRI issues like socio-scientific issues and contexts, how to deal with gender and diversity as well as ethical questions are fields of investigation in doctoral studies (see e.g. Birkholz, 2019).

DISCUSSION – A NEW CHALLENGE FOR SCIENCE EDUCATION

Responsible Research and Innovation (RRI) represents a contemporary view of the connection between science and society. The goal is to create a shared understanding of the appropriate roles of those who have a stake in the processes and products of science and technology, scientists as well as educators and the general public. It is estimated that a shared understanding and mutual trust will lead to safe and effective systems, processes and products of innovation (Sutcliffe, 2011).

Especially the Biosciences have the responsibility to form links to the society. STARBIOS2 aims to cope with this risk of the loose connection of research and society, by promoting the increasing alignment of European research with the needs and values of society (Colizzi at al, 2019).

Science education has an important role to educate the future scientists. What scientists do, how they work, innovate and make decisions are important subjects for contemporary science education. While science and technology develop, science education needs to renew itself and work along with the developments in science and technology. New educational models should trigger an inspiring and fruitful structural transformation regarding RRI issues. RRI in science education requires that students have creative thinking and problem solving skills. RRI deals with dilemmas and uncertain situations where students' arguments are as much important as the scientific facts. Therefore integrating RRI in science education requires a change in teaching methods and strategies in the higher education sector.

This paper demonstrates a possible way of supporting and steering of a structural transforming process in the Faculty Biology and Chemistry. Science educators play an important role in this process by supporting communication and negotiation between different stakeholders as well as offering didactical models and materials for the implementation of RRI issues. Educational building blocks, reflective activities, RRI modules, and curricula enrichment for bachelor´s, master´s and doctoral programmes have been reflected and further developed. A on-line RRI toolbox tailored for Faculty´s needs has been set up. Based on formative evaluation of RRI activities, a broad literature analysis, interviews and a faculty-wide questionnaire survey the Booklet of Recommendations "Towards a Sustainable and Open Science – Enhancing Responsible Research and Innovation in the Biosciences at the University of Bremen" (Elster, Barendziak, & Birkholz, 2019b). It will now be discussed and negotiated. Together with the on-line RRI toolbox it will form the sustainable outcome of the four-year-long process of RRI structural transformation and development of a RRI mission statement tailored to the Faculty Biology and Chemistry.

ACKNOWLEDGEMENT

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 709517.

REFERENCES

Birkholz, J. (2019). *Untersuchungen zur Wirksamkeit von Gruppenreflexionen auf das Wissenschaftsverständnis im Schülerlabor Backstage Science*. Dissertation. Bremen, Universität Bremen.

Bromme, R. (2000). Beyond one´s own perspective. The psychology of cognitive interdisciplinarity. In P. Weingart & N. Stehr (Eds.), *Practising interdisciplinarity* (pp. 115-133). Toronto: Toronto University Press

Capps, D. K., & Crawford, B. A. (2013). Inquiry-Based Instruction and Teaching About Nature of Science: Are They Happening? *Journal of Science Teacher Education*, 24, 497-526.

Clark, H. (1996). *Using Language.* Cambridge: Cambridge University Press

Colizzi, V., Mezzana D., Ovseiko, P.V., Caiati, G., Colonnello, C., Declich, A., Buchan, A.M., Edmunds, L, Buzan, E., Zerbini, L., Djilianov, D., Kalpazidou Schmidt, E., Bielawski, K.P., Elster, D., Salvato, M,, Alcantara, L.C.J., Minutolo, A., Potestà, M., Bachiddu, E., Milano, M.J., Henderson, L.R., Kiparoglou, V., Friesen, P., Sheehan, M., Moyankova, D., Rusanov, K., Wium, M., Raszczyk, I., Konieczny, I., Gwizdala, J.P., Śledzik, K., Barendziak, T., Birkholz, J., Müller, N., Warrelmann, J., Meyer, U., Filser, J., Khouri Barreto, F., Montesano, C. (2019). Structural Transformation to Attain Responsible BIOSciences (STARBIOS2): Protocol for a Horizon 2020 Funded European Multicenter Project to Promote Responsible Research and Innovation. *JMIR Res Protoc0l 8*(3):e11745 https://www.researchprotocols.org/2019/3/e11745/ (assessed January 19th, 2020)

Declich, A., & Starbios2 Project Partners (2019). Guidelines on RRI implementation in biosciences organisations. https://starbios2.eu/2019/starbios2-guidelines-on-rri-implementation-in-bioscience-organisations/ (assessed January 19, 2020)

Holzer, J., & Elster, D. (2019). Wake up. Predictors of stem cell donation for leukemia patients. In: *E-Proceedings of ESERA 2019 conference*, 26-30 August 2019, Bologna, University Bologna, forthcoming.

Elster, D. (2016). *Deliverable 5.1 First Interim Report*, University of Bremen, Bremen.

Elster, D., Barendziak, T., Birkholz, J. (2016). Science Education as a Trigger to Attain Responsible Research and Innovation. In Pixel: *New Perspectives in Science Education*, Conference Proceedings 2017, Florence/Libreria Universitaria Edizioni.

Elster, D., Barendziak, T., Birkholz, J. (2019a). *Towards a sustainable and open science. Enhancing responsible research and innovation in the biosciences at the University of Bremen.* Bremen: University of Bremen.

Elster, D., Barendziak, T., Birkholz, J. (2019b). Science Education as a trigger for RRI structural change. In: A. Declich and Starbios2 Project Partners (Eds.) Guidelines on RRI implementation in biosciences organisations (pp. 87-92). https://starbios2.eu/2019/starbios2-guidelines-on-rri-implementation-in-bioscience-organisations/ (assessed January 19, 2020)

Eschweiler, M., & Elster, D. (2018). Development of an analysis tool to promote the communication of knowledge about nanotechnology. In: In: Pixel (Ed.) *New Perspectives in Science Education,* Conference Proceedings 2017, Florence, Liberia Universitaria, 649-652.

France, B., & Gilbert, J. K. (2006). *A model of communication about biotechnology*. Rotterdam: Sense Publishers in cooperation with The New Zealand Biotechnology Learning Hub.

Griffiths, R. (2004). Knowledge production and the research- teaching nexus: The case of the built environment disciplines. *Studies in Higher Education* 29, no. 6: 709– 26.

Healey, M. (2005). Linking research and teaching: Exploring disciplinary spaces and the role of inquiry-based learning. In *Reshaping the University: New Relationships Between Research, Scholarship and Teaching*, edited by R. Barnett, 67– 78. Maiden head, UK: McGraw- Hill/Open University Press.

Jenkins, A. (2004). *A Guide to the Research Evidence on Teaching- Research Relations*. York, UK: The Higher Education Academy. Available online: https:// www.heacademy.ac.uk/system/ files/ id383_ guide_ to_ research_ evidence_ on_ teaching_ research_ relations.pdf. Accessed 20 June 2019.

Lederman, N. G., Antink, A., & Bartos, S. (2014). Nature of science, scientific inquiry, and socio-scientific issues arising from genetics: A pathway to developing a scientifically literate citizenry. *Science & Education*, *23*(2), 285-302.

Müller, N., & Elster, D. (2018). Promoting teacher students´ system competence by the development of a system approach in an interdisciplinary seminar. In: Pixel (Ed.) *New Perspectives in Science Education,* Conference Proceedings 2018, Florenz, 284-289.

Sadler, T. D. (2011). *Socio-scientific issues in the classroom.* Heidelberg: Springer

Starbios2 Consortium (2016). *Leaflet*, Paris: Sparks & Co.

Sutcliffe, H. (2011). *A report on Responsible Research and Innovation for the European Commission.* Retrieved from http://ec.europa.eu/research/science-society/document_library/pdf_06/rri-report-hilary-sutcliffe_en.pdf (2019-01-05)

Von Schomberg, V. & Von Schomberg, R. (2013). A Vision of Responsible Research and Innovation. In R. Owen, M. Heintz, & J. Bessant (Eds.), *Responsible Innovation* (pp. 51-74). London: John Wiley & Sons, Ltd.

TECHNOLOGY-ENHANCED LEARNING SUPPORTING ENGAGEMENT, ASSESSMENT, AND REFLECTION IN HIGHER EDUCATION SCIENCE

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In this paper, the results of a study conducted in higher education science across three groups of early-career scientists in the same university—undergraduate students, masters students, and doctoral students—will be presented. All three groups were taking similar versions of a Science & Society module that focused on the roles and responsibilities of scientists. The students from these groups provided short continuous feedback before, during, and after each lecture in the module, and focus groups were conducted with the students at the end of each module. The main factors being considered were the benefits and challenges of technology-enhanced learning in regards to student engagement, assessment, and reflection. This work highlighted that while the benefits are numerous, the challenges can often vary depending on the students' current level of higher education science.

Keywords: Higher Education, Technology, Reflection.

INTRODUCTION

In this study, technology-enhanced learning was compared across three different stages of higher education science: undergraduate, masters, and doctoral level. There have long been concerns about the standard of teaching in higher education science (Sunal et al., 2001). One of the ways to address such concerns and raise these standards is to integrate technology into the learning experience with the view of supporting student creativity, innovation, engagement, assessment, and reflection (Johnson & Carruthers, 2006).

The guiding research question was:

"What are the benefits and challenges of technology-enhanced learning in higher education science?"

This was tackled by breaking down the work into two sub-questions:

1. "How do these benefits and challenges relate to engagement, assessment, and reflection?"

2. "How do they compare between students in undergraduate, masters, and doctoral level courses?"

Technology was used to support engagement in this study through the use of audience response systems and virtual learning environments. In higher education there has been growing emphasis on finding ways for students to engage in lectures using their own smart devices, such as tablets or smartphones (Stowell, 2015). This follows the gradual move away from outdated radio frequency transmitters ('clickers') towards software solutions that rely on smart devices (Kay & LeSage, 2009; Koppen & Langie, 2013). For this study, engagement was facilitated and evaluated across three levels of higher education science using contemporary audience response systems.

Both self-assessment and peer-assessment were supported through the Blackboard Learn virtual learning environment (Heaton-Shrestha, et. al., 2007). Students uploaded their assignments and then anonymously reviewed and graded their classmates' work. Technology can speed up the assessment process, which aligns with the recommendations of Brookfield (2015) who noted that when it comes to providing student feedback: "immediacy is valued by students and demonstrates your responsibleness, an important element of authenticity" (p. 192). While reflection is often used as a means of practice-based professional learning (Thompson, 2000), this process of self-assessing personal development can offer early-career scientists a way to better understand their own learning.

METHOD

This work began by carrying out literature reviews of the three chosen areas of technology-enhanced learning: engagement, assessment, and reflection. Student feedback from the undergraduate, masters, and doctoral level students was recorded using reflection questions before and after each lecture on a Science & Society module.

Before each lecture the students were asked to record their initial understanding of the concepts that were going to be covered in class. After the lecture, the students were asked to reflect on their understanding of the concept, if it had changed, as well as any aspects of the lecture that were significant to them.

One of the goals of the module was to help early-career scientists to "take responsibility for their own learning" (Hall, 1996, p. 112). The module was underpinned by a general framework of social constructivism (Hodson & Hodson, 1998), but with a focus on how values, perceptions of socioscientific issues, and ethics all play a role in creating a mutual understanding of the world around us (Arghode, Yalvac, & Liew, 2013).

The students engaged in the lectures using software called "Poll Everywhere" — an audience response system that facilitates democratic decision-making in audiences (Shon & Smith, 2011; Kappers & Cutler, 2015). The students were asked to anonymously and independently provide feedback on their learning following the recommendations of Hughes, Kooy, and Kanevsky (1997) and answered questions using their own smart devices (spare iPads were provided to students without access to a smart device of their own). This use of audience response systems is common for large-scale events such as public lectures and festivals (Roche, Cullen, & Ball, 2016; Roche, Stanley, & Davis, 2016).

Reflective practice was integrated into the module in terms of teaching (Brookfield, 1995) and the students' reflective writing assignments (Bolton, 2010). At each level (undergraduate, masters, doctoral) a representative subset of the students took part in a focus group to provide feedback on their experience of the technology-enhanced aspects of the module. The focus groups followed the protocol described in Roche et al., (2017).

DISCUSSION AND CONCLUSIONS

As was expected, when addressing the research questions, technology-enhanced learning in higher education science posed both benefits and challenges (Table 1). Engagement through mobile technology was found to be a beneficial method of facilitating safe, anonymous, whole-class discussions in real-time. This was especially useful in large classes, and was found to be especially meaningful for participants who did not feel confident speaking out in a lecture. Such students found seeing their contributions appear anonymously on the lecture screen empowering.

For some masters students, and a larger group of doctoral students, there was a feeling that digital engagement deprived them of the opportunity to actively engage in lectures. This could be due to the smaller class sizes at masters and doctoral level, growing confidence to engage at those levels, or an average age difference compared to the undergraduate students. All of these factors are worthy of further consideration and follow-up research.

As has been found elsewhere, self and peer-assessment worked best when the students and staff jointly determined the criteria and marking rubrics (Dochy, Segers, & Sluijsmans, 1999). This is particularly relevant as many universities move more towards e-learning, distance learning, blended learning, and flipped classroom approaches. It is becoming increasingly important to understand the strengths and weaknesses of these approaches for student learning at different stages of higher education science.

Using technology to support reflection was found to equip students with valuable tools to observe, gather information, analyse, and draw conclusions on their own learning and development. Given the challenges that early-career scientists are facing (Powell, 2016; Roche & Davis, 2017) such skills are more pertinent than ever. The students responded best to having a clear model to follow.

One of the biggest challenges to emerge was balancing the burden on students to be continuously providing feedback, which was reported as more of an issue for the masters and doctoral students. The students discussed this in similar terms to the reflection "burnout" referred to by Anderson (1992, p. 308). While the drawbacks of technology-enhanced learning are smaller than the number of benefits, they could become more pronounced if several types of technology-enhancements are combined. This multiplier effect also requires further investigation. This would help form a framework for technology-enhanced learning that is determined by the needs of the students at different levels of higher education science.

Table 1. Benefits and challenges of technology-enhanced learning in relation to student engagement, assessment, and reflection.

Type of Technology-	Benefits	Challenges

enhanced Learning		
Engagement through mobile technology	Anonymity Facilitates real-time whole class discussions Empowering for less confident students More suitable for large undergraduate classes	Reduces opportunities for oral discussion in small groups (especially for postgraduate students)
Self and peer-assessment	Gives more ownership and agency to students in their assessment Reduces burden on staff to provide formative feedback	Critiquing a classmate's work can be an uncomfortable experience for some students
Reflection	Facilitates faster personal insights for students on their learning Develops critical thinking skills	Risk of reflection burnout

REFERENCES

Anderson, J. (1992). Journal writing: The promise and the reality. *Journal of Reading*, *36*(4), 304-309.

Arghode, V., Yalvac, B., & Liew, J. (2013). Teacher empathy and science education: A collective case study. *Eurasia Journal of Mathematics, Science & Technology Education*, *9*(2), 89-99.

Bolton, G. (2010). *Reflective practice: Writing and professional development*. London: Sage Publications Ltd.

Brookfield, S. (1995). *Becoming a Critically Reflective Teacher*. San-Francisco: Jossey-Bass.

Brookfield, S. D. (2015). *The skillful teacher: On technique, trust, and responsiveness in the classroom*. San Francisco: John Wiley & Sons.

Dochy, F. J. R. C., Segers, M., & Sluijsmans, D. (1999). The use of self-, peer and co-assessment in higher education: A review. *Studies in Higher education*, *24*(3), 331-350.

Heaton-Shrestha, C., Gipps, C., Edirisingha, P., & Linsey, T. (2007). Learning and e-learning in HE: The relationship between student learning style and VLE use. *Research Papers in Education*, *22*(4), 443-464.

Hall, C. (1996). Key teaching roles of a university lecturer and their integration into the quality systems of a New Zealand university. *Assessment & Evaluation in Higher Education*, *21*(2), 109-120.

Hodson, D., & Hodson, J. (1998). From constructivism to social constructivism: A Vygotskian perspective on teaching and learning science. *School Science Review*, *79*(289), 33-41.

Hughes, H. W., Kooy, M., & Kanevsky, L. (1997). Dialogic reflection and journaling. *The Clearing House: A Journal of Educational Strategies*, *Issues and Ideas*, *70*(4), 187-190.

Johnson, H., & Carruthers, L. (2006). Supporting creative and reflective processes. International Journal of *Human-Computer Studies, 64*(10), 998-1030.

Kappers, W. M., & Cutler, S. L. (2015). Poll Everywhere! Even in the Classroom: An Investigation into the Impact of Using Poll Everywhere in a Large-Lecture Classroom. *Computers in Education Journal*, *6*(20), 140-145.

Kay, R. H., & LeSage, A. (2009). Examining the benefits and challenges of using audience response systems: A review of the literature. *Computers & Education*, *53*(3), 819-827.

Koppen, E., & Langie, G. (2013). Replacement of a clicker system by a mobile device audience response system. In *Proceedings of the 41st SEFI annual conference: Engineering Education Fast Forward* (pp. 1-8). Leuven, Belgium.

Powell, K. (2016). Young, talented and fed-up: scientists tell their stories. *Nature News*, *538*(7626), 446.

Roche, J., Cullen, R. J., & Ball, S. L. (2016). The Educational Opportunity of a Modern Science Show. *International Journal of Science in Society*, *8*(3), 21-30.

Roche, J., & Davis, N. (2017). Should the science communication community play a role in political activism?. *Journal of Science Communication*, *16*(1), 1-4.

Roche, J., Davis, N., O'Boyle, S., Courtney, C., & O'Farrelly, C. (2017). Public perceptions of European research: an evaluation of European Researchers' Night in Ireland. I*nternational Journal of Science Education*, *Part B*, *7*(4), 374-391.

Roche, J., Stanley, J., & Davis, N. (2016). Engagement with physics across diverse festival audiences. *Physics Education*, *51*(4), 1-6.

Shon, H., & Smith, L. (2011). A review of Poll Everywhere audience response system. *Journal of Technology in Human Services*, *29*(3), 236-245.

Stowell, J. R. (2015). Use of clickers vs. mobile devices for classroom polling. *Computers & Education*, *82*, 329-334.

Sunal, D. W., Hodges, J., Sunal, C. S., Whitaker, K. W., Freeman, L. M., Edwards, L., Johnston, R. A., & Odell, M. (2001). Teaching science in higher education: Faculty professional development and barriers to change. *School Science and Mathematics*, *101*(5), 246-257.

Thompson, N. (2000). *Theory and practice in the human services*. Buckingham: Open University Press.

SCAFFOLDING RESEARCH-LIKE LABORATORY PROJECTS FOR FIRST-YEAR STUDENTS

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Research-based teaching is the cornerstone of university teaching. A central part of research-based teaching relates to students' work in inquiry-based projects where they make sense of and use research literature. Collaborative work with research methods and literature in the laboratory might be a key to develop students' sense of belonging to a specific academic field within the STEM disciplines. During the first years of studies, such teaching is however often challenged since novice students do not yet have the qualifications to work with an authentic research project. The present paper discusses findings from two first year courses in the study programs of chemistry and biotechnology, respectively. In both courses, students work with authentic research in the form of research papers and laboratory work with research-like activities. A comparison of the design of the two courses shows differences, e.g. in the extent of student autonomy, collaboration, feedback and peer-feedback. Students' learning experience, perceived learning outcomes and sense of belonging at the department were investigated with repeated questionnaires with open reflections and likert-scale questions. Based on these data possibilities and challenges related to designing research-like learning experiences for first-year students are discussed.

Keywords: Laboratory work in science, higher education, learning communities

INTRODUCTION

First-year university students' retention to the university and to the field of science and technology studies in particular is frequently discussed. Tinto (2017) suggests a focus on how to support students' persistence emphasizing a student perspective instead of an institutional perspective ('retention'). Understanding students' persistence can be approached by theories about intrinsic motivation referring to their experience of competence, autonomy and also relatedness (Ryan & Deci, 2017). 'Sense of belonging' referred to by Tinto (2017) as determinant for persistence is a complex construct with some similarity to 'relatedness'. It is dependent both on efficacy beliefs before entering the university and on students experience of being invited into a community of practice with peers and academics. Hence, there are reasons to believe, that being invited into collaboration about research, which can be seen as the core of the subject and its methods, might affect student persistence.

The present study involving cases from laboratory-intensive studies at the faculty of Science & Technology (ST) was inspired by the model of research-based education from Healey (2005) (figure 1) referring to both students' active involvement in research-processes and their work with research as content. Healey and Jenkins (2018) suggest that university students can be involved in research-like activities from an early stage in their studies: "..*given suitable support and encouragement many more students – and at an earlier stage in their courses – can be* *engaged in discovery activities than many staff initially think is possible ..*" (Healey & Jenkins 2018:54).

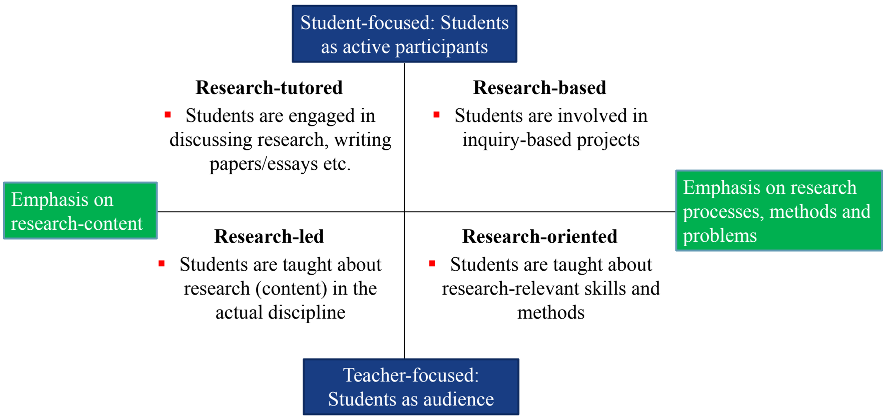

Figure 1. Research-based education (after Healy, 2005)

Healey and Jenkins (2018) discuss how to define 'undergraduate research' referring to this definition: "*..an inquiry or investigation conducted by an undergraduate student that makes an original intellectual or creative contribution to the discipline*" (Healey & Jenkins, 2018: 54). They suggest a broad understanding of the term "original contribution" and emphasize that you can speak about students' learning through research and inquiry even if the knowledge produced during the learning process is not necessarily new for the research society. This links to research in science education in particular about inquiry-based approaches such as IBSE (Inquiry based Science Education) and 5E (Engage, Explore, Explain, Elaborate, Evaluate). From technology education the so-called FITS model illustrates learning through design (Breukelen, Michels, Schure & de Vries, 2016) in iterative phases. The latter model inspired the phases used to represent the design of the two courses studied in here, namely 1) Preparation, 2) Experimental design, 3) Investigation, and 4) Report. Intentionally, these stages reflect the stages in an authentic research project.

In higher education the potential of transforming the traditional 'cookbook like laboratories' towards more inquiry-based approaches have been discussed in decades of research (Hofstein & Kind, 2012; Reid & Shah, 2007). Our previous work has evidenced how students' learning outcomes from laboratory teaching can be enhanced even with 'smaller' redesigns involving elements of 'guided inquiry' (Nielsen & Hougaard, 2018). This involves designing for learning both before, during and after a laboratory class, e.g. using pre-lab activities to make students engage with the content and methods, and scaffolding dialogue and critical reflection on data and methods during the activities in the laboratory (Nielsen & Hougaard, 2018).

In general academics believe strongly in the importance of research-based teaching with a direct link between research and teaching, but the term is not always used unambiguously (Robertson, 2007; Visser-Wijnveen et al., 2010). It can be used about transmission of research results to students, considering how the research performed at the local institution is integrated in the teaching or, alternatively, about challenging how students understand knowledge, knowledge-creation and research. However, there is no simple relationship between research productivity and teaching effectiveness of schools (Hattie & March, 1996; Brew 2001). How to frame students' work with research-based content and methods is basically a pedagogical question about: "*..attention to the design of the curriculum and how students learn*" (Healey & Jenkins, 2018).

At the faculty of Science & Technology at our university there is increasing emphasis on making students engage with research at early stages of the study programs. This has led to the development of several courses where first-year students work with primary research literature and laboratory work referring to this. The research presented here, refers to two specific courses "Introduction to Chemistry research" (ICR) and "Biotechnological project" (BTP). It is the purpose of both courses to give students an experience of working with research, but the designs of the courses are markedly different, as will be described below. In both courses, it was a challenge is to engage first-year students with complex research literature and research-like methods. The dilemma is that although it is difficult for the students, there are reasons to believe that a key to stimulating their persistence and sense of belonging at the university is indeed to scaffold them in collaborative work with research-like methods and content from cutting-edge research (Reid & Shah, 2007). This leads on to the following research questions.

Research questions

- How are the courses "Biotechnological project" (BTP) and "Introduction to Chemistry research" (ICR) designed and which activities do the students engaged in, during the phases of, 1) Preparation, 2) Experimental design, 3) Investigation, and 4) Report?
- What do the students emphasize as learning outcomes, possibilities and challenges after participating in one of the two courses?
- What characterizes the students' sense of belonging at the university in the beginning and after their second semester of study (including the BTP or ICR courses)?
- In which ways do the two courses contribute with a research-like experience for the students?

METHODS

The project operates implicitly with a design based research approach (Barab & Squire, 2004). The authors have been involved in suggesting minor elements in the course designs represented below in relation to the first research question. The findings from the present study are presented for the teachers to inform future redesign. The questions about perceived outcomes etc. were examined using a pre and post questionnaire with both likert-scale questions and essay questions for open reflections. The pre-questionnaire contained questions about the students' experiences from the first semester including questions about perceived outcomes from various teaching formats, their experience of mastering, and their expectations for the specific courses. Furthermore, there were items about sense of belonging (adapted from Trujillo & Tanner, 2014). These items were repeated in the post-questionnaire which also included questions about perceived outcomes, challenges as experienced by the students and experiences from working with cutting-edge research. Data analysis included frequency analyses and cross tabulations. Essay answers were analyzed using thematic analysis (Braun & Clarke, 2006). The pre-questionnaire was distributed to all students at a teaching session in the two courses in February 2019, with responses from 35 students from BTP and 34 from ICR.

Post-questionnaire was distributed (electronically) in May/June 2019 after the end of the course, and answered by 20 students from BTP and 26 from ICR (58% and 76%, respectively). A non-response analysis showed no systematic differences in answers in pre-questionnaire comparing respondents and missing answers from post-questionnaire.

RESULTS

In the following, the design of the two courses are illustrated (figure 2), and the perceived outcomes, challenges and possibilities are reported for the two cases one by one. Finally, the answers to the last two research questions are presented as a comparative analysis.

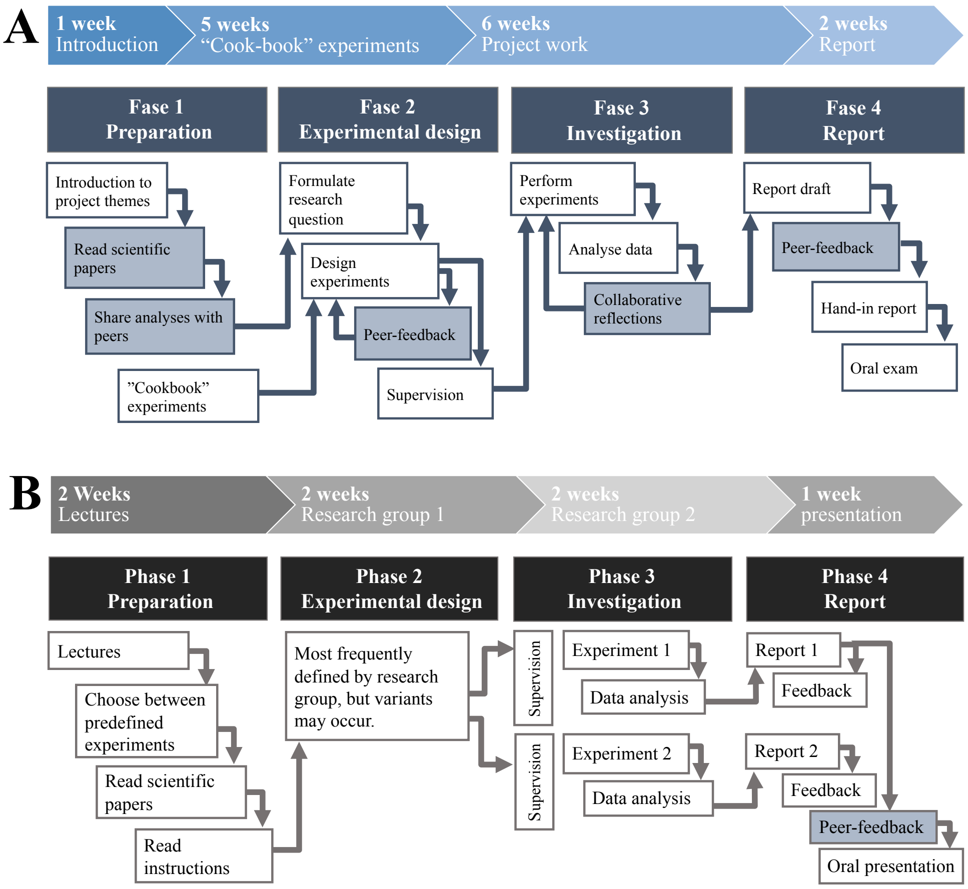

Figure 2. A schematic representation of students' tasks during the four phases of the redesigned courses: A) BTP B) ICR. Both courses account for 1/6 of the workload of the respective semester. Light blue boxes represent collaborative activities.

Design of the two courses

The BTP course (figure 2A) is offered at the second semester of the Biotechnology Engineering program. During a Preparation phase (phase 1) students attend introductory lectures and highly guided cookbook labs. In addition, they choose between different topic for their project and read one or a few research papers related to the topic. The topics ("Biosynthesis af Indigo",

”A cure for Phenylketonuria”, or”Development of antibiotic peptide”) are determined by the course lecturer. Common to all projects is that the students must clone and express a gene. During the Experimental Design phase (Phase 2) the students work in groups and autonomously decide which experiments to perform, and they make a project plan. After peer and teacher feedback, students adjust their plans and perform the planned experiments under guidance by teaching staff during the Investigation phase (Phase 3). At the end of the semester, in the Report phase (Phase 4), students hand-in a draft report for peer-feedback and subsequently a final report for assessment at the final exam. During all four phases of this design, emphasis has been put on scaffolding students´ inquiry and collaboration, e.g. via peer-feedback activities. Particular effort is put into the experimental design phase, where students work on designing the experimental setup.

The ICR course is offered at the second semester of the bachelor program in chemistry. The main intention with the course, as expressed by the course teacher is, that students gain experience with cutting-edge research in an authentic research laboratory and engage in collaboration with staff. The course is organized with a preparation phase (Phase 1) with a series of invited lectures about cutting-edge research at the department. The course coordinator assigns two experiments, offered by different research groups to groups of 2-4 students. The two student groups followed in this study performed the experiment ”Growing one-crystal topological insulators” or “Investigating protein structures at a biomaterial surface with femtosecond laser light”, respectively. In most cases, the experiment is predetermined by the research group and described in a cookbook-like manual. The students do not necessarily engage in any activities related to experimental design (Fase 2). During the investigation phase (Phase 3), the students work on two consecutive, but typically unrelated experiments, in two different research groups. Each experiment is reported in a lab report during the report phase (Phase 4). A collaborative task was designed for this phase, where students provide peer-feedback on a draft version on the oral presentation before a final presentation was assessed by the teacher.

Perceived outcomes, challenges and possibilities: BTP

In the post questionnaire 85% of the students reported a high or very high learning outcome from the BTP course as represented in figure 3. In both pre and post questionnaires, students were asked about their perceived learning outcomes from a broad range of teaching formats not restricted to this specific course. It can be seen in the representation in figure 3 that the majority (78 %) of students value the learning outcome from project work high or very high before the project work. In the post-questionnaire at the end of the second semester this number increases to 97 % (compare light blue columns with the dark blue).

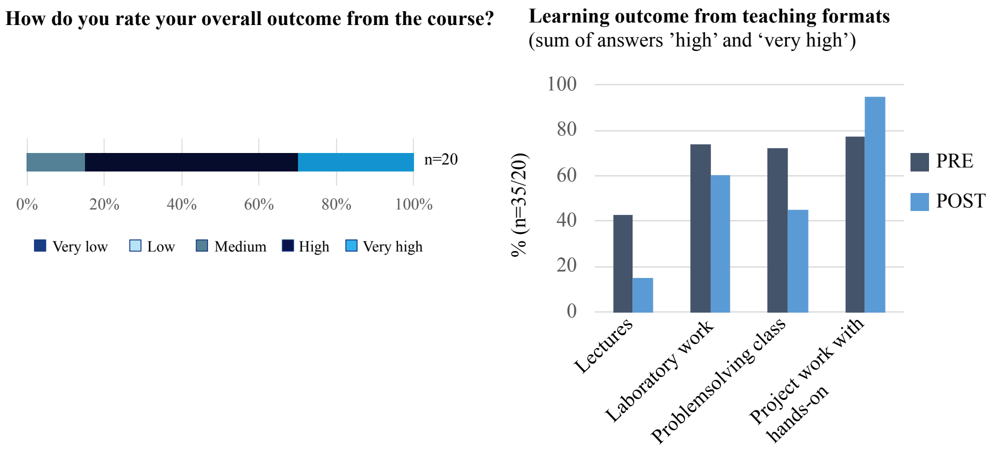

Figure 3. Learning outcomes from BTP (left) and learning outcomes from various teaching formats as expressed in the questionnaires before (pre) and after (post) project work (right).

In their reflections many of the students referred to the experience of autonomy in relation to their own project, and the influence on learning and motivation. They referred e.g. to being ”the master” of their project. Furthermore, there are indications that the students engaged in authentic inquiry process, but also that the guiding and scaffolding of both the experimental and writing tasks in Phases 1 and 2 were a good learning support.

- *"It has been really good to be in charge of the project ourselves and to have the freedom to investigate exactly what we find interesting"*
- *"The degree of autonomy made you think more about what we did and why we did it. You inquired into things in an entirely different way than you would usually do".*
- *"..that we had small assignments during the course (e.g. writing and giving feedback to peers on introduction and draft report). In this way you learned efficiently what you had to do, and what could be improved".*
- *".. in the beginning we had a manual, later on we had to design experiments with guidance from the teacher. I think this was really good and I learned a lot from having to figure out how things could be investigated in the lab"*

Challenges were identified, particularly relating to the use of research literature. The scaffolding of reading tasks was apparently not sufficient, and the perceived mastery of the theory low:

- *"There has not really been any theoretical "teaching". Therefore, theory has not been so in-depth and it is hard to answer questions regarding this in the exam".*

Perceived outcomes, challenges and possibilities: ICR

The majority (60%) of students attending the ICR course perceived their learning outcome as high or very high as evident from the representation in figure 4, left. In the open reflections the students particularly emphasized a perceived outcome relating to the experience of being in an authentic research laboratory and working in a research group (figure 4, right).

- *"The theory behind the project was nice to learn. It was a lot of fun to be part of a research group and learn how their daily routine works".*

- *"It has been exciting to see two different ways of working with chemistry..... And I have noticed how our auxiliary courses are more relevant than I thought"*

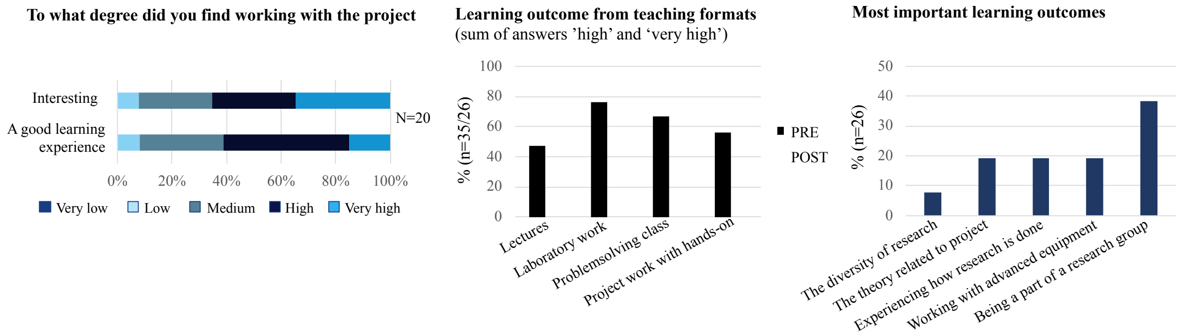

Figure 4. Learning outcomes from ICR (left) and learning outcomes from various teaching formats as expressed in the questionnaires before (pre) and after (post) project work (middle). Learning outcomes expressed in students' open reflections in the post-questionnaire where categorized and represented (right).

The challenges reported by the students mainly related to understanding the theory:

- *"It was difficult to understand the theory behind the experiments and do the data analysis because we do not understand what we are actually doing".*

It is interesting that these students apparently perceived the learning outcome from project work with hands-on lower than students from BTP before the project work. Additionally, in this course fewer students reported a high or very high outcome from project work in the post-questionnaire (grey) compared to the pre-course questionnaire (black).

The experience of mastering: Comparing before and after and across courses

The pre-questionnaires included questions asking students to what degree they expected to be able to perform specific tasks related to the project work, and the post-questionnaire correspondingly to what degree they experienced to be able to perform the tasks (figure 5).

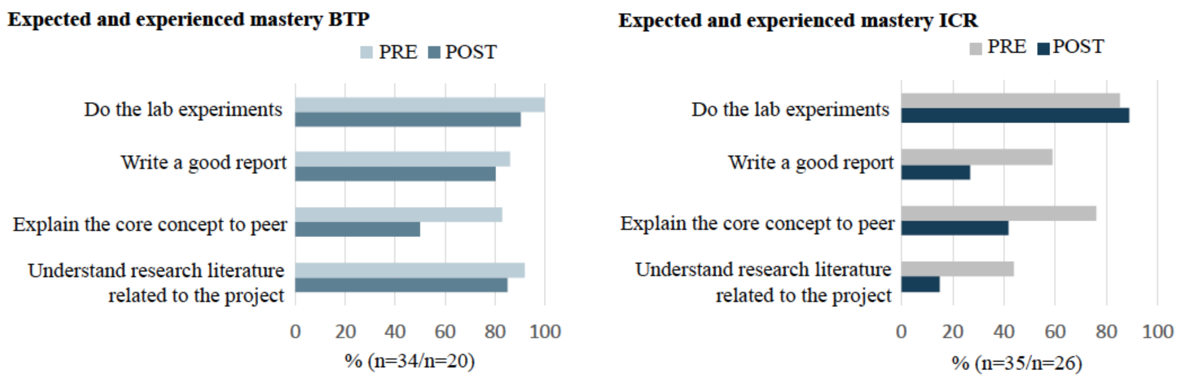

Figure 5. The expected and experienced mastery as reported before (pre) and after (post) project work in the BTP (left) and ICR (right). The figures represent the sum of the answers 'Agree' and 'Highly agree".

For BTP prior to the project work more than 80 % of the students stated that they agreed or highly agreed that they expected to be able to do the lab experiments, write a good report, explain core concepts, and understand research literature. After the course, 50% of the students agreed or highly agreed that they were able to explain core concepts, while 80% or more answered within these likert-categories for the remaining tasks. For ICR, the students' expected mastery before the project work was high relating to the experimental work and to explaining concepts (84 % and 76% respectively), whereas the numbers were lower (59 % and 44%) relating to writing a good report and understanding research literature. Interestingly, in this course the experienced mastery remained comparable to the expected only relating to performing the experimental work whereas the numbers for other tasks were halved.

A slight decrease in experienced mastery could be expected, as a decrease in student self-efficacy is typically during the first year of a university study (Tinto, 2017), but the difference between the two courses is remarkable. It is also noteworthy that although the experienced mastery in ICR is lower than the expected, the students rate their perceived outcome high (figure 4, left). The data presented in figure 5 emphasizes the finding above that in these courses it is a major challenge for students to read and understand research content and literature.

Sense of belonging: Comparing before and after and across courses

The students were asked about their feeling of belonging in their study program in pre- and post-questionnaires and the answers are represented in figure 6. One question addressed whether the students feel they have chosen the right study program (figure 6, upper part). For BTP a slightly higher percentage of students answered "agree" or "highly agree" after the course compared to before (90% compared to 72%) whereas for ICR these categories account for 80 % and 84% respectively, reflecting a minor decrease.

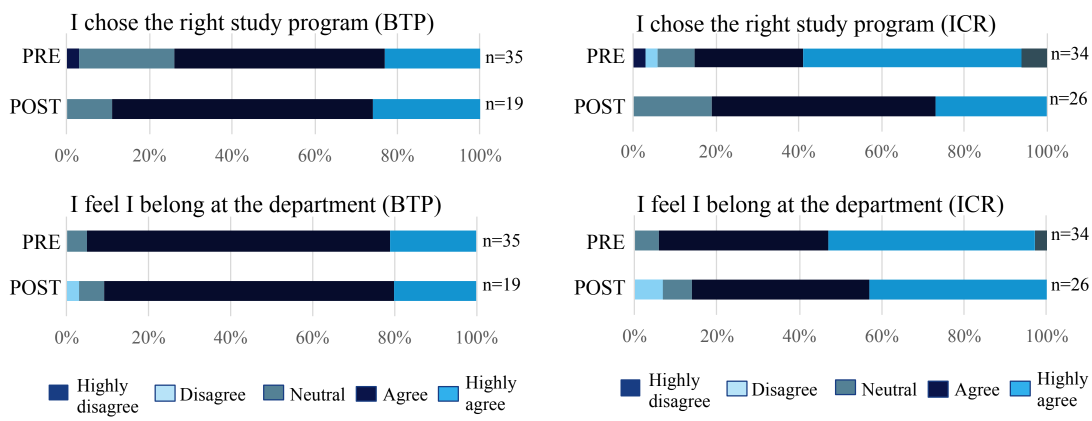

Figure 6. Sense of belonging before (pre) and after (post) project work in BTP (left) and ICR (right)

Another question addressed whether students' feel that they belong at the department (figure 6, lower part). Here 95% of students in BTP agree or highly agree in the post-questionnaire (91% pre). The corresponding numbers for ICR are comparable, namely 90% and 85%, respectively.

DISCUSSION

In the two courses BTP and ICR students have worked with research literature, guided experiments in the lab, data analysis and reports on data. The two courses were designed very differently, with e.g. more scaffolded possibilities for feedback and peer-feedback during BTP than ICR. Previous research has shown that scaffolding of the inquiry-based activities can be crucial (Hofstein & Kind, 2018; Nielsen & Hougaard, 2018), and the scaffolding of the collaborative activities appear to have been supportive according to the students' perceived learning outcomes, in particular at BTP. The students emphasize the progression through the course towards the more open inquiry approach. But students have also experienced some challenges. At both courses the students refer to a lack of support in working with the complex content. The students from ICR in particular emphasize the experience of working in a research group, e.g. working with the advanced equipment, as an important learning outcome. There are also indications of an authentic research experience including a growing understanding that research requires both creativity and persistence and that you do not always get the expected results. The students from ICR have experienced to master the tasks they were given in the laboratory, but they also reflect on how these tasks have been rather elementary, since they experienced that the procedure was predetermine similar to a (invisible) cookbook.

In what ways research-like?

The students' reflections on the two courses can be understood referring to motivation research (Ryan & Deci, 2017). The students from BTP have experienced and valued the autonomy that followed the first phase with guiding in the laboratory. These students have to a relatively high degree experienced to master the tasks associated with the project work, except for challenges in relation to perceived understanding of the theoretical content (including research literature). The students from ICR did not report the same experience of autonomy, but have experienced to master the relatively simple tasks they had in the research lab. In figure 7 the differences between how these two courses provided a research like experience for the students are illustrated with the green and yellow arrows in the model from Healey (2005).

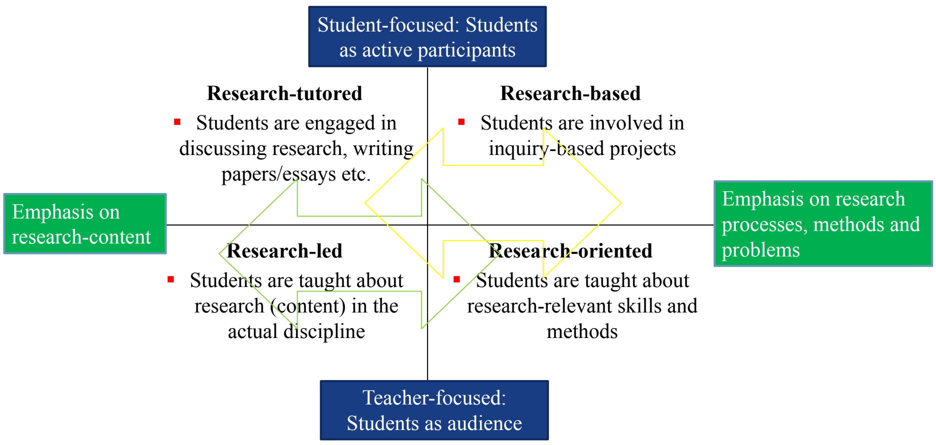

Figure 7. Using the model from Healey (2005), to compare the two courses.

A strength in the design of the BTP is that the students do their own inquiries in the laboratory. The students have to a relatively high degree an experience of mastering the task associated with completing a research-like project in the laboratory, even though they in reality worked in a teaching laboratory. Opposite to this, the students from ICR have been in authentic research laboratories. They value this, but have an experience of being audience to the real research, performing tasks of low complexity in the periphery of the research. They have however been introduced to the actual research in lectures and conversations with researchers and therefore the green arrow is mainly covering the lower field to the right in the model (figure 7).

Looking forward, one recommendation is to address the challenge about the complex theory when redesigning the courses. A first step could be to explicate, via dialogue with the students, that they are not expected to understand all details in the research papers at this stage of their studies. Scaffolding of the students work with research papers could involve pointing out certain elements they have to focus on, and gradually progress to help them learn how to read this genre of literature. This has for example been done with good results in several settings using the so-called C.R.E.A.T.E. approach (Hoskins et al., 2011), which focuses on scaffolding students understanding of the methods and the way data are represented.

REFERENCES

Barab, S. & Squire, K. (2004). Design-based research: Putting a stake in the ground. *The Journal of the Learning Sciences 13*(1), 1-14.

Braun, V. & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology, 3*, 77-101.

Breukelen, D.H.J., Michels, K.J., Schure, F.A. & DeVries M.J. (2016). The FITS model: An improved learning by design approach. *Australasian Journal of Technology Education.*

Brew, A. (2010). Imperatives and challenges in integrating teaching and research. *Higher Education Research & Development, 29*(2), 139-150.

Healey, M. (2005). Linking research and teaching: exploring disciplinary spaces and the role of inquiry-based learning. In R. Barnett (ed), *Reshaping the University: New Relationships between Research, Scholarship and Teaching,* 67-78. McGraw Hill: Open University Press.

Healey, M. & Jenkins, A. (2018). The role of academic developers in embedding high-impact undergraduate research and inquiry in mainstream higher education: twenty years of reflection. *International Journal for Academic Development, 23*(1), 52-64

Hofstein, A., & Kind, P.M. (2012). Learning in and from science laboratories. In B.J Fraser, K.G. Tobin and McRobbie, C.J. (eds). *Second international handbook of science education*, 189 - 207. Dordrecht: Springer.

Hoskins, S.G. et al. (2011). The C.R.E.A.T.E. approach to primary literature shifts undergraduates' self-assessed ability to read and analyze journal articles, attitudes about science and epistemological beliefs. CBE - Life Science Education, 10, 368-378.

Nielsen, B.L. & Hougaard, R.F. (2018). *Scaffolding students' reflective dialogues in the chemistry lab: Challenging the cookbook*. In ESERA 2017 proceedings.

Reid, N., & Shah, I. (2007). The role of laboratory work in university chemistry. *Chemistry Education Research and Practice 8*(2), 172-185.

Ryan, R.M. & Deci, E.L. (2017). *Self-determination theory.* New York: Guilford Publications

Tinto, V. (2017). Reflections on Student Persistence. *Student Success 8*(2), 1-8.

Trujillo, G. & Tanner, K.D. (2014). Considering the role of affect in learning: Monitoring students' self-efficacy, sense of belonging, and science identity. *CBE: Life Science Education 13*, 6-15.

Visser-Wijnveen, G.J. et al. (2010). The ideal research-teaching nexus in the eyes of academics: building profiles. *Higher Education Research & Development 29*(2), 195-210.

DEVELOPMENT AND EVALUATION OF A CHEMISTRY TEST FOR HIGHER EDUCATION

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The persistently high dropout rates in chemistry study programs can be traced back to a number of performance related problems students face during study entry phase (Maaz et al., 2018; Heublein, 2014; Ulriksen, Madsen, & Holmegaard, 2010). In Germany, the dropout rate has been shown to be 45 % for first semester students in chemistry study programs at universities and 34 % for their counterparts at universities of applied sciences (UAS) in 2012/2013 (Heublein & Schmelzer, 2018). Previous research on academic achievement has mainly focused on chemistry study programs at universities. Due to several differences between students from universities and students from UAS (Middendorff et al., 2017), it is difficult to transfer the results to students from UAS.

One research goal of the project CASSIS (Chemistry, Social Sciences and Engineering: Study success and dropout) lies in identifying subject-specific reasons for students' dropout at universities and at UAS referring to Heublein's (2014) model of the dropout process in order to improve study conditions evidence based depending on students' specific characteristics and on specific qualification aims.

Hence, we focus on the individual study process characterized by structural factors, psychological and physical resources, study behaviour, study motivation and performance in the studies. To investigate students' performance, it is necessary to develop and to evaluate content knowledge tests that can be used not only at universities, but also at UAS. This paper describes the construction and evaluation of such a test on content knowledge for the subject chemistry.

Keywords: higher education, evaluation, STEM education

THEORETICAL BACKGROUND

German higher education institutions – comparison between universities and universities of applied sciences

After having completed secondary school, students can obtain the upper secondary degree (*Abitur*) or a restricted upper secondary degree (*Fachhochschulreife*) which are equivalent to ISCED3 and which both give access to tertiary education (van Ackeren, Klemm, & Kühn, 2015). In general, the *Abitur* allows for studies at all universities. The *Fachhochschulreife* allows for studies at universities of applied sciences (UAS) and certain studies at universities. Although these higher education institutions award comparable bachelor or master degrees or rather ISCED6 or ISCED7 (van Ackeren et al., 2015), they are different in a number of ways. For instance, UAS show not only a greater vocationally orientation than traditional universities but they also emphasize the applicability of knowledge (Schindler & Reimer, 2010). Furthermore, students from UAS differ from students from traditional universities (Middendorff et al., 2017). The majority of students from traditional universities (90.5 %) have obtained the *Abitur*, whereas there are only 59.6 % of students from UAS with the same degree. Therefore, there are more students skilled in vocational training on UAS (36 %) compared to traditional universities (14 %) (Maaz et al., 2018).

Research project CASSIS

CASSIS aims at investigating whether the significance of the factors in Heublein's (2014) model (Figure 1) of the dropout process differs between universities and UAS in regard of different study programs. In addition, the interaction between these factors will be investigated in a longitudinal study. This paper focusses solely on chemistry study programs. First year chemistry students from two universities and two UAS are surveyed for three semesters. To investigate their performance in the studies within this period, it is necessary to develop and to evaluate a chemistry content knowledge test, which can be applied at both types of higher education institutions. Furthermore, this chemistry content knowledge test needs to contain a variety of chemistry-specific topics that are taught in the first three semesters. The pilot study includes the development and the evaluation of this test which are central in this article.

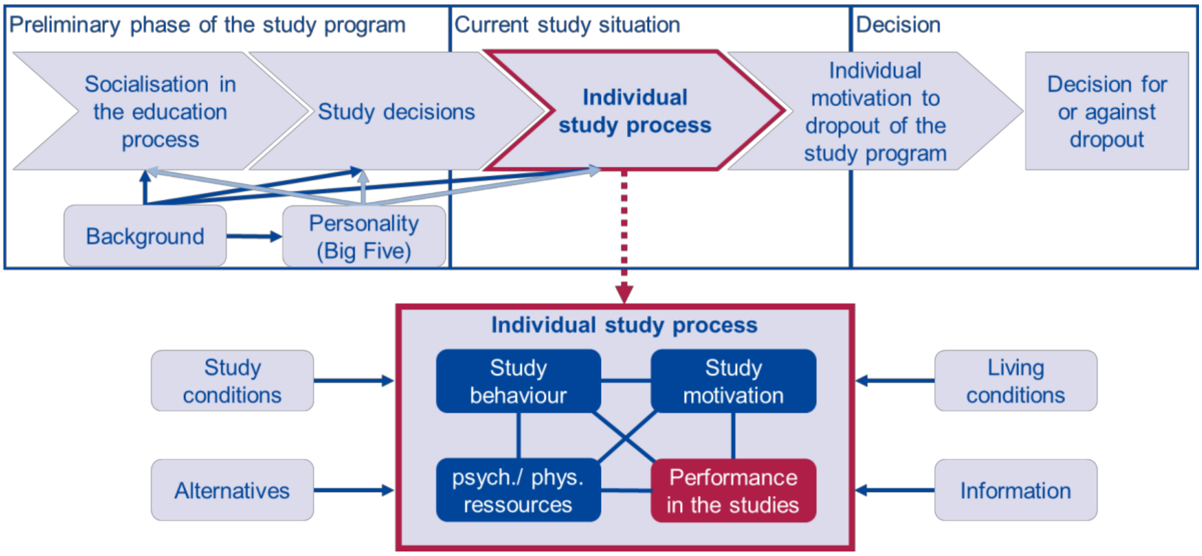

Figure 1 Model of the dropout process based on Heublein (2014).

METHOD AND SAMPLE

It is essential to check the test quality criteria of especially a new test instrument. The validity of a test is of particular importance and can only be given, if the test measures objectively and reliably (Moosbrugger & Kelava, 2012). The new test instrument shall not only measure students' chemistry content knowledge acquired during the first three semesters of their studies but also be suitable for the application at traditional universities and at UAS.

Regarding the content validity, it is first necessary to select relevant topics for the chemistry content knowledge test. In consideration of these topics, suitable items need to be chosen. Therefore, already existing and items can be used or new items can be developed, if it is necessary.

By comparing the curricula of the first, second, and third semester of chemistry study programs from two universities and two UAS, many relevant topics for the chemistry content knowledge test have been identified. All four chemistry study programs comprise courses in *General, Inorganic, Physical, Organic,* and *Analytical Chemistry*. To assess students' performance, overall tests for all courses are necessary. As a first step, the usability of already existing chemistry knowledge tests was checked. In a second step, these tests were modified and amended by additional items. All adapted tests were revised in a pilot study, while already empirically evaluated tests were not included in pilot study or only administered to new target groups.

Freyer, Asikainen, Hirvonen, & Sumfleth (2015) have developed a General Chemistry knowledge test that has been used at different universities including the University of Duisburg-Essen. We evaluated the applicability of the test at two UAS in winter semester 2017/2018 with positive results (Paczulla, Schüßler, Sumfleth, & Walpuski, 2018).

The research group ALSTER developed chemistry content knowledge tests for the disciplines *Inorganic, Physical, Organic,* and *Analytical Chemistry* that refer to the topics of the first two semesters (Averbeck, Hasselbrink, & Sumfleth, 2018; Dickmann, Rumann, & Opfermann, 2017). Within their research projects, these chemistry content knowledge tests were used at two universities. By comparing the topics in these tests with the identified relevant topics from the curricula, many existing items were selected for the new chemistry content knowledge test. Items covering the curriculum of the third semester were added with the support of local teaching staff. The chemistry content knowledge test contains 140 items and is divided into the four disciplines *Inorganic, Physical, Organic* and *Analytical Chemistry* (35 items for each discipline; each discipline contains 5 anchored items). All items are multiple-choice single-select items.

Students from University Duisburg-Essen have already taken chemistry content knowledge tests designed by Averbeck et al. (2018) and Dickmann et al. (2017). Thus, it was not necessary to involve students from this university again. Consequently, the investigation of the adapted test was carried out at one more university (*Uni*) and at two UAS at the beginning of summer semester 2018. Accordingly, students from the second (*2nd Sem*) and the fourth semester (*4th Sem*) participated in the study ($N_{total} = 179$, $n_{Uni} = 48$, $n_{UAS} = 131$; $n_{2nd\ Sem} = 81$, $n_{4th\ Sem} = 98$). Four test booklets were administered in a multi-matrix-design. The test booklets for students from the second and the fourth semester are identical. This makes it possible to examine, whether students from the fourth semester perform better than students from the second semester. Each student had 80 minutes to work on one test booklet.

The data of the chemistry content knowledge test is evaluated by using Winsteps® Rasch Measurement (Version 4.3.4) (Linacre, 2019). In particular with regard to objectivity and reliability of the test, the first step of the analysis focusses on the evaluation of the entire test regarding the Rasch model. By conducting a principal component analysis (PCAR), multidimensionality of the test was investigated.

RESULTS AND DISCUSSION

Due to low values for the item discrimination ($r < 0.2229$), five items were excluded from further data analysis. As shown in Table 1, there are good reliabilities for the whole sample and for the whole test. Furthermore, the person reliabilities for each higher education institution are good, whereas the item reliability for the single university is slightly below the desired value of .90 due to the small sample size (Linacre, 2018). As a result, person abilities can sufficiently be determined. Moreover, the item fit values show a satisfactory range ($0.75 \leq$ InfitMNSQ ≤ 1.35) providing evidence, that items fit the Rasch models. Regarding the entire sample, the whole test shows an adequate difficulty with the mean of item difficulty ($M_{Item\ difficulty} = 0.00$, SD = 1.06) being approximately equal with the mean of person abilities ($M_{Person\ abilities} = 0.08$, SD = 0.73). Consequently, not only the data fits the Rasch model well, but is also adequate for the focussed sample. Regarding students from UAS, it was possible to compare students' performance in the second and fourth semester. As expected, students from the fourth semester perform better than students from the second semester ($M_{Person\ abilities,\ UAS,\ 2nd\ Sem} = -0.33$, SD = 0.62; $M_{Person\ abilities,\ UAS,\ 4th\ Sem} = 0.27$, SD = 0.65; $t(129) = -5.28$, $p < .001$, $d_{Cohen} = 0.95$). Consequently, it is possible to measure the development of chemistry content knowledge during the study entry phase.

Table 1 Sample, reliabilities and fit-statistics estimated with Winsteps® Rasch Measurement (Version 4.3.4) (Linacre, 2019).

	Person			Item ($N_{Item,\ total}$ = 135)			
	Reliability	Separation	Abilities *M (SD)*	Reliability	Separation	Abilities *M (SD)*	Infit MNSQ (Range, *M*)
Total (N_{Person} = 179)	.86	2.51	0.08 (0.73)	.94	4.02	0.00 (1.06)	0.79 – 1.34 1.01
Uni (N_{Uni} = 48)	.81	2.04	0.54 (0.68)	.83	2.17	0.00 (1.37)	0.75 – 1.34 1.01
UAS (N_{UAS} = 131)	.85	2.35	-0.09 (0.69)	.92	3.29	0.00 (0.06)	0.78 – 1.35 1.01

Since the chemistry content knowledge test contains items from of the four disciplines *Inorganic, Physical, Organic* and *Analytical Chemistry*, multidimensionality of the entire test was investigated by conducting a principal component analysis of residuals. Due to the small sample size in comparison to the great number of items, the interpretation of the results (Table *2*) needs to be treated with caution (Linacre, 2018).

Table 2 Principal component analysis of residuals (PCAR) computed with Winsteps® Rasch Measurement (Version 4.3.4) (Linacre, 2019).

		Eigen-value	Observed percent-age of total variance	Observed percent-age of unexplained variance	Expected percentage of total variance
Total raw variance in observations		177.32	100.0 %		100.0 %
Raw variance explained by …	measures	42.32	23.9 %		23.5 %
	persons	16.45	9.3 %		9.2 %
	items	25.867	14.6 %		14.4 %
Raw unexplained variance (total)		135.00	76.1 %	100.0 %	76.5 %
Unexplained variance in…	1st contrast	4.40	2.5 %	3.3 %	
	2nd contrast	3.89	2.2 %	2.9 %	
	3rd contrast	3.51	2.0 %	2.6 %	
	4th contrast	3.22	1.8 %	2.4 %	
	5th contrast	3.21	1.8 %	2.4 %	

Due to the high number of items, it is possible that a random cluster of items is inter-correlated by accident (Linacre, 2018). Although the results (Table 2) seem to indicate several dimensions because of the great eigenvalues (< 2.0), the variance explained by the several contrasts (1.8 % to 2.5 %) are clearly below the variance explained by the item difficulties (14.6 %). Accordingly, the Rasch item difficulties of the unidimensional data explain more variance than a further dimension. This result suggests that the data structure is unidimensional. Furthermore, the disattenuated correlations between the person measures on the assumed cluster of items and the person measures on the other items (Table 3) indicate that the assumed cluster of items and the other items do not measure different things. Thus, the data structure is unidimensional.

Table 3 Approximate relationships between the person measures computed with Winsteps® Rasch Measurement (Version 4.3.4) (Linacre, 2019).

PCA Contrast	Item clusters	Pearson correlation	Disattenuated correlation	PCA Contrast	Item clusters	Pearson correlation	Disattenuated correlation
1	1 - 3	0.1867	0.4418	4	1 - 3	0.1612	0.2627
	1 - 2	0.7489	0.9593		1 - 2	0.5337	0.8399
	2 - 3	0.3008	0.7351		2 - 3	0.6272	0.8226
2	1 - 3	0.1614	0.2240	5	1 - 3	0.2857	0.4672
	1 - 2	0.6094	0.8126		1 - 2	0.6686	1.0000
	2 - 3	0.5775	0.7752		2 - 3	0.5730	0.7818
3	1 - 3	0.2327	0.3086				
	1 - 2	0.5141	0.7028				
	2 - 3	0.5723	0.7783				

Because of unidimensional data structure, the chemistry content knowledge test with its 135 items measures reliably one single construct. The Rasch models give evidence that it is suitable for estimating chemistry knowledge of students from universities and UAS. Linacre (2018) explains that test can be split into separate test instruments, if further dimensions are important and different enough to merit various measures. At this point, it should be mentioned that each item of the chemistry content knowledge test refers to one of the four disciplines *Inorganic, Physical, Organic* and *Analytical Chemistry*. Consequently and due to the results of the PCAR, it is allowed to divide the entire test into four tests concerning the four disciplines *Inorganic, Physical, Organic* and *Analytical Chemistry*.

For the main study, the tests for the four disciplines Inorganic, Physical, Organic and Analytical Chemistry need to be shortened. The shortened tests shall cover a wide range of topics of the related disciplines. Considering this intention, the item fit statistics and the results from Averbeck et al. (2018) and Dickmann et al. (2017), 20 items have been selected for each discipline (80 items in total).

OUTLOOK

The following main study has started at the beginning of winter semester 2018/2019. At the first measurement point (Table 4), 289 first year chemistry students from two universities and two UAS took part in the main study. In consideration of the curriculum at all participating higher education institutions, the tests in *General Chemistry, Physical Chemistry* and *Analytical Chemistry* have been applied to assess students' prior chemistry knowledge (Table *4*, MP 1) that students gained in secondary school. Besides students' school career, students' prior knowledge is a part of the socialisation in the education process of Heublein's (2014) model of the dropout process (Figure 1). Students' chemistry content knowledge as part of the performance at the studies (Figure 1) was surveyed at the beginning of summer semester 2019 (MP 2) and of winter semester 2019/2020 (MP 3). The last survey will take place at the beginning of summer semester 2020 (MP 4). In addition to students' content knowledge, further influencing factors from Heublein's (2014) model as study motivation, personality, background (e.g. socio-demographic background), study behaviour (e.g. self-evaluation, learning strategies) will be surveyed several times and investigated regarding their impact on study success in chemistry study programs.

Table 4 Schedule of chemistry subject knowledge in the main study.

		Survey at the beginning of…			
		winter semester 2018/2019 (MP 1)	summer semester 2019 (MP 2)	winter semester 2019/2020 (MP 3)	summer semester 2020 (MP 4)
Test instrument	General Chemistry	X	X	X	
	Physical Chemistry	X	X	X	X
	Analytical Chemistry	X	X	X	X
	Organic Chemistry		X	X	X
	Anorganic Chemistry		X	X	X

REFERENCES

Averbeck, D., Hasselbrink, E., & Sumfleth, E. (2018). Academic Achievement of Chemistry Freshmen – Interrelations between prerequisites and Content Knowledge Acquisition. In Finlayson, O.E., McLoughlin, E., Erduran, S., & Childs, P. (Eds.), *Electronic Proceedings of the ESERA 2017 Conference. Research, Practice and Collaboration in Science Education*, Part 17 (co-ed. Guisasola, J.), (pp. 2214-2224). Dublin, Ireland: Dublin City University. ISBN 978-1-873769-84-3

Dickmann, T., Rumann, S., & Opfermann, M. (2017). Visuelles Modellverständnis: Ein Prädiktor für Studienerfolg?! [Visual Model Comprehension: A Predictor for Study Success?!]. In C. Maurer (Ed.). *Qualitätsvoller Chemie- und Physikunterricht - normative und empirische Dimensionen.* Gesellschaft für Didaktik der Chemie und Physik. Jahrestagung in Regensburg 2017 (503-506). Universität Regensburg.

Freyer, K., Asikainen, M. A., Hirvonen, P. E, & Sumfleth, E. (2015). Studienanfängerinnen und Studienanfänger im Fach Chemie. Deutschland und Finnland im Vergleich [Chemistry First Semester Students. Comparison between Germany and Finland]. *CHEMKON, Vol. 22* (2), 75-81. doi: 10.1002/ckon.201410245

Heublein, U. (2014). Student Drop-out from German Higher Education Institutions. *European Journal of Education, Vol. 49* (4), 497-513.

Heublein, U. & Schmelzer, R. (2018). *Die Entwicklung der Studienabbruchquoten an den deutschen Hochschulen. Berechnungen auf Basis des Absolventenjahrgangs 2016 [Development of dropout at German higher education institutions. Calculations based on graduation year 2016]. DZHW-Projektbericht Juli 2018.* Hannover: DZHW.

Linacre, J. M. (2019). Winsteps® 4.3.4 [Computer Software]. Beaverton, Oregon, from www.winsteps.com.

Linacre, J. M. (2018). *Winsteps® Rasch measurement computer program User's Guide*. Beaverton: Winsteps.com

Maaz, K., et al. [Autorengruppe Bildungsberichterstattung] (2018). *Bildung in Deutschland 2018. Ein indikatorengestützter Bericht mit einer Analyse zu Wirkungen und Erträgen von Bildung [Education in Germany 2018. A report regarding indicators including an analysis of effects and results of education]*. Bielefeld: wbv Publikation.

Middendorff, E., Apolinarski, B., Becker, K., Bornkessel, P., Brandt, T., Heißenberg, S., & Poskowsky, J. (2017). *Die wirtschaftliche und soziale Lage der Studierenden in Deutschland 2016: 21. Sozialerhebung des Deutschen Studentenwerks durchgeführt vom Deutschen Zentrum für Hochschul- und Wissenschaftsforschung [The economic and social Situation of Students in Germany 2016: 21st Social Survey of the German National Association for Student Affairs conducted by the*

German Centre for Research on Higher Education and Science Studies (DZHW)]. Berlin: Bundesministerium für Bildung und Forschung (BMBF).

Moosbrugger K., & Kelava, A. (2012). *Testtheorie und Fragebogenkonstruktion [Testtheory and questionnaire construction]*. Berlin, Heidelberg: Springer Verlag.

Paczulla, B., Schüßler, K., Sumfleth, E., & Walpuski, W. (2018, September). *Studienerfolg und Studienabbruch in Chemiestudiengängen (CASSIS) [Study Success and Dropout in Chemistry Study Programs (CASSIS)]*. Poster session presented at GDCP Jahrestagung 2018, Kiel, Germany.

Schindler, S., & Reimer, D. (2010). Differentiation and social selectivity in German higher education. *Higher Education, Vol.61* (3), 261-275.

Ulriksen, L., Madsen, L. M., & Holmegaard, H. T. (2010). What do we know about explanations for drop out/opt out among young people from STM higher education programmes? *Studies in Science Education*, *Vol. 46* (2), 209-244.

van Ackeren, I., Klemm, K., & Kühn, S. M. (2015). *Entstehung, Struktur und Steuerung des deutschen Schulsystems: Eine Einführung (3., überarb. und aktual. Aufl.) [Creation, Structure and Control of the German Education System: An Introduction]*. Wiesbaden: VS Verlag für Sozialwissenschaften; Springer VS.

CRITERIA-BASED ASSESSMENT OF KNOWLEDGE IN BIOLOGY IN HIGHER EDUCATION

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Assessment of knowledge is a key part of all programs. In higher education, the assessment process since 2006 also has had an ambition to be equivalent in Europe through a joint agreement in Bologna. Standards and guidelines for quality assurance are made, for example that criteria for and method of assessment are published in advance to enhance transparency. Course objectives are formulated as student-centered learning outcomes coupled with assessment criteria that describe what the learner is expected to do and to what level. At some Swedish universities, the reform was completed in 2007. A question is thus, how learning outcomes and assessment criteria are expressed in biology courses of today. All course plans and course documents from the academic year 2015/2016 in biology at one university have been collected and categorized according to type of assessment criteria. This study focuses qualitatively expressed assessment criteria, i.e. differences in quality are expressed with words. Three different categories were found. The quality of student answers are assessed as different levels of abilities, different levels of relational complexity or different levels of attributes. Possible knowledge taxonomies affecting the criteria are discussed as well as the lack of critical analysis of assessment practice in higher education courses. The influence of view of knowledge is highlighted and differences in preconditions for knowing in different sub disciplines. Consequences for teaching and learning and possible solutions are raised.

Keywords: biology, higher education, assessment criteria

INTRODUCTION

Assessment of knowledge is a key part of all programs. In the standards and guidelines for quality assurance in the European Higher Education Area (ESG, 2015), it states that "The criteria for and method of assessment as well as criteria for marking are published in advance; the assessment allows students to demonstrate the extent to which the intended learning have been achieved " (p.12). The Bologna process in Europe includes a shift of attention from what is taught to what the student is expected to know and is able to do at the end of the course or program, as well as being more explicit and transparent with assessment criteria.

However, Torrance (2007) describes how this transparency (and measurability) which is supposed to give rise to an absolute and equal treatment are increasingly time-consuming processes. Torrance (*ibid*) believes that the quest for transparency encourage an instrumental approach to learning and can further be characterized as "… a move from assessment *of* learning, through the currently popular idea of assessment *for* learning, to *assessment as learning*, where assessment procedures and practices come completely to dominate the learning experience, and 'criteria compliance' comes to replace 'learning"' (p. 282). Furthermore, it has been shown in studies by, for example, Orsmond and Merry (2013) that students may have different ease with or difficulties in understanding what the criteria actually mean.

In a school-level review, it was shown that new assessment systems take almost ten years to anchor among teachers (Lindberg, 2013). This development can be compared to the implementation of the Bologna process in Sweden, where the shift to completely new type of syllabus was transposed in less than a year, and university teachers would learn completely new ways of designing courses and examinations (Lindberg-Sand, 2012).

At a university in Sweden, the teachers in science subjects went from formulating course goals that mirrored the intentions of the teachers, to learning outcomes that should specify what the students were supposed to be able to do, if they passed the course. Further, before the Bologna process, the assessments at the science faculty were based on credits, or points, which corresponded to a three-graded scale: failed, passed, and passed with distinction. The new directions not only meant a restructuring of course material, but also included to write assessment criteria for a seven-graded scale: A, B, C, D E, Fx, F (where Fx and F corresponds to failed). The criteria would qualitatively describe how the different grades corresponded to the learning outcomes of the course.

Different kinds of supporting material were developed, in order to support the teachers in transforming their course plans and other course documents. This can also be seen internationally. For example, Moon (2006) has written texts about how to link learning outcomes with assessment criteria as well as examples of how to write them. In a narrow perspective, it is about changing verbs. Instead of a formulation where the student should 'know' (goal), the student should be able to 'distinguish', 'identify', 'compare' (learning outcome). Instead of getting 60% or 80% credits on a written exam, the student should get a written statement in beforehand about what kind of assessment criteria that should be met by the student.

However, how do you differentiate and formulate what the student should be able to do in seven different steps, for all the learning outcomes? As a teacher in science in higher education, you are an expert *within* your subject, but not especially equipped to reason *about* your subject. One way for the teacher to solve it, is to simply put an adjective in front of the content: sufficient insight into the subject, satisfactory, good.., very god… and excellent insight into the subject. So, what has actually happened? What do the assessment criteria look like today, some 10 years after the implementation of the Bologna process?

Aim and question

This study is part of a larger study that aims at developing knowledge of the assessment practice in higher education based on the experienced university teacher. The purpose of this study is to categorize the content of the assessment criteria in different courses in biology. The questions is: How are assessment criteria qualitatively expressed in courses in biology?

METHOD

All course plans and course documents from the academic year 2015/2016 in biology at a university in Sweden have been collected. The formulated assessment criteria have been categorized inspired by Sadler (2005). The assessment criteria were dived into three themes, A- non-qualitative grading criteria, B - qualitative grading criteria and C -different combination of activities.

This study focus on twelve course plans that have assessment criteria that are qualitative (B), which means that the assessment criteria are expressed with words, which describe levels of understanding.

The assessment criteria from the different courses in theme (B) are further categorized into sub-categories. In this presentation, examples of assessment criteria from different sub-categories are chosen in order to show differences between them. The assessment criteria sometimes involve a lot of text describing what criteria the student should meet for the specific grade in relation to all learning outcomes in the course. Text that has not been included in examples or citations are notated as brackets […].

RESULTS

How are assessment criteria qualitatively expressed in courses in biology? The assessment criteria were distributed into three different sub-categories 1) abilities, 2) relational complexity, 3) attributes. One example from course documents are shown for each category. The examples are then followed by a comment that show how the criteria has been read. Only grade E (passed, lowest grade) and grade A (excellent, highest grade) are shown as illustrations. The course example is introduced with a learning outcome, which is connected to the assessment criteria. This was not always the case. In some instances, the learning outcomes and assessment criteria were not obviously in relation to each other. The results are further interpreted and discussed in the next section.

1) The quality of student answers are assessed as different levels of *abilities*.

Course (1)

Example of learning outcome: *Compare and contrast different disciplinary approaches to social-ecological systems, and explain in what contexts they are more or less useful*.

Example of assessment criteria:
Grade A - *excellent insight and deep understanding of how the module concepts are related to research social-ecological systems. Excellence in analysis, assessment and synthesis in written and oral discussions*.
Grade E - *can recapitulate the contents of the course and define the basic concepts discussed in the different module components*.

Comment: The content concerns different abilities; define basic concepts compared to be able to relate to research and do analysis. There is a difference in what the student is supposed to know or do for the different grades. For the grade E the student should be able to ‘recapitulate’, ‘define’ the ‘basic concepts’ and the text does not even mention or require any analytical skills or any additional skills in discussing and explaining the module concepts . Grade A demands abilities like ‘analysis’, ‘synthesis’ and how concepts are ‘related to’ social-ecological systems.

2) The quality of student answers are assessed as different levels of *relational complexity*.

Course (2)

Example of learning outcome*: Explain basic concepts in molecular genetics; these include recombination, meiosis, replication, transcription and protein synthesis*.

Example of assessment criteria:
Grade A - *Can critically analyze different concepts in molecular genetics and put these into a larger context. Possess a full picture of the molecules that control different processes in molecular genetics and how these are interconnected*. […]
Grade E - *Explain basic concepts in molecular genetics without major misunderstandings. Can name a few important molecules and show acceptable understanding for how these control processes in molecular genetics*. […]

Comment: The content concerns knowing concepts and molecules, and doing that in a successively more complex way. For grade E, the student can 'name' basic concepts, 'name' a few molecules and show 'simple' or acceptable understanding of processes. In grade A, the higher level corresponds to 'critically analyze' different concepts and put into a 'larger context' 'integrated to a structure' (a full picture of the molecules) that are 'interconnected'.

3) The quality of student answers are assessed with different levels of *attributes* (adjectives).

Course (3)

Example of learning outcome: *Be able to utilize existing tools for taxonomic, systematic and ecological analysis of information such as are collected from scientific object collections and data collections.*

Example of assessment criteria:
Grade A - *Very well executed analyses and problem solving during the time allotted, conducted with a very high degree of autonomy and scientific maturity.* […]
Grade E - *Analyses executed. Some understanding of the problems presented and the theoretical background*. […]

Comment: The content concerns being able to do an analysis. The grade E corresponds to an analyses that is simply done and the student show 'some' understanding, a kind of 'sufficient' level. The grade A correspond to a 'very well executed analysis in a kind of 'excellent' manner. In this example, the content in the assessment criteria concerns the same ability, namely to perform an analysis, but it does not state what might be involved in a very well executed analysis (other than performed independently, on time and with maturity).

DISCUSSION

How are assessment criteria qualitatively expressed in courses in biology?

The principles of alignment and Blooms taxonomic pyramid guide course design and assessments as well as how the assessment criteria are formulated, in European higher education (see, for example, Kennedy, 2006, or Moon, 2006). The category 1) above (the quality of student answers are assessed as different levels of abilities), show clear traces of a "Bloomish" terminology, where the words describing the lowest and higher grades can be seen corresponding to the hierarchy of Blooms pyramid (Bloom, 1956). A possible knowledge taxonomy is therefore Bloom, where knowledge is fragmented into different distinct cognitive abilities, and where the ability to analyze is among the top cognitive abilities.

However, the underlying principles of higher education assessment have been used quite uncritically (Sadler, 2009). That which constitute the basis for a higher or lower grade can have several different interpretations, based on what view of knowledge and knowing one entails. The Bloomish perspective is about a view of knowledge where it can be fragmented into different distinct steps. The higher cognitive skills are also not part of the lower skills. For example, 'analysis' is not something that you may be more or less skilled at. Instead, the ability only emerges *after* other cognitive skills are in place.

An alternative approach is the SOLO taxonomy (Structure of the Observed Learning Outcome), which assess students' work in terms of increasing complexity. The model was once created by Biggs and Collis for schools (1989) and is now widely used internationally in higher education. The model starts with few aspects of the task at hand (uni-structural) towards a more relational and an integrated whole, and ends in multi-structural and generalized untaught applications. The category 2 in the result section above (the quality of student answers are assessed as different levels of relational complexity), can be seen as an example of this taxonomy. The understandings of molecular concepts increases in relational complexity, from a basic understanding to be able to put them in a larger context. In a study done by Chan, Tsui, Chan, and Hong (2002) they interpret student answers with SOLO taxonomy and compares to Blooms taxonomy. They see some application problems when applying SOLO and the ambiguities in interpreting for example what is' multi-structural'. They also state that Blooms taxonomy have "…a clearer division of categories that are mutually exclusive…" (p. 518). This also strengthen the view that we really need to examine more, what we mean are examples of quality of knowing (in biology). Questions to ask are for example, do we really have mutually exclusive abilities? Alternatively, what do multi-structural relations actually mean? Moreover, how do these different views of knowing affect the teaching and learning situation?

The last category in the results above, 3) different levels of an attribute, describes what the student is expected to do and to what level, but the level is described as 'very well' and it is unclear what that really entails. Since this is a study only of written material, it is possible that the actual teaching and learning activities makes it more clearly for the students on what is a good performance or a better performance. It is hard work to write what it means to know something good or better, and in time pressed schedules, it is easy to fall back to manuals and premade verbs. All three examples show at the same time a view of increasing quality going from some kind of "sufficient" basic performance (knowing "basic concepts"), to an "excellent", more complex, relational and analytic ability. The difference between the categories is how the abilities are shown: if being able to analyze is an ability that shows as a higher cognitive ability or can be graded and performed better or worse ("analyze performed, analyze performed very well”). If knowing concepts is an ability that may involve few concepts or may involve putting the concepts into a larger context and how processes are interconnected.

Biology is a university subject that, by its very nature, spans different perspectives, types of problems and approaches to solving them and various central conceptual contexts. One could therefore talk about different forms of knowledge (Hirst, 1974) even if it concerns one discipline (Flodin, 2015). Biology is about molecular processes, the functions of organelles, about cells and organs, and further about how ecological processes interact in different biomes. This means that biology encompasses very different conditions for teaching and learning and thus for assessment and what qualities of knowledge mean. Therefore what constitutes a knowledgeable student differ. It might be to know many definitions of concepts or a knowledgeable student can name many plants or use different tools for analysis.

Bloxham, den-Outer, Hudson and Price (2016) show how experienced teachers in the subject history vary greatly in their interpretation of assessment criteria and the authors believe that we must stop pretending that grading is consistent. Instead, we should be honest with the students and actively help them understand how assessment is a complex activity. The authors mean that if we can understand the roots of variation, what it is that allows teachers to vary in their assessment, then maybe that would help in identifying strategies to reduce variation or to understand if it is actually possible to reduce variation. Sadler (2009) argues that we need to see the assessment from a holistic perspective where teachers balance different aspects of the student's work that cannot be fully captured in specified criteria.

The student and the lecturer might need, together as far as possible, to conceptualize or make visible what constitutes examples of good quality of knowledge, or as Boud (2009) emphasizes, based on what kind of accepted standard the quality is formulated. We therefore need to highlight what kind of expertise different qualities mean. In this way, the teaching can be developed towards an increasing degree of transparency in how the discipline perceives qualities in the knowledge. This, in turn, could mean other didactic priorities and processes in teaching practice than, for example, alignment alone (compare to Sadler, 2009).

Absolute transparency and justice thus seem impossible to achieve and may not be what is central. Assessment criteria and the assessment processes can instead be developed into, not only a kind of functional checklist, but also to become part of developing the understanding of fundamental qualities of the knowledge at hand. Overall, studies show that assessment is a complex process and that we need to gain more knowledge about what happens in specific assessment situations.

CONCLUSIONS

How are assessment criteria qualitatively expressed in courses in biology?

This study show that it is important to question:

- the view of knowledge expressed in templates and other course supportive material
- the view of the assessment process as transparent
- what aspects of assessment need to be explicit and in what way?

The professional assessment is further not captured solely by means of assessment criteria.

REFERENCES

Biggs, J. B., Collis, K. F. (1989) Towards a model of school-based curriculum development and assessment using the SOLO taxonomy, *Australian Journal of Education*, 33 (2), pp. 151–163.

Bloom, B.S. (Ed.) (1956). *Taxonomy of educational objectives: the classification of educational goals. Handbook 1, Cognitive domain*. New York: Longman.

Bloxham, S., den-Outer, B., Hudson, J., & Price, M. (2016). Let's stop the pretence of consistent marking: exploring the multiple limitations of assessment criteria. *Assessment & Evaluation in Higher Education,* 41(3), 466-481.

Boud, D. (2009). How Can Practice Reshape Assessment? In J. Gordon (Ed.), *Assessment, learning and judgement in higher education.* Dordrecht: Springer.

Chan, C. C., Tsui, M. S., Chan, M. Y., & Hong, J. H. (2002). Applying the structure of the observed learning outcomes (SOLO) taxonomy on student's learning outcomes: An empirical study. *Assessment & Evaluation in Higher Education*, 27(6), 511-527.

ESG (2015). Standards and Guidelines for Quality Assurance in the European Higher Education Area (ESG). (2015). Brussels, Belgium.

Flodin, V. (2015). *En didaktisk studie av kunskapsinnehåll i biologi på universitetet: med genbegreppet som exempel* (PhD thesis). Stockholm: Institutionen för matematikämnets och naturvetenskapsämnenas didaktik, Stockholms universitet.

Hirst, P. H. (1974). *Knowledge and the Curriculum*. A Collection of Philosophical Papers. London : Routledge.

Kennedy, D. 2006. Writing and using learning outcomes: a practical guide, Cork, University College Cork. Downloaded 2019-01-31 from: https://cora.ucc.ie/handle/10468/1613

Lindberg, V. (2013). Betyg och bedömning i svensk didaktisk forskning 1990-2009. In L. Lindström, V. Lindberg & A. Pettersson (Reds.), *Pedagogisk bedömning: Att dokumentera, bedöma och utveckla kunskap* (3 uppl.) Stockholm: Liber.

Lindberg-Sand, Å. (2012). The Embedding of the European Higher Education Reform at the Institutional Level: Development of Outcome-Based and Flexible Curricula? In A. Curaj, P. Scott, L. Vlasceanu, & L. Wilson (Eds.), *European higher education at the crossroads: between the Bologna process and national reforms* (s. 191-207). Dordrecht: Springer Science and Business Media.

Moon, J. (2006). Linking levels, learning outcomes and assessment criteria–EHEA version. In WUS, Budva: Curriculum Development and ECTS Seminar.

Orsmond, P., & Merry, S. (2013). The importance of self-assessment in students' use of tutors' feedback: A qualitative study of high and non-high achieving biology undergraduates. *Assessment & Evaluation in Higher Education*, 38(6), 737-753.

Sadler, D. R. (2005). Interpretations of criteria-based assessment and grading in higher education. *Assessment & Evaluation in Higher Education,* 30(2), 175-194.

Sadler, D. R. (2009). Indeterminacy in the use of preset criteria for assessment and grading. *Assessment & Evaluation in Higher Education,* 34(2), 159-179.

Torrance, H. (2007). Assessment *as* learning? How the use of explicit learning objectives, assessment criteria and feedback in post-secondary education and training can come to dominate learning. *Assessment in Education*, 14(3), 281-294.

HIGH SCHOOL AND UNIVERSITY STUDENTS' UNDERSTANDING OF SOLUBILITY AND SOLUBILITY PRODUCT CONCEPTS. A PHENOMENOGRAPHIC APPROACH.

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From a socio-constructivist approach to the practice of teaching and learning, recognizing the different ways of reasoning of students is crucial when considering the objectives and contents of teaching. Solubility equilibrium offers a source of teaching-learning problems both at High School and University level. The dynamic concept of equilibrium, the relationship between solubility and the solubility product constant (Ksp) as well as the qualitative meanings of these magnitudes may be a cause for these problems. Teaching-learning of the Solubility Equilibrium (SE) phenomena has not been deeply researched from a pedagogical point of view, if compared with other chemistry subjects. In this sense, a questionnaire has been developed to evaluate students' ideas about solubility and Ksp concepts and to test the presence of teaching-learning problems. This research was carried out with a random sample of 243 students from the last course of different High Schools in Spain, and 97 students who were studying the first year of Physics at the University of the Basque Country. The questions used in this research were qualitative and focussed more on explanations than on obtaining a result by applying a formula. The results showed that some students have severe learning difficulties related to the qualitative solubility and Ksp concepts. This research offers information about the students′ understanding of SE, which could be useful in planning curriculum to facilitate the teaching-learning process.

Keywords: Chemistry Education, Secondary School, Higher Education, Solubility Product

INTRODUCTION

Solubility equilibrium and related concepts such as the dynamic nature of this equilibrium and the qualitative interpretation of the solubility product constant (Ksp) are fundamental to understand both heterogeneous equilibrium and some of its technical applications connected to everyday life. Indeed, this type of equilibrium takes place both in processes of industrial interest and in natural phenomena. So, we are in daily contact with compounds that dissolve in water to a greater or lesser extent. For example, sodium hydrogen carbonate, more known as baking soda, has been used as a home remedy for acid reflux for many years. In its dissolution process, a solubility equilibrium is established. Furthermore, sodium carbonate is obtained industrially from precipitation reactions, stalactites and stalagmites are produced by precipitation of calcium carbonate and caries appear when tooth enamel, hydroxyapatite, dissolves in acidic medium. Understanding these equilibriums becomes crucial in choosing some social decisions about chemistry and commercial products.

The most important concepts involving chemical equilibrium (acid-base, redox, solubility and complex formation) are found in the basic curriculum of introductory courses in chemistry, and are essential to understand key issues of our environment. In Spain, the basic curriculum of compulsory secondary education and bachelor of the Ministry of Education (Royal Decree 1105/2014) explicitly includes these concepts which are expanded in a phased progression of learning. Thus, the subject of Physics and Chemistry (ages 14-16) devotes a block to chemical reactions where contents such as substances, mixtures and aqueous solutions are developed. The evaluable Learning Standards of this subject determine that students should, among others, identify the solvent and the solute when analysing the composition of homogeneous mixtures of special interest. In the subject of Chemistry of High School (ages 16-18), within the block "Quantitative aspects of chemistry", students must work on contents related to solutions (ways of expressing concentration, preparation and colligative properties), heterogeneous equilibria and precipitation reactions. These contents are revisited in the first courses of science degrees so the most commonly used books of general chemistry (Chang 2008, Petrucci 2017) also include the equilibrium of solubility and its main characteristics (dynamic nature of equilibrium, Ksp, temperature effect on solubility, common ion or parallel reactions). Even so, research on chemical equilibrium has shown the persistence of general teaching-learning problems in secondary school and university (Quilez-Pardo 1995).

MODELS EXPLAINING SOLUBILITY AND SOLUBILITY PRODUCT CONCEPTS

Solubility equilibrium is usually explained in the context of compounds with a relatively low solubility, that is, compounds that dissociate only a little bit. In the development of the theoretical framework of Chemistry some concepts involved in this topic must be rigorously defined: the dissolution process of a salt in aqueous solution, the importance of stoichiometry, when a salt is sparingly soluble or practically insoluble, saturated solutions, etc. Knowing these items as prerequisites, students will be in a position to understand the existence of a dynamic equilibrium in a saturated solution in which the constant (Ksp) provides information about the equilibrium displacement.

The concept of solubility becomes necessary when appreciating the different easiness of substances to dissolve. IUPAC (Orange Book, 2019) defines it as "*The analytical composition of a saturated solution, expressed in terms of the proportion of a designated solute in a designated solvent, is the solubility of that solute. The solubility may be expressed as a concentration, molality, mole fraction, mole ratio, etc.*" According to IUPAC, in macroscopic qualitative terms, solubility is defined as the ability of a substance to be solved in another substance at a given temperature. Solubility product (Ksp), for its part, provides information about the extent of the direct reaction versus the inverse one and it is defined by IUPAC (Orange Book, 2019) as "*The product of the ion activities raised to appropriate powers of an ionic solute in its saturated solution expressed with due reference to the dissociation equilibria involved and the ions present*". According to this definition this magnitude provides a qualitative view about the equilibrium displacement towards the ions formation. In general terms, taking into account the stoichiometry, the higher the Ksp value, the more soluble the substance is.

IUPAC texts are written for and addressed to professionals, but students are far away from being experts in chemistry. Thus, in order to facilitate them to grasp the meaning of the concepts, making clear the different levels in which chemistry works becomes fundamental. In this sense, although the observable facts are described at a macroscopic level, is in the sub-microscopic level were the explanation to these facts is hidden. The symbolic level, in which drawings are transformed into letters and numbers, simplifies representations and allows students to understand the real meaning of mathematic calculations. Therefore, students must be able to establish appropriate connections between these three levels.

However, even though macroscopic, sub-microscopic and symbolic levels are fundamental prerequisites to understand the chemical concepts in general and the specific concepts of solubility and solubility product (Ksp) studied in this work in particular, students are generally asked to solve exercises about these concepts in a mathematic way. In general, two kinds of exercises exist: (i) starting from Ksp students must calculate the concentrations of cations and anions, then calculate the molar solubility of the compound and finally its solubility in other units or (ii) starting from the solubility of the compound they must calculate its Ksp. This way of working allows knowing the students' mathematic comprehension of the process, but offers little information about their understanding on solubility and Ksp concepts and its differentiation. In the next section, previous work on students' understanding of the relations between solubility and solubility equilibrium will be reviewed.

STUDENTS´ CONCEPTIONS OF SOLUBILITY AND SOLUBILITY EQUILIBRIUM CONSTANT

The review of previous research on teaching-learning problems about solubility and heterogeneous chemical equilibrium is limited to concepts included in the basic curriculum of introductory courses in chemistry (Quílez-Pardo & Solaz-Portolés, 1995; Banerjee, 1991; Voska & Heikkinen, 2000). In this sense, Ebenezer & Erickson (1996) conducted a phenomenographic study in which students' grade 11 responded to an interview consisting on different tasks and questions. Their objective was to elicit students' conceptions of solubility prior to formal instruction on solutions. The students' explanations allowed researchers to visualize their different ideas about the way a salt dissolves in a solvent. Some of them considered it as a physical transformation from solid to liquid, for others it was a chemical transformation of solute; another focused its explanation through the density of solute or the amount of space in solution stating that "*substances do not dissolve because they do not find sufficient space in the dissolving medium"*. Finally, other students thought the solubility was exclusively dependent on the size of solute or in some specific property of solute.

Other research studies also show that students have several misconceptions about chemical equilibrium at High School and University levels (Driel, 2002; Huddle & Pillay, 1996). Educational research on solubility equilibrium has shown evidence of poor learning achieved by High School students (HSS) (Onder, 2006; Cam 2013), but few studies have been developed at the university level (Raviolo, 2001). Most studies on students' ideas about the concept of equilibrium in solubility focus more on the ability to solve mathematical problems (Rahmi, 2017; Hawkes, 1998; Raviolo, 2001; Gunter, 2018) than on the description of students' visions of these concepts (Onder, 2006; Gorodetsky, 1985; Cam, 2013). Few research papers indicate in their conclusions how HHS in general present alternative ideas in all concepts related to equilibrium in solubility. In a more recent study, Setiowati *et al.* (2018) analysed the thinking of HSS about the concepts of solubility and solubility equilibrium. They found serious difficulties in the understanding of both concepts and detected different misconceptions expressed by many of them. This paper also shows the existence of students' problems to understand the concept of solubility equilibrium, especially because they ignore the law of neutrality of charge in solution and the concept of solubility.

Educational research on solubility equilibrium has shown evidence of poor learning achieved by HSS, but few studies have been developed at the university level. Raviolo (2001) highlights in his work that: *"Although students of general chemistry often correctly solve different kinds of numerical problems (in solubility equilibrium, for example, Ksp and solubility calculations), this alone does not guarantee a conceptual understanding of the phenomenon because of misconceptions that persist after instruction"*. According to this author, if we want University students (US) to develop an adequate conceptual understanding, their learning process should include as objectives the ability to offer explanations and descriptions at the macroscopic level (experiments), the sub-microscopic level (atoms, molecules, ions) and the symbolic level (symbols, formulas, equations) as well as the ability to establish appropriate connections between these three levels.

Research in science education has revealed the existence of many difficulties in the teaching and learning of the concepts related to solubility equilibrium. As shown, several studies have revealed students' difficulties in analysing the concept of solubility. Many of them analyse how students' mathematical resolution improves through new methodologies (Günter, 2018), but few studies are aimed at elucidating students' difficulties with solubility equilibrium concept. Usually, solubility equilibrium is considered an easy item when compared with other equilibriums (acid-base and redox), so the time spent on its study is usually shorter. Nevertheless, the research studies published about the topic and the teaching experience disagree with that conclusion. Thus, in this work we aim to answer the following research questions:

1. What do students of last year at High School and first year at University understand about the concepts of solubility and solubility product in introductory chemistry courses?
2. What conceptions and forms of reasoning do these students use in explaining solubility and solubility product concepts from a macroscopic level?

METHODS

In this research a transversal study involving a sample formed by 243 students chosen randomly from different Spanish last year High School (aged 18) and 97 studying an introductory course of chemistry during their first year of Physics degree at the University of the Basque Country has been done. A questionnaire comprising twelve conceptual free-response questions about solubility (four questions), equilibrium of solubility (two questions), factors influencing solubility (three questions) and relationship between solubility and solubility equilibrium constant (three questions) was designed. Both University and HSS studied the topic of solubility equilibrium before answering the questionnaire, which was filled out in exam situation. This work will be focused exclusively on two of those questions related to the qualitative aspects of solubility (named question Q1) and solubility equilibrium constant (named question Q2). The two questions start from a fictitious situation between two students who find a table with the solubility constant of several salts.

The students' answers were subjected to a rigorous phenomenological analysis. Phenomenology shows how the different ways of perceiving and understanding reality can be classified into different categories. In recent years, phenomenology, as a rigorous form of qualitative research has experienced a great development, especially in higher education (Tight, 2016), making use of the obtained results to elaborate new teaching approaches with the aim of improving students' learning. Phenomenography is a qualitative research approach which aims to investigate and describe the full range of ways in which people think about or experience a concept or phenomenon (Marton, 2015). It deals with how the range of ways of perceiving and understanding reality can be classified into a system of hierarchic categories of growing complexity. In our study, the range of conceptions of solubility and Ksp given by HSS and US is enclosed into a hierarchic series of descriptive categories, following the criteria of Marton and Booth (1997). Such categories were constructed based on students' responses themselves, and the system of categories was organised to reflect an increasing level of understanding about what solubility and Ksp are. The research group, made up of three people, examined all the answers separately, looking for a pattern in the response categories and selecting the most significant between them. Once the initial categories were established, the researchers met to discuss and review them until a consensus was reached on the final categories. The intrarater kappa Cohen reliability coefficient averaged 0.84 for the questions, indicating a very significant degree of agreement in the judges' criteria for applying the categories used to interpret the responses. Thus, the refined final definition of the system of categories used to analyse students' conceptions was obtained after an iterative process of comparison, discussion, and re-definition to consensus. When disagreement about a description category or the location of responses to a specific category appeared, it was resolved by just using evidence of students' understanding as a reference.

RESULTS

The results presented here are part of a study that aims to examine students' ideas about solubility and solubility equilibrium. This work deals exclusively with two questions (named Q1 and Q2) of the questionnaire that focus more on the qualitative aspects of solubility and solubility equilibrium constant, rather than on getting a result by using a mathematical formula. In this way, the objective of the questions was to obtain an in-depth knowledge of the students' thinking.

Q1. Explain the qualitative meaning of the concept of "solubility".

Q2. Explain the qualitative meaning of the concept of "solubility product".

In question Q1 students were asked for a qualitative definition of solubility. As mentioned above, a correct qualitative definition of solubility should explain that it offers a measurement of the ability of a substance to dissolve in another substance. The preliminary results of the study show that both, university and HSS tend to give only a quantitative definition of solubility; avoiding the qualitative answer they have been asked about. Less than 10% of students, in both cases, responded with a suitable qualitative definition of solubility (A category - i.e. *solubility offers a measure of the ability of a substance to dissolve in another substance*), and around 15% and 40% (HSS and US respectively) gave a proper quantitative definition of solubility (B category). A fairly high amount of students showed conceptual errors in their answers (C category). These types of errors can be categorized into subcategories in turn, and their origin is detected when the student:

- Defines the solubility as any concentration of the solution.
- Refers to any amount of solute dissolved in an amount of solvent / solution.
- Confuses solubility with concentration in qualitative terms: saturated, concentrated, diluted
- Confuses solubility with the amount of solute that dissolves (mass), without considering the total solution

- Defines the solubility in terms of the s of the Ksp formula. (The solubility has no value by itself)
- Confuses solubility with the physical dissolution process
- States that solubility is a property of the solvent

The other erroneous answers no classifiable into the previous ones were classified as inconsistent (D category). Finally, it is remarkable that 58,0% of HSS did not answer the question while only a 7.2% of US did not answer it. The results of the students' answers to the question Q1 are shown in percentages in table 1.

Table 1. Results for the Question Q1

Descriptive Category	High School % (N=243)	University % (N=97)
A.- Solubility offers a measure of the ability of a substance to dissolve in another substance. (Qualitative idea)	9.1%	5.2%
B.- Its measurement is obtained as the maximum amount of solute, which can be dissolved in a given volume at a given temperature. (Quantitative idea)	14.8%	40.2%
C.- Incorrect	12.8%	35.1%
D.- Inconsistent	5.3%	12.4%
No Answer	58.0%	7.2%

In question Q2 students were asked for a qualitative definition of Ksp. The results of our study show that, as occurred in the previous question, university and HSS tend to give only a quantitative definition of solubility product, avoiding the qualitative answer they have been asked about. It is remarkable that, less than 3% of students, both university and high school, answered the question in the correct way (A category). Therefore, most of the students were not able to offer a qualitative definition. On the contrary, some of them provided a correct quantitative (operative) definition (B category), which implies that for them Ksp basically has only a mathematical meaning. These students offered a correct operational definition of the solubility product formula based on the chemical reaction expressed as: A_aB_b (s) $\rightarrow aA^{+b} + bB^{-a}$, where the solubility product constant is expressed as: Ksp (A_aB_b) = $[A^{+b}]^a \cdot [B^{-a}]^b$. Apart from the categories mentioned above, several incorrect ways of interpreting the sense of the equilibrium constant were identified. C category groups those students who have a utilitarian idea of Ksp. For them the Ksp is a subsidiary constant and it has no value by itself. It is used to calculate the solubility or it is used to determine when a compound will precipitate. D Category includes explanations that limit the definition to affirm that Ksp is a constant, or just paraphrase the question. In category E, erroneous visions of solubility constant are grouped, for example, those students who confuse Ksp with Qsp (ion product). In this case, they focus on the mathematical expression of the constant as a function of the concentrations of the ions of the dissolved salt, but without making reference to the fundamental factor: it represents the concentration of these ions when the equilibrium has been reached. For other students Ksp is identified with the amount in mass (g) or with the concentration of the dissolved salt. Other different erroneous answers that do not fall into any of the previous classifications and do not have sufficient entity to generate their own category were classified like incoherent (F category). For example, High School student 34 maintains that *"Solubility is the process by which a solute is dissolved totally or partially by a solvent and the solubility product is the result obtained after the previous process"*. It should be noticed that 64.2% of HSS did not answer this question, while only 17.5% of US did not answer it. The results of the students' answers to the question Q2 are shown in percentages in table 2.

Table 2. Results for the Question Q2

Descriptive Category	High School % (N=243)	University % (N=97)
A.- Correct Qualitative definition of Ksp	2.5%	2.1%
B.- Correct Cuantitative definition of Ksp	0.8%	23.7%
C.- Utilitarian value	2.1%	22.7%
D.- Limit the definition to affirm that Ksp is a constant, or paraphrase the question	6.2%	7.2%
E.- Incorrect	24.3%	14.4%
F.- Incoherent	7.4%	12.4%
No Answer	64.2%	17.5%

CONCLUSIONS AND IMPLICATIONS

This study aims to evaluate students' ideas about the macroscopic meaning of the concepts of solubility and the solubility equilibrium constant (Ksp) in order to detect teaching-learning problems about these concepts. As stated in some evaluation proposals on conceptual knowledge about solubility equilibrium, in order to guarantee a conceptual understanding of this phenomenon, a diagnosis of difficulties related to solubility basic concepts is necessary (Raviolo 2001). In this sense, the research findings of this study have allowed to highlight some of the students original ideas related to the subject.

The results of this study show that, even after studying these topics during one or two years, students' ideas about them are far away of their scientific meaning. Notwithstanding, the results for US are significantly better. It is especially remarkable that more than a half of HSS were not able to answer the questions. In general, the ideas about the concept of solubility are more accurate than those of Ksp showing that solubility concept is better settled, as other works affirm (Setiowati, 2019). This is in some way logical because the concept of solubility is studied in previous years whilst HSS studied Ksp for the first time. It is important to emphasize the fact that most of the HSS could give neither the qualitative meaning of solubility nor that of Ksp. Several of them developed incorrect ideas, and only a few offered explanations fitting the qualitative scientific model. In contrast, US students offered well-established ideas about solubility and less elaborate ideas of Ksp.

We can affirm that, in general, students cannot give a meaningful explanation for the concept of Ksp and its usefulness to understand solubility equilibrium. Instead, they generate a wide spectrum of alternative conceptions such as considering both concepts being the same, confuse Ksp with the ion-product expression, Qsp, or focus only on the mathematical expression of the constant without making reference to the fact that it represents the concentration of these ions when the dissolution equilibrium has been reached. Other students identified Ksp with the amount in mass (g) or with the concentration of the dissolved salt and, finally, a significant percentage give meaningless explanations or no explanations at all.

As mentioned above, this analysis is a small part of a larger study that tries to determine students' learning problems related to the solubility equilibrium. Our research has provided meaningful insights into students understanding of this equilibrium. It is a fact that having a prior knowledge of the problems students must face in the study of these concepts can help to prevent possible mistakes by considering them into the teaching process. Using these findings, the objective of our future research will be to design teaching tasks related with them, useful to put students in situation of using scientific work strategies to enable them to grasp the meaning of these concepts and to establish its macroscopic, sub-microscopic and symbolic connections. It is suggested that research with the objective of designing teaching materials and subsequently implementing them with students is necessary to reduce the gap between the teaching of the concept of solubility, solubility constant and their understanding. A second phase of our research could take us to develop a teaching sequence design for introductory chemistry courses at secondary school and university taking into account the students' difficulties in order to improve the teaching-learning process.

ACKNOWLEDGEMENTS

We thank our colleagues from the Science, Technology and Mathematics Education Research Group (STEM-ERG) from the University of the Basque Country, who provided insight and expertise that greatly assisted the research, and for comments that greatly improved the manuscript.

REFERENCES

Banerjee, A. C. (1991). Misconceptions of students and teachers in chemical equilibrium. *International journal of science education, 13*(4), 487-494.

Cam, A., & GEBAN, Ö. (2013). Effectiveness of case-based learning instruction on students' understanding of solubility equilibrium concepts. *Hacettepe Üniversitesi Eğitim Fakültesi Dergisi,* [H.U. Journal of Education] 44, 97-108

Chang, R. (2008). General chemistry: the essential concepts. Boston: McGraw-Hill.

Driel, J. H., & Gräber, W. (2002). The teaching and learning of chemical equilibrium. In *Chemical education: Towards research-based practice* (pp. 271-292). Springer, Dordrecht.

Ebenezer, J. V., & Erickson, G. L. (1996). Chemistry students' conceptions of solubility: A phenomenography. *Science Education*, *80*(2), 181-201.

Gorodetsky, M., & Gussarsky, E. (1986). Misconceptualization of the chemical equilibrium concept as revealed by different evaluation methods. *European Journal of Science Education*, *8*(4), 427-441.

Günter, T. (2018). The effect of the REACT strategy on students' achievements with regard to solubility equilibrium: using chemistry in contexts. Chemistry Education Research and Practice, 19(4), 1287-1306.

Hawkes, S. J. (1998). What should we teach beginners about solubility and solubility products? *Journal of chemical education*, *75*(9), 1179.

Huddle, P. A., & Pillay, A. E. (1996). An in-depth study of misconceptions in stoichiometry and chemical equilibrium at a South African university. *Journal of Research in Science Teaching, 33*(1), 65-77.

IUPAC. Compendium of Chemical Terminology, 2nd ed. (the "Gold Book"). Compiled by A. D. McNaught and A. Wilkinson. Blackwell Scientific Publications, Oxford (1997). Online version (2019-) created by S. J. Chalk. ISBN 0-9678550-9-8. https://doi.org/10.1351/goldbook. Pg 83 and 84.

Marton, F. (2015). Necessary conditions of learning. New York, NY: Routledge

Marton, F., & Booth, S. (1997). *Learning and awareness*. Mahwah, NJ: Lawrence Erlbaum Associates.

Nakiboğlu, C., & Nakiboğlu, N. (2019). Exploring prospective chemistry teachers' perceptions of precipitation, conception of precipitation reactions and visualization of the sub-microscopic level of precipitation reactions. *Chemistry Education Research and Practice*, 20(4), 873-889.

Önder, I. & Geban, Ö. (2006). The effect of conceptual change texts oriented instruction on students' understanding of the solubility equilibrium concept. *H.U Journal of Education*, vol. 30, pp. 166-73, 2006.

Petrucci, R. H., Herring, F. G., Bissonnette, C., & Madura, J. D. (2017). General chemistry: principles and modern applications. Pearson.

Quílez-Pardo, J., & Solaz-Portolés, J. J. (1995). Students' and teachers' misapplication of Le Chatelier's principle: Implications for the teaching of chemical equilibrium. *Journal of Research in Science teaching, 32(*9), 939-957.

Rahmi, C., Katmiati, S., Wiji, & Mulyani, S. (2017, May). Students' mental models on the solubility and solubility product concept. In *AIP Conference Proceedings* (Vol. 1848, No. 1, p. 030001). AIP Publishing.

Raviolo, A. (2001). Assessing students' conceptual understanding of solubility equilibrium. *Journal of Chemical Education*, *78*(5), 629.

Royal Decree 1105/2014. Real Decreto 1105/2014, de 26 de diciembre, por el que se establece el currículo básico de la Educación Secundaria Obligatoria y del Bachillerato. Ministerio de Educación, Cultura y Deporte, Madrid (3 de enero de 2015), 169-546.

Setiowati, H., & Utomo, S. B. (2018). Students' misconceptions on solubility equilibrium. *In Journal of Physics: Conference Series* (Vol. 1022, No. 1, p. 012035). IOP Publishing

Tight, M. (2016). Phenomenography: The development and application of an innovative research design in higher education research. *International Journal of Social Research Methodology*, 19(3), 319-338.

Voska, K. W., & Heikkinen, H. W. (2000). Identification and analysis of student conceptions used to solve chemical equilibrium problems. *Journal of Research in Science Teaching, 37(2),* 160-176.

SPECIES DIVERSITY AS A FACTOR IN THE DESIGN OF FOOD CHAINS

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This paper focuses on the importance of familiarity with the species diversity of ecosystems for the proper use of the food chain concept. The research objective was to explore if pre-service preschool and primary teachers can correctly name specific examples of food chains in Slovenian forests. The study included 170 students from the University of Ljubljana's Faculty of Education. The students had to list four examples of food chains and explain what a food chain is. The majority of students do not have as much difficulty understanding the concept of a food chain, but they have limited familiarity with species diversity and animal nutrition, which makes it difficult for them to adequately form food chain examples. A quarter of respondents did not offer a single correct example of a food chain in the forest. It turned out that some students find it difficult to understand the role of arrows in a food chain even after the end of the university basic biology course. The arrows were often missing or facing the wrong direction. Some students think fungi are primary producers in the food chain. Many students are not familiar with the nutrition of common forest species. Pre-service teachers' knowledge about forest species diversity is fundamental to facilitate their construction and understanding of a food web in an authentic, local context.

Keywords: food chain, knowledge, student

INTRODUCTION

In ecology, consumption sequences are illustrated with various diagrams, such as food chains and food webs. A food chain represents a linear sequence of organisms or the transfer of energy accumulated in food from a primary producer through a sequence of consumers, whereby each predator in the chain is also food for another organism (Chapin III, Matson, and Vitousek, 2011; Odum and Barrett, 2005). The species are related to each other as members of the chains, which are thus called food chains or trophic chains. Only about 10 to 20% of the energy is transferred to the higher trophic level from one chain member to another. Consequently, the number of chain members is limited to four or five (Odum and Barrett, 2005; Odum, 1989). The links between chain members are illustrated by arrows that indicate the direction of energy, conversions, and substance passing. Organisms are included as producers, consumers or decomposers. Food chains are not isolated from each other but are linked to food or trophic webs. In such systems, the relationships between organisms are not only linear, like in the chain, but developed in different directions (Tome, 2006).

Knowledge of food chains and food webs is a popular ecological topic in pedagogical research (e.g., Adeniyi, 1985; Allen, 2017; Eilam, 2012; Hogan, 2000; Leach et al., 1996; Wyner and Blatt, 2018). Allen (2017) reports that most five-year-olds can perceive key concepts related to food chains. However, several researchers report that students at all levels of education often struggle with understanding the complexity of food chains and food webs (Hogan, 2000; Eilam, 2012; Wyner and Blatt, 2018). Students confuse the two concepts, even though some had a proficient understanding of food web interactions, but were unable to connect school science understanding with the daily life activities (Wyner and Blatt, 2018). Griffiths and Grant (1985) reported that students understand the food web only as a set of more food chains. They have problems in understanding energy transfer in these systems and indirect influences between organisms (Hogan, 2000; Leach et al., 1996). They often do not perceive themselves as a part of the food chain or the web (Wyner and Blatt, 2018).

This article presents the findings of preliminary research, focusing on the importance of knowing the species diversity of ecosystems for the proper use of the concept of a food chain. A review of literature and articles did not yield any studies focusing on this aspect of the problem described. We were interested in whether pre-service preschool and primary teachers, who will teach children about ecological concepts such as food chain and species diversity, can correctly name specific examples of food chains in Slovenian forests.

Research questions (RQ)

(RQ1) How well do pre-service teachers understand the concept of food chains?

(RQ2) How well do pre-service teachers know the species diversity of forest in Slovenia?

RESEARCH METHOD AND DESIGN

The study included 170 students from the University of Ljubljana's Faculty of Education. Of these, 105 were students in the undergraduate program in preschool education enrolled in the course Primary Science, and fifty-five were students in the undergraduate program in primary education enrolled in the course Science and Biology. In addition, ten students in the undergraduate program were questioned about their understanding of an example of a food chain in the Slovenian forest.

The data were collected in the academic year 2016/17 and 2017/18. The knowledge test took place in February or. June 2017. We gave the students a written task: "Describe four examples of food chains in the Slovenian forest. Each example of a food chain should consist of at least three links (plant, herbivore, and carnivore) and should not be repeated between the chains." With this question, we wanted to check the understanding of the concept of the food chain and the knowledge of the species variety of forest organisms. We subsequently carried out ten in-depth interviews with students of the primary teacher study program who did not participate in the knowledge test. We asked them more in detail about the understanding of the presentation of the food chain (each student was shown an example of a food chain with three articles: pine → pine leaf caterpillar → cuckoo bird). We were interested in whether students know that the diagram shown is the food chain, why the plant is in the first place of the food chain, what the order of the organisms in the chain is, and what the arrows in the diagram represented.

Collected data were quantitatively processed. The data processing procedures used included descriptive statistics procedures. The frequencies (f) and percentages (f%) were calculated. The results are displayed graphically or tabularly. The data obtained through interviews were processed qualitatively.

FINDINGS

Preliminary results showed that only 11% of the students correctly cited four examples of food chains in the forest (Fig. 1). About a quarter of the respondents did not offer even one correct example of a chain. The students most often incorrectly defined plant taxa. Various plant parts, plant forms, or plants replaced by fungi and other heterotrophic organisms were cited. Students also lacked familiarity with the nutritional habits of individual groups of animals and, consequently, placed them in the wrong trophic levels. There was also a lack of understanding of the importance of arrows and their direction in the food chain. There was often no arrow or it pointed in the wrong direction, toward the primary producers. Among the errors, we also detected inadequate examples of organisms that cannot be found in forest ecosystems. Figure 2 explains students' most frequent misconceptions related to the food chain.

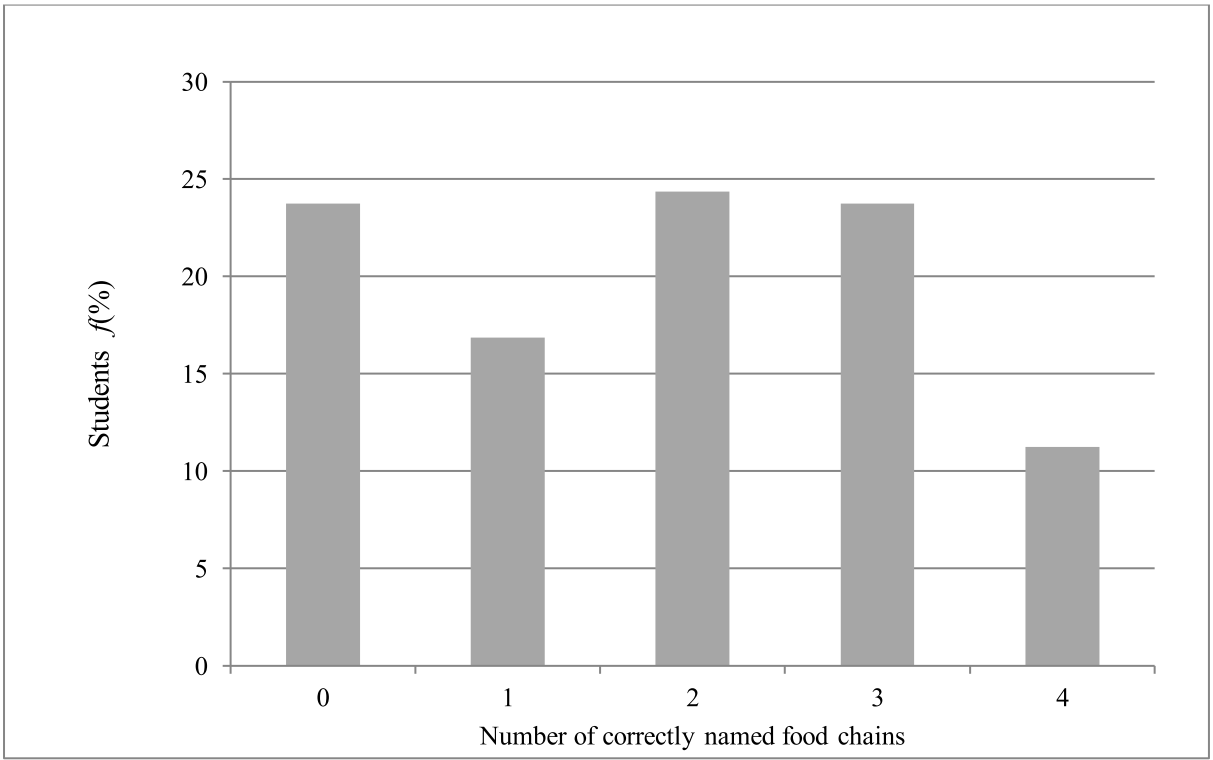

Figure 1: Frequency of students who correctly cited examples of the food chain.

Among the plants, the use of Spermatophyte samples was predominant (94.1%), and mammals (55.5%), birds (17.3%) and insects (16.4%) were among the groups of animals. The students listed twenty-four different types of plants. Plants with a total share of records exceeding 10% are grass, oak, and beech. The students listed forty-four different species of animals or groups of animals. Those most often cited in the food chains were foxes, squirrels, deer, and rabbits. Fungi were also mentioned in the food chains and were cited twenty-four times. Only in five out of twenty-four times fungi were properly placed in the food chain. Four different fungi or their groups were listed.

Table 1 & 2. List of ten most frequently mentioned species of plants and animals or their higher taxons.

Plant taxon	*f*	*f*(%)
grass	110	19.10
oak	71	12.33
beech	58	10.07
hazel	36	6.25
spruce	34	5.90
fern	29	5.03
clover	22	3.82
chestnut	13	2.26
raspberry	11	1.91
dandelion	10	1.74

Animal taxon	*f*	*f*(%)
fox	120	9.48
squirrel	110	8.69
roe deer	84	6.64
hare	83	6.56
wolf	63	4.98
bear	55	4.34
lynx	50	3.95
leaf louse	42	3.32
ladybird	40	3.16
mouse	40	3.16

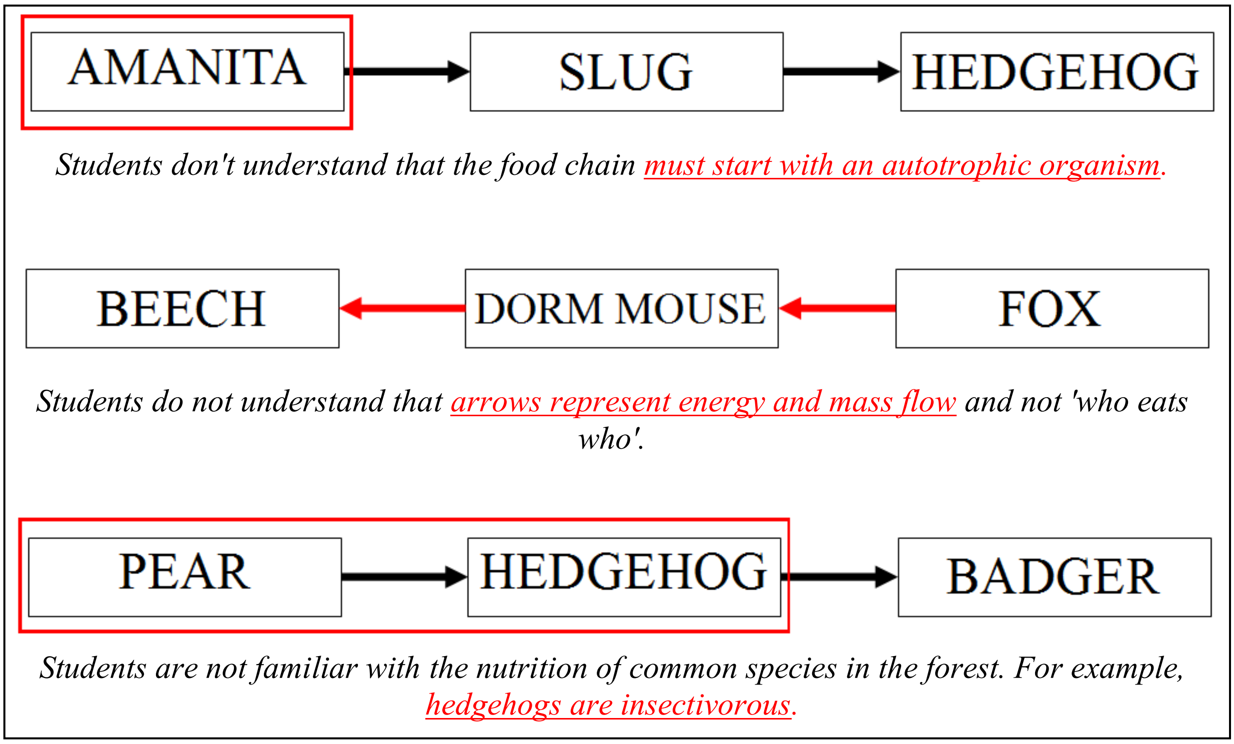

Figure 2. Examples of misconceptions about food chains.

DISCUSSION

The curriculum for preschool education expects that pre-school children learn about different natural ecosystems and relationships between organisms in ecosystems in the local environment. Among the global goals, it is stated that it is necessary to promote "experiences and learning about the living and non-living nature in its diversity, connection, constant change, and aesthetic dimensions" (Curriculum for preschool education, 1999, p. 38). Curriculum for elementary school, especially science and technology, natural sciences and biology, further develops concepts in ecology. The concepts of the food chain and food web are discussed for the first time in the fifth grade of elementary school, in the field of science and technology. Among the learning goals, it is stated that pupils need to be able to compose simple food chains and link them to the food web (Curriculum: primary education program Natural Sciences and Technology, 2011). In the first research question, we were therefore interested in whether pre-service preschool and primary teachers were properly trained in the interpretation of the concept of the food chain. From the results of the study, it can be seen that almost a quarter of respondents did not correctly compose food chains in the forest. The other three-quarters of the respondents correctly stated one, two, three or four examples of food chains in the forest.

Most of the students did not have difficulties in understanding the concept of a food chain, but they had more difficulty with knowing forest species diversity (the second research question) and animal nutrition. The students compensated for their unfamiliarity with species variety by using more general biological concepts, e.g. shrubs, trees, and undergrowth. They also referred to various plant parts (e.g., leaves, fruits) or classified fungi as primary producers. The limited number of species recorded in food chains also testifies to their limited knowledge of the diversity of tree species and other forest plants. They mostly mentioned spermatophytes, although many species of ferns and mosses can also be observed in Slovenian forests. Lack of knowledge of plants and the ability to determine plant species may reflect their lack of interest in plants and “plant blindness” (Wandersee and Schussler, 2001). Students also showed limited familiarity with animal species in the forest. Mammals predominated among species mentioned by students. They also lacked familiarity with the feeding habits of individual groups of animals, which is why they classified them incorrectly in trophic levels.

Only some of the pre-service teachers had difficulties with understanding concepts of trophic levels or the role of plants as primary producers in the food chain. Similarly, Eilam (2012) reports secondary school students to fail to regard plants as essential elements in the food chain. She reported that novice students’ definitions of food chains lacked basic ecological concepts like producers, the location of the decomposers or the function of organic matter in supplying matter as well as energy. In the present study, some students have difficulty understanding the role of arrows in the food chain – constructing food chains with missing arrows or reversely directed towards producers. It can be concluded that some students still do not understand what arrows actually illustrate. Students often explain the food chain primarily as relationships between organisms, where the predator eats prey and accordingly direct the arrows toward the primary producer. Similar problems with students’ understanding of energy transfer were reported in previous studies (Hogan, 2000; Leach et al., 1996). Wyner and Blatt (2019) report that the majority of interviewed teachers and students were unable to connect the food they eat with ecosystem food webs even though some had a proficient understanding of food web interactions, but were unable to connect school science understanding with the daily life activities. A similar conclusion can be made in the case of students' knowledge about forest species diversity which is fundamental to facilitate their construction and understanding of a food web in the authentic, local context. Only in this way, one can reasonably expect understanding and wider social support for the conservation and sustainable use of forests and other natural resources.

REFERENCES

Adeniyi, E. O. (1985). Misconceptions of Selected Ecological Concepts Held by Some Nigerian Students. *Journal of Biological Education, 19*(4), 311–316.

Allen, M. (2017). Early understandings of simple food chains: A learning progression for the preschool years. *International Journal of Science Education, 39*(11), 1485–1510.

Balvanera, P., Pfisterer, A. B., Buchmann, N., He, J. S., Nakashizuka, T., Raffaelli, D., & Schmid, B. (2006). Quantifying the Evidence for Biodiversity Effects on Ecosystem Functioning and Services. *Ecology Letters, 9*(10), 1146–1156.

Chapin III, F. S., Matson, P. A., & Vitousek, P. (2011). *Principles of terrestrial ecosystem ecology*. Springer Science & Business Media.

Eilam, B. (2012). System thinking and feeding relations: learning with a live ecosystem model. *Instructional Science, 40*(2), 213–239.

Forest Europe, (2011). *State of Europe's Forests 2011. Status and Trends in Sustainable Forest Management in Europe.* UNECE and FAO.

Griffiths, A. K., & Grant, B. A. C. (1985). High School Students' Understanding of Food Webs: Identification of a Learning Hierarchy and Related Misconceptions. *Journal of Research in Science Teaching, 22*(5), 421–436.

Hogan, K. (2000). Assessing students' systems reasoning in ecology. *Journal of Biological Education, 35*(1), 22–28.

Kurikulum za vrtce. (1999). Ljubljana: Ministrstvo za šolstvo in šport.

Leach, J., Driver, R., Scott, P., & Wood-Robinson, C. (1996). Children's ideas about ecology 3: ideas found in children aged 5-16 about the interdependency of organisms. *International Journal of Science Education, 18*(2), 129–141.

Odum, E. P., & Barrett, G. W. (2005). *Fundamentals of ecology*, 5th ed. Belmont, CA: Thomson Brooks/Cole.

Odum, E. P. (1989). *Ecology and Our Endangered Life-Support Systems*. Sunderland: Sinauer Assoc. Inc. Publishers.

Tome, D. (2006). *Ekologija: organizmi v prostoru in času*. Ljubljana: Tehniška založba Slovenije.

Učni načrt: program osnovnošolskega izobraževanja Biologija. (2011). Ljubljana, Zavod Republike Slovenije za šolstvo, str. 5–43. Pridobljeno dne 1.5.2018 s http://www.mizs.gov.si/fileadmin/mizs.gov.si/pageuploads/podrocje/os/prenovljeni_UN/UN_Biologija.pdf.

Učni načrt: program osnovnošolskega izobraževanja Naravoslovje. (2011). Ljubljana: Zavod Republike Slovenije za šolstvo, str. 6–37. Pridobljeno dne 1.5.2018 s http://www.mizs.gov.si/fileadmin/mizs.gov.si/pageuploads/podrocje/os/prenovljeni_UN/UN_naravoslovje.pdf.

Učni načrt: program osnovnošolskega izobraževanja Naravoslovje in tehnika. (2011). Ljubljana: Zavod Republike Slovenije za šolstvo, str. 5–33. Pridobljeno dne 1.5.2018 s http://www.mizs.gov.si/fileadmin/mizs.gov.si/pageuploads/podrocje/os/prenovljeni_UN/UN_naravoslovje_in_tehnika.pdf.

Wandersee, J. H., & Schussler, E. E. (2001). Toward a Theory of Plant Blindness. *Plant Science Bulletin, 47*, 2–9.

Wyner, Y., & Blatt, E. (2018). Connecting ecology to daily life: how students and teachers relate food webs to the food they eat. *Journal of Biological Education*, 1–22.

PRACTICAL PERFORMANCE ASSESSMENT OF EXPERIMENTAL COMPETENCE IN SCIENCE TEACHER EDUCATION LABORATORY CLASSES

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Laboratory classes are a key feature in chemistry studies at university level. They are meant to develop practical skills, process abilities, an awareness of the safety aspects of laboratory work and risk-assessment, acquisition of knowledge and understanding. At our home and other universities teacher trainees spend almost half of their contact time in laboratories, consuming lots of material and personal resources. Since the late 1970s some educators have seriously questioned both the effectiveness and the role of laboratory work. In order to judge the impact of lab classes, it is necessary to systematically assess the effects of laboratory instruction concerning student learning and growth.

We therefore developed an open inquiry, practical performance assessment to evaluate experimental competence of trainee chemistry teachers based on a deductively developed competence progression model. Therefore, students are confronted with an everyday object and asked to develop an experimental problem-solving-strategy. Data is collected by a written lab report, video- and audio-records via camera glasses and is qualitatively analysed to evaluate experimental competence regarding conceptual knowledge, process abilities, practical skills as well as the awareness of the safety and environmental aspects.

The results of a pilot study hints at a growth in a lot of aspects of conceptual knowledge, process abilities and foremost in practical skills. Nevertheless some problems persist which are similar to those found at school-level researches: Students seem to understand laboratory work primarily as a search for the 'correct' answer. Hence, many of them develop inquiry questions to which they already know the answer, do not generate falsifiable hypotheses, ignore unexpected observations and do not anticipate the risks of apparatus and chemicals properly.

Keywords: Laboratory Work in Science, Performance Assessment, Initial Teacher Education (Pre-service)

INTRODUCTION

Knowledge, abilities and skills concerning experiments are an important part of scientific literacy as "purpose of science education" (Bybee, McCrae, & Laurie, 2009), such as "scientific inquiry competence", "scientific inquiry", "inquiry skills" or "science practices" (Arnold, Boone, Kremer, & Mayer, 2018; Baur, 2018; Gehlen, 2016; Meier, 2016). Experimental competence is therefore addressed both in the development of curricula and international comparative studies (Gut & Mayer, 2018; Ministerium für Schule und Bildung des Landes Nordrhein-Westfalen [MSB], 2019; National Research Council [NRC], 2013), which underlines its importance among the necessary professional knowledge for chemistry teachers, too (Hartmann, Upmeier zu Belzen, Krüger, & Pant, 2015; Konferenz der Kultusminister

[KMK], 2014; Strübe, Tepner, & Sumfleth, 2017). Experimental competence is furthermore essential for safety aspects (KMK, 2014), to understand the empirical nature of science (Lederman, Abd-El-Khalick, Bell, & Schwartz, 2002) and last but not least for motivation (Becker & Hildebrandt, 2000).

Our responsibility as researchers in teacher education is the analysis of teachers' competences and their systematic development (Ferber, 2014; Rieß, 2012; Wellnitz, 2012). Laboratory classes can be regarded as a medium for instruction (Hofstein & Lunetta, 2004) to learn more about experiments but the success of this resource-intensive form of learning has hardly been studied for chemistry teacher education (Abd-El-Khalick et al., 2004; Berry, Mulhall, Gunstone, & Loughran, 1999; Hofstein & Lunetta, 2004; Kambach, 2018).

In order to learn more about the experimental competence of our students, we first compiled a model on the basis of existing models, designed an assessment that covers all relevant aspects and then developed a scoring system based on the model to evaluate students level of competence.

COMPETENCE MODEL

Experimental competence is regarded as an independently measurable competence construct (Bybee et al., 2009; Gut & Mayer, 2018) being both a possible outcome and a prerequisite for meaningful laboratory work (Abd-El-Khalick et al., 2004). In our project we understand experimental competence as a problem solving strategy (Gut & Mayer, 2018) and define it, inspired by the definition of competence by Weinert (2002), as:

> *individually utilisable conceptual knowledge, procedural abilities, practical skills, awareness of safety and environmental aspects, as well as personal motivation, willingness and creativity to use these problem-solving skills successfully and responsibly in variable situations by using experiments.*

Following this we compiled a model of experimental competence, based on extensive literature research by assigning all aspects found to the competence dimensions on three different levels, which was accomplished later by a fourth level: <I. This model was repeatedly tested in performance assessments and five times revised in an iterative-cyclical process. We are currently conducting an expert survey to validate the categorisation according to competence dimensions and the taxonomy of the levels. The current version of the model contains four aspects of ‘conceptual knowledge’, 15 of ‘procedural abilities’, five of ‘practical skills’, six of ‘awareness of safety and environment’ each on four levels and 6 of ‘personal competence’ on three levels. By the large extent of aspects we try to cover the competence construct as completely as possible, in order to avoid an underrepresentation of the actual scope of competence (Messick, 1995).

Conceptual knowledge is defined here as propositional or declarative knowledge of facts, concepts, principles (Shavelson & Ruiz-Primo, 1999), that is derived from what is mentioned by the participants in the assessment. Procedural abilities are defined as procedural knowledge (Gut & Mayer, 2018) and abilities that are needed to acquire empirical evidence (Mayer, 2007; Shavelson & Ruiz-Primo, 1999) and that are applied to a concrete problem or phenomenon given in the assessment. Practical skills are defined as actions controlled at the sensomotoric level (Emden, 2011) in the form of the exercise of scientific techniques at the practical level (Meier, 2016).

Each aspect is represented on four levels referring to the quality, problems are solved with: level <I: insufficient concerning demands of lab class, level I: sufficient, reproducing, level II: satisfactory, applying, level III: most complex, reflecting.

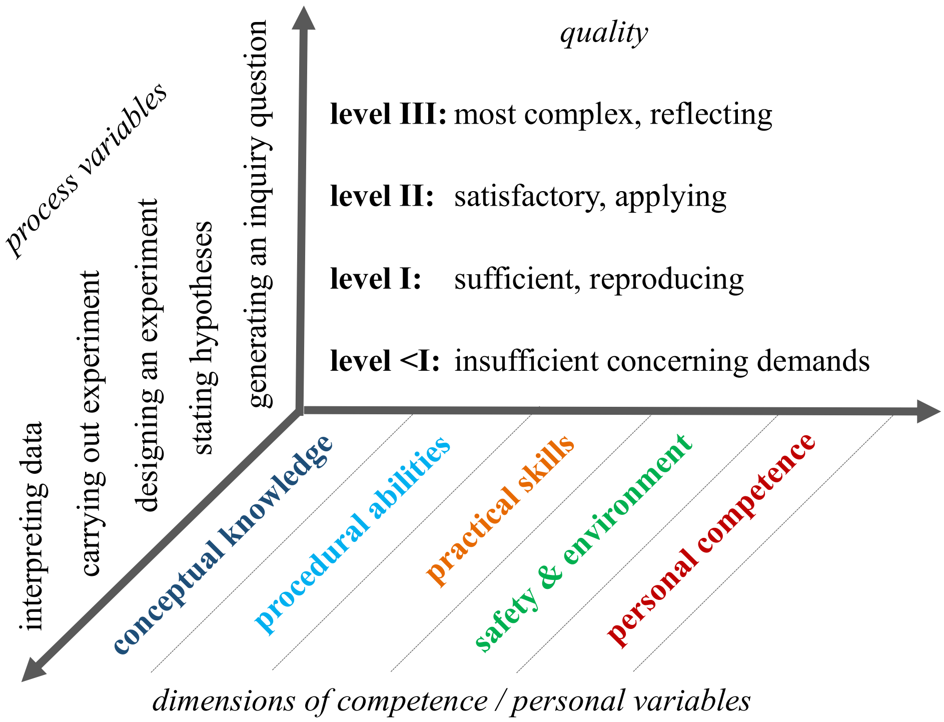

Figure 1. Model of experimental competence.

Although most aspects found in existing literature are regarded as process-orientated, the conceptual expertise determines the quality of the solution to the highest degree (Hammann, 2004; Vorholzer, 2015). Considering this, the differentiation in competence dimensions is not absolute, but rather analytical as was also shown in an expert rating. Nonetheless it is supposed to allow a more precise diagnosis and thus, in the long run, to support learners individually.

For example, the stating of hypotheses, though it requires a lot of knowledge, is considered as a procedural ability to gain evidence. On level one students utter assumptions concerning their inquiry question. On level two they are supposed to add reasons and mention relevant variables and on level three they have to explain their hypothese(s) theory-based.

Our competence model is used for self-assessment, as well as for external assessment, i.e. interpreting laboratory reports, video and audio data acquired from the performance assessments. In order to test the reliability of the competence model, Cronbach's Alpha was calculated for 203 self-assessments by chemistry-students before and after their first semester. A value of .940 was achieved for the entire construct and values between .692 and .906 for the individual competence dimensions.

PERFORMANCE ASSESSMENT

Assessing experimental competence is described as a need for science education research (Abd-El-Khalick et al., 2004; Gut & Mayer, 2018). There are many ways by which experimental competence has been tried to be measured such as paper and pencil test, computer-based simulation or performance assessment, of which the latter is considered the most adequate (Arndt, 2016; Arnold et al., 2018; Dickmann, 2016; Emden, 2011; Kambach, 2018; Schreiber, 2012; Shavelson & Ruiz-Primo, 1999). Ruiz-Primo & Shavelson (1996) define it as 'an assessment that provides students with laboratory equipment, poses a problem, and allows students to use these resources to generate a solution.' However, performance assessments are not undisputed, because they cause an enormous expenditure of costs and time, especially in evaluating data (Dickmann, Eickhorst, Theyßen, Neumann, & Schreiber, 2014). In addition, the results can vary greatly in relation to time and task (Gut & Mayer 2018), which can be also true for more standardised written tests (Dickmann, 2016). Since we did not find any studies on the development of experimental competence among university chemistry students, we decided to explore practical performance assessment in a qualitative setting in order to obtain first insights.

Based on our definition and model, competence is always related to specific problems and therefore needs to be assessed with specific tasks. These must be open (Bell & Banchi, 2008) and concerned to everyday life phenomena (Abd-El-Khalick et al., 2004). We developed an open practical performance assessment that enables students to create their own inquiry question (Fricke, 2018) and pursue an individually constructed experimental path, including the generation of hypotheses, experimental design and the evaluation of hypotheses. By doing so, participants have to search in a hypothesis space as well as in an experimental space according to Scientific Discovery as Daul Search [SDDS] (Klahr & Dunbar, 1988). Thus we try to examine as much as possible of what is understood as experimental competence.

So far two different tasks have been implemented, in which participants must develop ideas what to do with either mulled white wine after Christmas or with the remaining brine of pickled gherkins. In both cases they were asked to

1. generate an inquiry question,
2. state hypotheses,
3. design an experiment,
4. carry out an experiment and observe/measure and
5. analyse data and draw conclusions.

While students are familiar with these five process-steps, they are not with the phenomenon, which varies. Thus competence-irrelevant aspects of the task are minimized (Messick, 1995) and the complexity of the open setting reduced.

The assessment consists of three parts. After distribution of the task, participants have 15 minutes to prepare, 40 minutes to conduct and 15 minutes for postprocessing and writing a laboratory report. While working in laboratory, students are wearing camera glasses recording video and audio data. To ensure safety aspects and offer assistance when needed, they are accompanied by a lab assistant. The latter also asks given questions, such as 'Which hypotheses would you like to test regarding your inquiry question?' or 'which security aspects do you have to consider?' This standardises the assessment as a response format (Ruiz-Primo & Shavelson, 1996) to a certain degree by structuring, allowing comparability of different experimental approaches and reduces the extraneous cognitive load of participants (Reiners, 2017) just as the everyday life context does (Krell, 2018; Mayer, 2007; Ziemek, Keiner, & Mayer, 2005). But at the same time, we have to be careful not to suggest the impression of a uniform scientific method, which does not exist in such a way (Lederman et al., 2002). So far there is no evidence that the order of process in a scientific activity indicates a high or low level of experimental competence (Shavelson & Ruiz-Primo, 1999; Arndt, 2016; Meier, 2016; Gut & Mayer, 2018), so we do not expect any negative effects of this guidance.

EVALUATION

In each exam, data is collected by students' free verbal expressions, answers to the guided questions of the assistants, observable actions and written lab reports. This allows us to focus not only on a product, but also on more procedural abilities and manual skills (Gehlen, 2016; Schreiber, 2012), i.e. to consider experimental competence as comprehensively as possible. Nonetheless it remains a very complex, multilayered and highly inferent construct. All data are analysed according to Mayring (2014) through qualitative content analysis. Therefore, we first identify any event that might provide insight into the experimental competence of the participant and then attribute a category and level to each one.

So far, 43 examinations have taken place with 31 candidates. Except from one student who did a synthesis, all of them followed one of these three different problem-solving approaches, regardless whether the task was about pickled gherkins or on muled wine:

1. qualitative *analysis* of substances (especially ions contained),
2. measurement of quantity by *distillation* and
3. by *titration*.

These approaches can be regarded as experimental problem types similar to those stated by Metzger, Gut, Hild & Tardent (2014). Thus, to foster the reliability of evaluation we also differentiate between these three experimental approaches by using three different coding guidelines. These vary in the inductively derived anchor examples for each problem type but in one point also in the categories: in a titration stoichiometric calculation is an important aspect that does not occur with distillation or analysis.

Until now we have arranged a suitable guide for distillation with the help of assessments of a preliminary study. For example, if participants answer to the question about their hypothesis that alcohol can be separated from wine by heating it in a distillation apparatus, this is coded as level I. If this separation is explained to some extent by everyday experience it is coded as level II and as level III, if different boiling points of ethanol and water differ are explained on sub-microscopic level.

So far, six assessments of a different sample have been evaluated in detail by two intercoders with mostly acceptable reliabilities around 0.80 according to Holsti. The results are summarised in a grid, thus offering the opportunity to compare performance at different times (pre/post lab class or at different stages of their study), between students and with their self-evaluation.

FIRST RESULTS

Although only a few data have been systematically evaluated so far, the assessment format and competence model have been developed to such an extent that we can gain first insights into the experimental competence of pre-service chemistry teachers. Overall, an increase in experimental competence could be observed after lab classes and at later stages of studies, which mainly affected conceptual knowledge, process abilities and practical skills. However, it is hard to say whether these progressions are the outcome of the laboratory classes or of other influence. Similar to results found at school-level projects (Berry et al., 1999; Hofstein & Lunetta, 2004; Kambach, 2018; Meier, 2016) our study reveals particular deficiencies which have to be addressed in teacher education:

- Research questions and hypotheses are often constructed around specific experimental methods typically connected to the phenomenon, and thus mostly serve as a confirmation of students' pre-existing expectations ('confirmation bias' (Kambach, 2018)).
- Learners do not refer to their knowledge, even if they have it, when formulating hypotheses, analysing data and, above all, on security aspects.
- Thus hazards that may arise from materials and chemicals often cannot be anticipated or dismissed.
- Control-of-variables strategy is sometimes inadequate, rarely considered explicitly.
- Measurements are performed inaccurately, and observations and data are inadequately processed.
- Data are only evaluated according to expectations.
- Errors are rarely explained, procedural errors and limits of the experiment are only partially recognized, although they are sometimes corrected during performance.

CONCLUSION AND OUTLOOK

We will develop our model and assessment format further to achieve an even higher degree of validity and reliability. Therefore, we have started an expert survey on the gradation and categorisation of the competence model, will develop coding guidelines for the other two experimental problem types ('analysis' and 'titration') and test a third task beside 'wine' and 'brine'. Based on this, further strategies will be developed to examine more profoundly and quantitatively.

Our open assessment certainly poses high demands on our students (Kirschner, Sweller, & Clark, 2006). However, these are comparable to those in schools, where teachers have to design an inquiry question about an everyday life phenomenon relevant to their students and guide them through an exemplary ideal-typical experimental process (KMK, 2014; MSB, 2019; NRC, 2013). Therefore, teachers have to be experimentally competent to a high degree. In order to achieve this goal, our competence model and practical assessment give us the possibility to diagnose the competence level individually and differentiated, to work out which aspects need to be addressed more intensively in laboratory classes. Perhaps school-level interventions could serve this purpose, such as to open up experiment instructions (Bernholt, Walpuski, Parchmann, & Sumfleth, 2009), to train assistants more intensively (Fricke, 2018), to address control-of-variables strategy explicitly (Schwichow, Croker, Zimmerman, Höffler, & Härtig, 2016) as well as scientific methodology (Mannel, 2011; Reiners 2017), to offer further training (Telser, 2019), to foster cognitive activation (Platova, 2017) or to provide systematic feedback (Marschner, 2011).

REFERENCES

Abd-El-Khalick, F., BouJaoude, S., Duschl, R., Lederman, N., Mamlok-Naaman, R., Hofstein, A., . . . Tuan, H.-l. (2004). Inquiry in science education: International perspectives. *Science Education*, *88*(3), 397–419.

Arndt, K. (2016). *Experimentierkompetenz erfassen*. Berlin: Logos.

Arnold, J., Boone, W., Kremer, K., & Mayer, J. (2018). Assessment of Competencies in Scientific Inquiry Through the Application of Rasch Measurement Techniques. *Education Sciences, 8*(4), 184.

Baur, A. (2018). Fehler, Fehlkonzepte und spezifische Vorgehensweisen von Schülerinnen und Schülern beim Experimentieren. *Zeitschrift für Didaktik der Naturwissenschaften, 24*(1), 115–129.

Becker, H.-J., & Hildebrandt, H. (2000). Interessen und Motivation als Gegenstand der chemiedidaktischen Ausbildung - Fehlanzeige? In R. Brechel (Ed.): *Zur Didaktik der Physik und Chemie. Probleme und Perspektiven. Vorträge auf der Tagung für Didaktik der Physik, Chemie in München 1999* (pp. 84–86). Alsbach: Leuchturm.

Bell, R., & Banchi, H. (2008). The Many Levels Inquiry of Inquiry comes in various forms. *Science and Children, 46*(2), 26–29.

Bernholt, S., Walpuski, M., Parchmann, I., & Sumfleth, E. (2009). Kompetenzentwicklung im Chemieunterricht: Mit welchen Modellen lassen sich Kompetenzen und Aufgaben differenzieren? *NiU Chemie, 20*(111/112), 78–85.

Berry, A., Mulhall, P., Gunstone, R., & Loughran, J. (1999). Helping Students Learn from Laboratory Work. *Australian Science Teachers Journal, 45*(1), 27–31.

Bybee, R., McCrae, B., & Laurie, R. (2009). PISA 2006: An assessment of scientific literacy. *Journal of Research in Science Teaching, 46*(8), 865–883.

Dickmann, M. (2016). *Messung von Experimentierfähigkeiten*. Berlin: Logos.

Dickmann, M., Eickhorst, B., Theyßen, H., Neumann, K., & Schreiber, N. (2014). Measuring experimental skills in large-scale assessments: Developing a simulation-based test instrument. In C. P. Constantinou, N. Papadouris, & A. Hadjigeorgiou (Eds.), *Science Education Research For Evidence-based Teaching and Coherence in Learning: Proceedings of the ESERA 2013 Conference*. Nicosia, Cyprus.

Emden, M. (2011). *Prozessorientierte Leistungsmessung des naturwissenschaftlich-experimentellen Arbeitens: Eine vergleichende Studie zu Diagnoseinstrumenten zu Beginn der Sekundarstufe I*. Berlin: Logos.

Ferber, N. I. (2014). *Entwicklung und Validierung eines Testinstruments zur Erfassung von Kompetenzentwicklung im Fach Chemie in der Sekundarstufe I*. Berlin: Logos.

Fricke, A. (2018). *Interaktive Skripte Im Physikalischen Praktikum: Entwicklung und Evaluation von Hypermedien für die Nebenfachausbildung*. Berlin: Logos.

Gehlen, C. (2016). *Kompetenzstruktur naturwissenschaftlicher Erkenntnisgewinnung im Fach Chemie*. Berlin: Logos.

Gut, C., & Mayer, J. (2018). Experimentelle Kompetenz. In D. Krüger, I. Parchmann, & H. Schecker (Eds.), *Theorien in der naturwissenschaftsdidaktischen Forschung* (pp. 121–141). Berlin: Springer.

Hammann, M. (2004). Kompetenzentwicklungsmodelle: Merkmale und ihre Bedeutung - dargestellt anhand von Kompetenzen beim Experimentieren. *MNU, 57*(4), 169–203.

Hartmann, S., Upmeier zu Belzen, A., Krüger, D., & Pant, H. A. (2015). Scientific Reasoning in Higher Education: constructing and evaluating the criterion-related validity of an assessment of pre-service science teachers' competencies. *Zeitschrift für Psychologie, 223*(1), 47–53.

Hofstein, A., & Lunetta, V. N. (2004). The laboratory in science education: Foundations for the twenty-first century. *Science Education, 88*(1), 28–54.

Kambach, M. (2018). *Experimentierprozesse von Lehramtsstudierenden der Biologie* (Dissertation. Humboldt-Universität zu Berlin, Germany).

Kirschner, P. A., Sweller, J., & Clark, R. E. (2006). Why Minimal Guidance During Instruction Does Not Work: An Analysis of the Failure of Constructivist, Discovery, Problem-Based, Experiential, and Inquiry-Based Teaching. *Educational Psychologist, 41*(2), 75–86.

Konferenz der Kultusminister (2014). *Ländergemeinsame inhaltliche Anforderungen für die Fachwissenschaften und Fachdidaktiken in der Lehrerbildung*: Beschluss der Kultusministerkonferenz vom 16.10.2008 i.d.F. vom 09.10.2014.

Krell, M. (2018). Schwierigkeitserzeugende Aufgabenmerkmale bei Multiple-Choice-Aufgaben zur Experimentierkompetenz im Biologieunterricht: Eine Replikationsstudie. *Zeitschrift für Didaktik der Naturwissenschaften, 24*(1), 1–15.

Lederman, N., Abd-El-Khalick, F., Bell, R., & Schwartz, R. (2002). Views of nature of science questionnaire: Toward valid and meaningful assessment of learners' conceptions of nature of science. *Journal of Research in Science Teaching, 39*(6).

Mannel, S. (2011). *Assessing scientific inquiry: Development and evaluation of a test for the low-performing stage*. Berlin: Logos.

Marschner, J. (2011). *Adaptives Feedback zur Unterstützung des selbstregulierten Lernens durch Experimentieren*.

Mayer, J. (2007). Erkenntnisgewinnung als wissenschaftliches Problemlösen. In D. Krüger & H. Vogt (Eds.), *Theorien in der biologiedidaktischen Forschung: Ein Handbuch für Lehramtsstudenten und Doktoranden* (pp. 177–186). Berlin: Springer.

Mayring, P. (2014). *Qualitative content analysis: theoretical foundation, basic procedures and software solution*. Klagenfurt.

Meier, M. (2016). *Entwicklung und Prüfung eines Instruments zur Diagnose der Experimentierkompetenz von Schülerinnen und Schülern*. Berlin: Logos.

Messick, S. (1995). Validity of psychological assessment: Validation of inferences from persons' responses and performances as scientific inquiry into score meaning. *American Psychologist, 50*(9), 741–749.

Metzger, S.; Gut, C.; Hild, P.; Tardent, J. (2014): Modelling and assessing experimental competence: An interdisciplinary progress model for hands-on assessments. In: C. P. Constantinou, N. Papadouris & A. Hadjigeorgiou (Eds.): *Science Education Research For Evidence-based Teaching and Coherence in Learning. Proceedings of the ESERA 2013 Conference* (pp. 2063–2070). Nicosia, Cyprus: European Science Education Research Association (Strand 11).

Ministerium für Schule und Bildung des Landes Nordrhein-Westfalen (2019). *Kernlehrplan für die Sekundarstufe I Gymnasium in Nordrhein-Westfalen Chemie*.

National Research Council (2013). *Next Generation Science Standards*. Washington, D.C.: National Academies Press.

Platova, E. (2017). *Optimierung eines Laborpraktikums durch kognitive Aktivierung*. Berlin: Logos.

Reiners, C. S. (2017). *Chemie vermitteln*. Berlin, Heidelberg: Springer Berlin Heidelberg.

Rieß, W. (2012). Ein (fachdidaktisches) Rahmenmodell zum Experimentieren im mathematisch-naturwissenschaftlichen Unterricht. In W. Rieß, M. A. Wirtz, B. Barzel, & A. Schulz (Eds.), *Experimentieren im mathematisch-naturwissenschaftlichen Unterricht: Schüler lernen wissenschaftlich denken und arbeiten* (pp. 153–164). Münster: Waxmann.

Ruiz-Primo, M. A., & Shavelson, R. J. (1996). Rhetoric and reality in science performance assessments: An update. *Journal of Research in Science Teaching, 33*(10), 1045–1063.

Schreiber, N. (2012). *Diagnostik experimenteller Kompetenz: Validierung technologiegestützter Testverfahren im Rahmen eines Kompetenzstrukturmodells*. Berlin: Logos.

Schwichow, M., Croker, S., Zimmerman, C., Höffler, T., & Härtig, H. (2016). Teaching the control-of-variables strategy: A meta-analysis. *Developmental Review, 39*, 37–63.

Shavelson, R. J., & Ruiz-Primo, M. A. (1999). Leistungsbewertung im naturwissenschaftlichen Unterricht: Evaluation in Natural Science Instruction. *Zeitschrift für Lernforschung, 27*(2), 102–127.

Strübe, M., Tepner, O., & Sumfleth, E. (2017). Einsatz von Experimenten im Chemieunterricht. Ergebnisse aus ProwiN 2. In C. Maurer (Ed.), *Implementation fachdidaktischer Innovation im Spiegel von Forschung und Praxis: GDCP-Jahrestagung in Zürich 2016* (pp. 384–387). Regensburg: GDCP.

Telser, V. (2019). *Erfassung und Förderung experimenteller Kompetenz von Lehrkräften im Fach Chemie*. Berlin: Logos Berlin.

Vorholzer, A. S. (2015). *Wie lassen sich Kompetenzen des experimentellen Denkens und Arbeitens fördern?* Berlin: Logos.

Weinert, F. E. (2002). Vergleichende Leistungsmessungen in Schulen. In F. E. Weinert (Ed.), *Leistungsmessungen in Schulen* (2nd ed., pp. 17–31). Weinheim: Beltz.

Wellnitz, N. (2012). *Kompetenzstruktur und -niveaus von Methoden naturwissenschaftlicher Erkenntnisgewinnung*. Berlin: Logos.

Ziemek, H.-P., Keiner, K.-H., & Mayer, J. (2005). Problemlöseprozesse von Schülern der Biologie im naturwissenschaftlichen Unterricht: Ergebnisse quantitativer und qualitativer Studien. In R. Klee, A. Sandmann, & H. Vogt (Eds.), *Forschungen zur Fachdidaktik* (pp. 29–40). Innsbruck, Wien, Bozen: Studien.

SURVEYING UNIVERSITY STUDENTS' PROBLEM SOLVING SKILLS IN REALISTIC SETTINGS

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Solving problems in physics is one of the core learning objectives in physics education on all levels. In our study we analyze the problem solving skills of German first year university students. Here the typical problems are fairly mathematised and complex. For this we developed a new test instrument that mimics the appearance of a real problem sheet used in typical tutorials and that can be used at three test times during the first year. The students solve these problems and are interviewed about their solving process afterwards.

Based on these data, we are able to distinguish two groups of problem solvers which differ by their overall success but which also show significant differences in the used resources – content knowledge and problem schemes. The latter are of special interest because they are only rarely taught explicitly in those classes.

Keywords: Problem Solving; Diagnostic Tools; Higher Education

INTRODUCTION

Learning to solve physical problems is one of the core objectives in physics education on all levels. At German universities physics students typically attend frontal lectures laying out relevant content knowledge and additional tutorials where students get (typically fairly mathematised and complex) problems for homework which then are discussed (and probably graded) the week after. These tutorials and the discussed problems can thus be seen as a core learning opportunity when studying physics – both for factual knowledge and for problem solving skills. The efficacy of these classes in teaching problem solving skills is however relatively underresearched.

In our project we investigate the problem solving skills of first year students at a German university by using a setting very similar to the real-world situation of solving tutorial problems. In the analysis we concentrate on the overall success and on cognitive resources (physics knowledge and problem schemes) used. The findings could be used to improve the relevant classes and to help students to efficiently acquire problem solving skills.

THEORETICAL BACKGROUND

A problem in general is classically defined containing three features: an initial state (which is known), a goal state (which is to be reached) and a gap between them that has to be bridged (Maloney, 2011). Our study is based on the more specific problem definition by Smith (1991, p. 8): "A problem is any task that requires analysis and reasoning toward a goal (or 'solution'). This analysis and reasoning must be based on an understanding of the domain from which the task is drawn. A problem cannot be solved by recall, recognition, or reproduction […]. Whether or not a task is defined as a problem is not determined by how difficult or by how perplexing it is for the intended solver. 'Problem solving,' therefore, becomes the process by which a system generates an acceptable solution to such a problem." which accounts for problems that can be identified as knowledge based, i.e. that requires knowledge of the domain to be solved efficiently.

The process of solving such problems is often described as a series of steps without prescribing their order of execution (Dewey, 2002; Pólya, 1985). The contemporary model by Friege (2001; figure 1) describes the solving process of knowledge based problems in four steps: During the problem representation the solver generates a mental model of the posed situation (Savelsbergh, 1998).

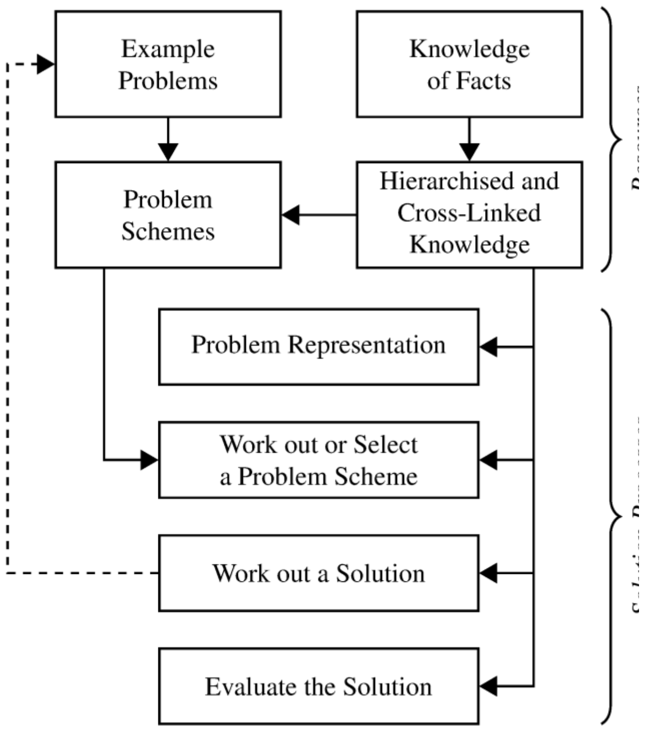

Figure 1: Model of knowledge based problem solving (Friege, 2001).

To find an approach, novices may use one or several strategies described in literature (Larkin, McDermott, Simon, & Simon, 1980). Experts however often just seem to know the right solution approach because of their expertise in the field and often show some kind of intuition which relies on a kind of specialised knowledge of typical problems and their solutions (VanLehn, 1989).

Based on this approach, the solver then works out the solution and probably evaluates it. After that evaluation – but in principle at any other point in the process – the problem solver might jump into another step to redo some of the work. Finally, the worked out solution might generate a new example problem and thus helps to solve other, similair problems.

For this process, the problem solver has to use two distinct cognitive resources: A hierarchised and cross-linked knowledge of the domain is essential for virtually all steps as it forms the cognitive basis for understanding the problem text, relating it to a mental model, and carrying out any further work that is based on any knowledge of facts or procedures within that domain. That content knowledge typically can be easily tested by paper-pencil-tests (like Woitkowski, Riese, & Reinhold, 2014).

The more interesting resource (at least in our context) are problem schemes which play a crucial role in finding a suitable solution approach. These can be considered the main source for experts expertise and intuition. The notion of problem schemes is based on the observation that novices sort given problems according to surface characteristics, while expert sort according to common structures of typical approaches and solution strategies Chi, Feltovich, and Glaser (1981). This can be interpreted as indications the existence of schemes (Friege & Lind, 2006), i. e. groups of problems based not on surface characteristics but on the underlying structure and working mechanisms. These Schemes are generated (i.e. learned) by aggregating several example problems' solutions and grouping them into problem classes by abstracting from interchangeable objects and identifying similar structures in each problem (Kolodner, 1983).

RESEARCH QUESTIONS

Out of the broader research interest of the project KEMΦ (Development of Competencies in Physics during the First Year at University), for this paper we concentrate on the problem solving skills of first year physics students at German universities. We will discuss the following two questions:

(1) In what way can more and less successful problem solvers be characterised?

(2) What resources are used for solving the problems, and to what extend can we find evidence for the use of problem schemes?

The results here may lead us in improving the students' learning of problem solving skills at universities.

METHOD

Sample and Times of Testing

The sample was recruited in the context of the KEMΦ content knowledge test, which is administered to physics students in their very first week at German universities. Those students were asked to participate in an additional study concerning their problem solving skills. In autumn 2017 eight students could be recruited this way. Two further tests were administered to the same group at the end of their first and their second semester.

A sample overview is shown in table 1. Six participants were enrolled as physics students, two to become physics secondary school teachers. The reported grades are comparable with the grades of the whole cohort. Two participants dropped out after the first time of testing.

Test Instrument

For this study, an interview guide and 3 problem sheets – one for each time of testing – where devised. Each sheet first contains a standard problem that is probably known to the students, and three mathematically or conceptually more advanced problems. Each sheet's problems can be solved with variations of the same scheme in the domain of classical mechanics (schemes from Chi et al., 1981; 1st: inclined launch and equations of motion; 2nd: balance of forces and

Test Person	ToT	Programme	Final Exam Grade (Abitur)	Last Grade in Physics at School
KID16	1–3	Physics	1	1–
MRE04	1–3	Physics	1,5	2,0
NBR16	1–3	Physics	1,5	1,0
NLD03	1	Teacher	2,6	1,0
NEN15	1–3	Physics	1,6	1,0
NHL10	1	Physics	3	3
NRD02	1–3	Physics	1	1+
UHI30	1–3	Teacher	2	1

Table 1: Sample overview. Grades are given from 1 (best) till 6 (worst) as reported by the students. ToT is the time of testing the test persons took part in.

harmonic oscillation; 3rd: conservation of energy and momentum) within different outer contexts. This allows for a more detailed analysis on the cost of only covering few schemes.

The problem sheets are designed to match real exercise sheets from the students' physics lectures, both in outer appearance and in problem selection. To make the test situation further similar to the real world setting, students may use a calculator, books, lecture notes or the internet during the problem solving process as required.

The test persons first get an introduction into the method of thinking aloud and then solve the given problems this way. This typically takes about 60 to 90 minutes. The following 30-minute interview consists of 4 phases as in table 2.

Audio of both parts of the test is recorded and transcribed; written solutions are collected. For analysis, the interview and written solution were considered primarily, as the audio from the problem solving process is often rather difficult to understand and to follow without the more explicit explanations in the interview.

RESULTS

Characterisation of successful problem solvers

The interview data combined with the written solution give a coherent image of the success in solving the problems. We were able to generate five levels of success from the data: (A) difficulties with the problem representation, (B) no working solution approach, (C) partially working approach, (D) working approach with difficulties later on and (E) correct solution. Those categories correspond to specific steps of the model in figure 1. All 5 categories were found in the material.

Interesting here is that all four problem solutions by one test person at one time of testing either fall into the categories A, B and / or C or all four solutions fall into the more successful

Part 0	*Without looking at problem sheet or solutions* What was the overall topic of the problems? Give a specific account of the problem texts. (problem representation) Where there similarities between the problems? (surface or structural, problem schemes)
Part 1	*Without own solution* General approach to the problem sheet (order of solution, correspondence with real exercise sheets) Self assessed success (self-perception, recognition of in-/correct solutions) Sort problems by difficulty (difficulty generating problem characteristics, reflection of own skills)
Part 2	*Problems are discussed in the order they were solved* Comprehensibility of the problem (problems with representation or content knowledge) Solution approach (how approach was found, indicators for problem schemes) Difficulties with further solution (possible factors for giving up on problem, missing knowledge)
Part 3	Comparison to real exercise sheet (validity concerns, degree of realism)

Table 2: The four interview phases. For every given question its intention is given in brackets.

categories C, D and / or E. This can interpreted as an easy, albeit coherent way to differentiate two degrees of overall success when solving these problems.

The two test persons who dropped out of the study after the first test exhibited less success in solving the problems.

Used resources and problem schemes

Identifying problem schemes is more interpretative and was done in a two step procedure. First, indicators for the presence of a scheme are devised from literature as (1) problem scheme is explicitly named and explained (Larkin, 1983); (2) problem representation is very short or left out entirely (Simon & Simon, 1978); (3) students indicate routine or approaches being intuitively clear (Reinhold, Lind, & Friege, 1999; VanLehn, 1989); (4) the solution seems intuitively clear to the student (Chi, Glaser, & Rees, 1982) and typically (5) all solutions have at least a correct solution approach (Chi et al., 1982).

On this basis the students' performance on the whole test including the interview can be categorised by the degree of presence of problem schemes: (O) no indication for problem scheme; (P) first indication for developing problem scheme; (Q) during the test the scheme is developed to be successfully used at least at the last problem; (R) the solution approach part (algorithm) of the scheme is functionally available while the classification of problems is not fully able to decide when to use the scheme; (S) the problem scheme is fully developed from the beginning.

Here we see that in eight of the twenty tests the scheme was developed either at category R or S and those test persons had correct approaches to most or all of the problems. The case of students developing the scheme during the test only occurs in three cases. The other nine cases showed no scheme (category O or P).

Two interesting results are that students who exhibit successful problem solving most of the time also show strong indicators for the use of problem schemes. On the other hand, those who did not succeed in solving the problems also showed next to no indicators of problem schemes. Further, students who exhibits signs of problems with the needed content knowledge also show no signs of available problem schemes.

DISCUSSION AND CONCLUSION

This test format can be used to gain relevant information about students' problem solving abilities. When asked about the level of authenticity of these problems, the student indicated that these problem sheets where realistic in form but comparatively short (which was intended to keep required times manageable). Several of the problems where known as standard problems to the more successful students.

Although the problems and schemes differed between test times, we see an overarching difference between students who are successful and those who are not. Two main differences can be identified between these relatively stable groups: The less successful group was not able to choose appropriate knowledge for interpreting and approaching the problem. The more successful group mostly could use the appropriate problem scheme to quickly and safely find a suitable approach which may be interpreted as having more "routine".

These results can be seen as strong reasons to see problem schemes as a major factor when it comes to the ability to solve typical physics problems. However, the finding that about half of the students tested do not show signs of available problem schemes and must be regarded as very poor problem solvers – even after the first year of studying physics at university – must be considered problematic.

Concerning physics classes at university, this poses the question why some of the students successfully acquire these schemes and some do not. One element here might be a lack of content knowledge (which is used to generate these schemes by abstraction and grouping) but another might be a lack of practice (more example problems would give them more material to work on when generating those schemes). This poses the question how we can revise our lectures and tutorials to enable those less successful students to do that abstraction and grouping step which helps them generate usable problem schemes?

From theory, we would expect two strategies to be relevant when fostering the acquisition of problem schemes: First, students should discuss the solution to several problems in detail, and especially discuss the structure of their respective solution. This should enable the students to collect a larger reservoir of example problems. Secondly, students should discuss heuristics of the kind “when do we use this strategy or that approach” and be instructed to regard the deeper functional structure of a problem situation rather than surface characteristics. This might foster the classification of known example problems into categories which then might help generate problem schemes.

ACKNOWLEDGEMENT

This research was funded by the Deutsche Forschungsgemeinschaft (DFG, German Research Foundation) – WO 2181/2-1.

REFERENCES

Chi, M. T. H., Feltovich, P. J., & Glaser, R. (1981). Categorization and representation of physics problems by experts and novices. *Cognitive Science, 5*, 121–152.

Chi, M. T. H., Glaser, R., & Rees, E. (1982). Expertise in problem solving. In R. J. Sternberg (Ed.), *Advances in the Psychology of Human Intelligence*. Hillsdale, NJ: Erlbaum.

Dewey, J. (2002). Wie wir denken. [How we think.] Zürich: Pestalozzianum.

Friege, G. (2001). *Wissen und Problemlösen: Eine empirische Untersuchung des wissenszentrierten Problemlösens im Gebiet der Elektrizitätslehre auf der Grundlage des Experten-Novizen-Vergleichs. [Knowledge and problem solving. An empirical investigation of knowledge based problem solving in the domain electricity on the base of expert-novice comparisons]*. Studien zum Physiklernen: Vol. 19. Berlin: Logos.

Friege, G., & Lind, G. (2006). Types and Qualities of Knowledge and their Relations to Problem Solving in Physics. *International Journal of Science and Mathematics Education, 4*(3), 437–465.

Kolodner, J. L. (1983). Toward an understanding of the role of experience in the evolution from novice to expert. *International Journal of Man-Machine Studies, 19*, 497–518.

Larkin, J. H. (1983). The Role of Problem Representation in Physics. In D. Gentner & A. L. Stevens (Eds.), *Mental Models* (pp. 75–98). Hillsdale, NJ: Lawrence Erlbaum.

Larkin, J. H., McDermott, J., Simon, D. P., & Simon, H. A. (1980). Models of Competence in Solving Physics Problems. *Cognitive Science, 4*, 317–345.

Maloney, D. P. (2011). An overview of physics education research on problem solving. In C. Henderson & K. A. Harper (Eds.), *Reviews in PER Vol. 2, Getting Started in Physics Education research*. College Park, MD: American Association of Physics Teachers.

Pólya, G. (1985). *How to solve it: A new aspect of mathematical method* (2nd ed.). Princeton, NJ: Princeton University Press.

Reinhold, P., Lind, G., & Friege, G. (1999). Wissenszentriertes Problemlösen in Physik [Knowledge centered problem solving in physics]. *Zeitschrift für Didaktik der Naturwissenschaften, 5*(1), 41–62.

Savelsbergh, E. (1998). *Improving Mental Representations in Physics Problem Solving*. Enschede: Twente University.

Simon, D. P., & Simon, H. A. (1978). Individual differences in solving physics problems. In R. Siegler (Ed.), *Children's thinking: What develops?* (pp. 325–348). Hillsdale, NJ: Lawrence Erlbaum.

Smith, M. U. (1991). A View from Biology. In M. U. Smith (Ed.), *Toward a unified Theory of Problem Solving: Views from the Content Domains*. (pp. 1–19). Hillsdale, NJ: Lawrence Erlbaum.

VanLehn, K. (1989). Problem Solving and Cognitive Skill Acquisition. In M. L. Posner (Ed.), *Foundation of Cognitive Science* (pp. 527–579). Cambridge, MA: MIT Press.

Woitkowski, D., Riese, J., & Reinhold, P. (2014). Prospective physicists' and physics teachers' content knowledge – First results of a Germany-wide study. In C. P. Constantinou, N. Papadouris, & A. Hadjigeorgiou (Eds.), *E-Book Proceedings of the ESERA 2013 Conference: Science Education Research For Evidence-based Teaching and Coherence in Learning* (p. 28). Nicosia, Cyprus: European Science Education Research Association.

PART 18: STRAND 18

Methodological Issues in Science Education Research

Co-editors: *Shulamit Kapon & Marianne Odegaard*

CONTENTS

STRAND 18: INTRODUCTION

METHODOLOGICAL ISSUES IN SCIENCE EDUCATION RESEARCH ASPECTS OF EPISTEMOLOGY, ONTOLOGY AND AXIOLOGY.

The focus of the presentations in Strand 18 - Methodological Issues in Science Education Research - is not the generation of novel knowledge or insights in science education, but rather the processes by which this knowledge and insights are created, validated, evaluated, and disseminated. Papers in this strand can be situated in any context of science education research; the common ground is the focus on the research methods, and the discussion of aspects of epistemology, ontology and axiology.

The contributions to this year proceedings include five chapters that present and problematize a span of methodological issues in science education research. The first two chapters discuss instruments and surveys. Toma et al. problematize and question the validity of existing instruments for measuring students' attitudes in science education, by critical examination of their psychometric properties. Teo discusses the design and validation of a survey that aims to measure science teachers' views about students with special needs, the self-efficacy of these teachers about teaching students with special needs, and their familiarity with teaching practices appropriate for inclusive science classrooms. The next two chapters discuss innovative research methods in science education research. Bolte et al. show how eye tracking can be used to examine the applicability of Gestalt psychology principles to effective design of demonstration in chemistry. Espinoza et al. examine the applicability and efficiency of machine learning for automated content analysis that identifies different inquiry-based learning phases in transcriptions of authentic face-to-face discussions of students; and compare it to human coding. The last chapter focus on systematic methods for curriculum design. Kamphorst and Kersting argue that the combination of Design Based Research, and the Model of Educational Reconstruction provides a productive synergy that can guide effective curriculum design particularly in abstract areas such as modern physics.

Marianne Ødegaard & Shulamit Kapon

A SYSTEMATIC REVIEW OF SCIENCE EDUCATION ATTITUDE INSTRUMENTS PSYCHOMETRIC PROPERTIES

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Following a systematic review procedure, the psychometric properties of science education attitude instruments (N = 62) retrieved from the WOS and SCOPUS database were in-depth analyzed. Findings reveal that attitude instruments published in science education between 2004 and 2018 years are generally lacking theoretically underpinnings and validity psychometric evidences, which calls into question the results obtained to date, demands a re-examination of the conclusions reached in this line of research, and highlights the need to improve practices in instrument validation.

Keywords: attitudes toward science, development and validation, instrument.

INTRODUCTION

One decade ago, Blalock et al.'s (2008) review warned about the lack of psychometric properties of the measurement instruments in science education published between 1935 and 2005. Since then, new approaches to improve student's interest in science have gained momentum, with an increase in research implementing and evaluating different educational interventions (NAE & NRC, 2014). Given the conceptual and methodological issues underpinning the instruments reviewed by Blalock et al.'s (2008), it is necessary to evaluate if the instruments designed in recent years have better psychometric evidence than the ones analysed previously.

For this reason, the purpose of this study is to identify and examine the psychometric properties of attitude toward science instruments developed and published between 2004 and 2018 to determine whether new science education efforts for improving students' attitudes towards science are being complemented by the development of valid and reliable quantitative questionnaires.

METHOD

A systematic psychometric review was conducted following the PRISMA statement for systematic reviews and meta-analysis (Liberati et al. 2009). Accordingly, studies were deemed relevant based on the following inclusion criteria: (a) instrument validation study, (b) instruments measuring attitudes, (c) quantitative instruments. Potentially relevant articles were identified in the Web of Science Core Collection (WOS) and Scopus database using the following search strategy: *attitud* OR view* OR opinion* OR image* OR motivation* AND scien* AND scale* OR instrument* OR measur* OR survey* OR questionnaire* OR tool* AND validat* OR develop* OR psychometric* OR properties OR evaluat**. A follow-up snowball technique was used by screening the reference list of eligible studies to include potentially relevant articles that were not retrieved using the search strategy. Search was restricted by the following filters: (a) articles, (b) written in English or Spanish, (c) indexed in the Education & Educational Research (in WOS) and Social Science categories (in Scopus), and (iv) published since 2004 to June 2018, that builds upon and updates Blalock et al.'s (2008) study. The psychometric properties reported in included studies were assessed using a checklist created *ad-hoc* for this study following recent recommendations as the ones from the Standards for Educational and Psychological Testing (AERA, APA & NCME, 2014). In this study, we report the results related to the theoretical framework adopted and the validity evidences reported in each reviewed study. The full-reference for the reviewed studies are included in the Appendix.

RESULTS

A total of 1327 records were retrieved, of which 1055 were excluded after applying search filters. Of the remaining 272 articles, 174 were excluded after reading title and abstracts for not meeting inclusion criteria. After removing duplicated records, searching for full articles copies, and examining the reference list of eligible articles, 61 studies reporting on the development and validation of 62 attitude instruments were retained for in-depth analyses.

Up to 30 of the 62 reviewed assessments (48.4%) were developed without a clear conceptualization of the attitude construct and thus were not guided by any theoretical framework. Of the remaining instruments referring to theory, it was used in a problematic way, like replacing theory constructs with other constructs without a rationale, or extracting factors representing two theoretically distinct factors under the same umbrella/factor (e.g. including in one factor items measuring interest, self-efficacy and outcome expectations).

Table 1. Descriptive statistics on validity psychometric evidences reported

Validity evidences	N	%
Content & face		
Expert panel	27	43.5
Target population	23	37.7
Not reported	23	37.1
Criterion		
Concurrent	3	4.8
Predictive	10	16.1
Not reported	49	79.0
Construct		
Structural		
EFA	43	69.4
CFA	32	51.6
IRT	11	17.7
Not reported	2	3.2
Hypothesis testing		
Convergent	23	37.1
Discriminant	13	21.0
Discriminative	30	48.4
Not reported	19	30.6

[a] EFA-CFA (Exploratory-confirmatory factor analysis); IRT (Items response theory).

In relation to validity, although all instruments were presented as valid tools for attitude measurement, for the most part this was only supported by the reporting of few validity psychometric properties. Thus, 36 of the 62 assessments (58.1%) were validated reporting less than three out of the nine total possible validity evidence, with five instruments reporting only one validity evidence. A closer examination of the validity results reported reveals that overall, test developers failed to provide consistent evidence for some fundamental types of validity psychometric properties (Table 1). Thus, in up to 23 of the 62 assessments (37.1%), evidence for content and face validity was inexistent, and for only 23 assessments (37.1%) the content validity was examined using interviews with the target population of study. As for criterion related validity, concurrent or predictive tests were missing in 49 of the 62 assessments (79%). The concurrent validity was examined for only three assessments (4.8%) and the predictive validity was assessed in only 10 out of the 62 analysed assessments (16.1%). In addition, information regarding hypothesis-testing construct-type of validity was rather limited. 39 of the 62 instruments (62.9%) were not tested for convergent validity, and the discriminant validity was not assessed in 49 assessments (79%). The ability of the proposed assessments to correctly discriminate between groups it should be able to discriminate (i.e. discriminative validity) was not reported for 32 of the 62 assessments (51.6%).

DISCUSSION

Results of this review reveal that methodologically strong and psychometrically sound attitude instruments in science education continue to be scarce and that most of Blalock et al.´s (2008) criticism are still relevant for newly developed science attitudes instruments. Among the reviewed instruments, most were of deficient quality according to current standards. While some instruments were rooted in a theory, no dominant framework of attitudes toward science informing the development and validation process was identified, and therefore many distinct factors hypothesized to be measuring attitudes toward science were reported in each study without justification. This lack of a clear conceptualization of what constitutes attitudes toward science led to instruments with inconsistent construct structure, with factors loadings not reflecting the intended construct, many cross loadings, or different factor structure in translated versions.

As for the validity evidences, most instruments were not subjected to enough psychometric analyses in order to be promoted as valid tools. Specifically, the lack of studies reporting on the convergent and discriminant validity of the proposed instruments is highly worrying. Considering that attitude is a multidimensional construct, these results are kind of problematic and the construct validity of many instruments remains unclear and calls into question the ability of most reviewed instruments to validly measure individuals' attitudes. Likewise, the lack of temporal stability evidence (i.e. test-retest validity) calls into question the ability of the analysed instruments to measure attitudes consistently and accurately in repeated administrations. Since these instruments could be used to track the development of students' attitudes and to examine interventions impact on the construct under study, the use of assessments lacking temporal stability evidence will lead to results which validity is unknown at best.

Several implications arise from these findings. First, a greater conceptualization of the attitude toward science construct is crucially required. Until then, it is advisable to abandon any attempt to further develop instruments based on existing ones and to avoid the use of instruments that do not have a theoretical framework. Second, instruments should be submitted to test-retest reliability evidence before being advocated and used in quasi-experimental time-series design or intervention studies with multiple longitudinal test data collection. Third, most reviewed instruments should be subjected to further empirical work to provide more validity evidences. Finally, it is worth considering the need for a re-examination of the assumptions reached in attitude toward science research derived from the use of these instruments.

In conclusion, the findings of this review study reveal that although a rather large body of attitude instruments was developed and published in the science education field in the last 14 years, the conceptual and methodological quality of most of them are below modern standards for educational and psychological testing. These results can be useful as it highlights those aspects that need improvement when developing and validating attitudes instruments in science education research.

ACKNOWLEDGEMENTS

Funded by 2017-2021 Ph.D. research fellowship (UBU) and MINECO-AEI EDU 2017-89405-R research project.

REFERENCES

AERA, APA & NCME. (2014). *Standards for educational and psychological testing*. Washington, DC: American Educational Research Association.

Blalock, C. L., Lichtenstein, M. J., Owen, S., Pruski, L., Marshall, C., & Toepperwein, M. A. (2008). In pursuit of validity: A comprehensive review of science attitude instruments 1935-2005. *International Journal of Science Education, 30*(7), 961–977. doi:10.1080/09500690701344578

Liberati A., Altman D.G., Tetzlaff J., Mulrow C., Gøtzsche P.C., Ioannidis J.P.A., Clarke M., Devereaux P.J., Kleijnen J. & Moher D. (2009). The PRISMA statement for reporting systematic reviews and meta-analyses of studies that evaluate health care interventions: explanation and elaboration. *Journal of Clinical Epidemiology* 62(10), e1–e34.

NAE & NRC (2014). *STEM integration in K-12 education: Status, prospects, and an agenda for research.* Washington, DC: The National Academies Press.

APPENDIX: REVIEWED STUDIES

Abd-El-Khalick, F., Summers, R., Said, Z., Wang, S., & Culbertson, M. (2015). Development and large-scale validation of an instrument to assess Arabic-speaking students' attitudes toward science. *International Journal of Science Education*, *37*(16), 2637–2663. doi:10.1080/09500693.2015.1098789

Adams, W. K., Perkins, K. K., Podolefsky, N. S., Dubson, M., Finkelstein, N. D., & Wieman, C. E. (2006). New instrument for measuring student beliefs about physics and learning physics: The Colorado learning attitudes about science survey. *Physical Review Special Topics - Physics Education Research,2*(1), 1–14. doi:10.1103/PhysRevSTPER.2.010101

Adams, W. K., Wieman, C. E., Perkins, K. K., & Barbera, J. (2008). Modifying and validating the colorado learning attitudes about science survey for use in chemistry. *Journal of Chemical Education, 85*(10), 1435–1439. doi:10.1021/ed085p1435

Andrews, S. E., Runyon, C., & Aikens, M. L. (2017). The math-biology values instrument: Development of a tool to measure life science majors' task values of using math in the context of biology. *CBE Life Sciences Education, 16*(45), 1–12. doi:10.1187/cbe.17-03-0043

Bauer, C. F. (2008). Attitude toward chemistry: A semantic differential instrument for assessing curriculum impacts. *Journal of Chemical Education, 85*(10), 1440–1445. doi:10.1021/ed085p1440

Bayar, A., & Karamustafaoğlu, O. (2015). The Colorado learning attitudes about science survey (CLASS): The study of validity and reliability. *International Journal of Secondary Metabolite*, *2*(1), 40–57.

Blanco Blanco, Á., Casas Moreno, Y., & Mafokozi Ndabishibije, J. (2016). Adaptación y propiedades psicométricas de escalas sociocognitivas. Una aplicación en el ámbito vocacional científico-matemático. *REOP - Revista Española de Orientación y Psicopedagogía, 27*(1), 8–28. doi:10.5944/reop.vol.27.num.1.2016.17005

Caputo, A. (2017). A brief scale on attitude toward learning of scientific subjects (ATLoSS) for middle school students. *Journal of Educational, Cultural and Psychological Studies, 2017*(16), 57–76.

Cheung, D. (2009). Developing a scale to measure students' attitudes toward chemistry lessons. *International Journal of Science Education, 31*(16), 2185–2203. doi:10.1080/09500690802189799

Chiang, W. W., & Liu, C. J. (2014). Scale of academic emotion in science education: Development and validation. *International Journal of Science Education, 36*(6), 908–928. doi:10.1080/09500693.2013.830233

Dermitzaki, I., Stavroussi, P., Vavougios, D., & Kotsis, K. T. (2013). Adaptation of the students' motivation towards science learning (SMTSL) questionnaire in the Greek language. *European Journal of Psychology of Education, 28*(3), 747–766. doi:10.1007/s10212-012-0138-1

Dijkstra, E. M., & Goedhart, M. J. (2012). Development and validation of the ACSI: Measuring students' science attitudes, pro-environmental behaviour, climate change attitudes and knowledge. *Environmental Education Research, 18*(6), 733–749. doi:10.1080/13504622.2012.662213

Douglas, K. A., Yale, M. S., Bennett, D. E., Haugan, M. P., & Bryan, L. A. (2014). Evaluation of Colorado learning attitudes about science survey. *PhysicalReview Special Topics - Physics Education Research, 10*(2), 1–10. doi:10.1103/PhysRevSTPER.10.020128

Ergün, A., & Balçın, M. D. (2017). Turkish adaptation of questionnaire on attitudes towards engineers and scientists. *International Electronic Journal of Elementary Education, 10*(1), 103–113. doi:10.26822/iejee.2017131891

Fortus, D., & Vedder-Weiss, D. (2014). Measuring students' continuing motivation for science learning. *Journal of Research in Science Teaching, 51*(4), 497–522. doi:10.1002/tea.21136

Glynn, S. M., Brickman, P., Armstrong, N., &Taasoobshirazi, G. (2011). Science motivation questionnaire II: Validation with science majors and nonscience majors. *Journal of Research in Science Teaching, 48*(10), 1159–1176. doi:10.1002/tea.20442

Glynn, S. M., Taasoobshirazi, G., & Brickman, P. (2009). Science motivation questionnaire: Construct validation with nonscience majors. *Journal of Research in Science Teaching, 46*(2), 127–146. doi:10.1002/tea.20267

Guzey, S. S., Harwell, M., & Moore, T. (2014). Development of an instrument to assess attitudes toward science, technology, engineering, and mathematics (STEM). *School Science and Mathematics, 114*(6), 271–279. doi:10.1111/ssm.12077

Heredia, K., & Lewis, J. E. (2012). A psychometric evaluation of the Colorado learning attitudes about science survey for use in chemistry. *Journal of Chemical Education, 89*(4), 436–441. doi:10.1021/ed100590t

Hiller, S. E., & Kitsantas, A. (2016). The validation of the citizen science self-efficacy scale (CSSES). *International Journal of Environmental and Science Education, 11*(5), 543–558. doi:10.12973/ijese.2016.405a

Hillman, S. J., Zeeman, S. I., Tilburg, C. E., & List, H. E. (2016). My attitudes toward science (MATS): The development of a multidimensional instrument measuring students' science attitudes. *Learning Environments Research, 19*, 203–219. doi:10.1007/s10984-016-9205-x

Kennedy, J., Quinn, F., & Taylor, N. (2016). The school science attitude survey: A new instrument for measuring attitudes towards school science. *International Journal of Research & Method in Education, 39*(4), 422–445. doi:10.1080/1743727X.2016.1160046

Kind, P., Jones, K., & Barmby, P. (2007). Developing attitudes towards science measures. *International Journal of Science Education, 29*(7), 871–893. doi:10.1080/09500690600909091

Korur, F., Vargas, R. V., & Serrano, N. T. (2016). Attitude toward science teaching of Spanish and Turkish in-service elementary teachers: Multi-group confirmatory factor analysis. *Eurasia Journal of Mathematics, Science and Technology Education, 12*(2), 303–320. doi:10.12973/eurasia.2016.1215a

Lamb, R. L., Annetta, L., Meldrum, J., & Vallett, D. (2012). Measuring science interest: Rasch validation of the science interest survey. *International Journal of Science and Mathematics Education, 10*, 643–668. doi:10.1007/s10763-011-9314-z

Liou, P. Y. (2014). Evaluating measurement properties of attitudinal items related to learning science in Taiwan from TIMSS 2007. *Journal of Baltic Science Education, 13*(6), 856–869.

Mahoney, M. P. (2010). Students' attitudes toward STEM: Development of an instrument for high school STEM-based programs. *The Journal of Technology Studies, 36*(1), 24–34. doi:10.1007/s11165-013-9387-5

Maier, M. F., Greenfield, D. B., & Bulotsky-Shearer, R. (2013). Development and validation of a preschool teachers' attitudes and beliefs toward science teaching questionnaire. *Early Childhood Research Quarterly, 28*, 366–378. doi:10.1016/j.ecresq.2012.09.003

Marsh, H. W., Abduljabbar, A. S., Abu-Hilal, M. M., Morin, A. J. S., Abdelfattah, F., Leung, K. C., … Parker, P. (2013). Factorial, convergent, and discriminant validity of TIMSS math and science motivation measures: A comparison of Arab and Anglo-Saxon countries. *Journal of Educational Psychology, 105*(1), 108–128. doi:10.1037/a0029907

Morgan, M., Collins, W., Sparks, G., & Welch, J. (2018). Identifying relevant anti-science perceptions to improve science-based communication: The negative perceptions of science scale. *Social Sciences, 7*(64), 1–18. doi:10.3390/socsci7040064

Navarro, M., Förster, C., González, C., & González-Pose, P. (2016). Attitudes toward science: Measurement and psychometric properties of the test of science-related attitudes for its use in Spanish-speaking classrooms. *International Journal of Science Education, 38*(9), 1459–1482. doi:10.1080/09500693.2016.1195521

Oh, Y. J., Jia, Y., Lorentson, M., &LaBanca, F. (2013). Development of the educational and career interest scale in science, technology, and mathematics for high school students. *Journal of Science Education and Technology, 22*, 780–790. doi:10.1007/s10956-012-9430-8

Owen, S. V., Toepperwein, M. A., Pruski, L. A., Blalock, C. L., Liu, Y., Marshall, C. E., & Lichtenstein, M. J. (2007). Psychometric reevaluation of the women in science scale (WiSS). *Journal of Research in Science Teaching, 44*(10), 1461–1478. doi:10.1002/tea.20187

Puvirajah, A., Verma, G., Li, H., & Martin-Hansen, L. (2015). Influence of a science-focused after-school program on underrepresented sigh-school students' science attitudes and trajectory: A survey validation study. *International Journal of Science Education, Part B: Communication and Public Engagement, 5*(3), 250–270. doi:10.1080/21548455.2014.930210

Randler, C., Hummel, E., Gläser-Zikuda, M., Vollmer, C., Bogner, F. X., &Mayring, P. (2011). Reliability and validation of a short scale to measure situational emotions in science education. *International Journal of Environmental & Science Education, 6*(4), 359–370.

Romine, W., Sadler, T. D., Presley, M., & Klosterman, M. L. (2014). Student interest in technology and science (SITS) survey: Development, validation, and use of a new instrument. *International Journal of Science and Mathematics Education, 12*, 261–283. doi:10.1007/s10763-013-9410-3

Sabah, S., Hammouri, H., &Akour, M. (2013). Validation of a scale of attitudes toward science across countries using Rasch model: Findings from TIMSS. *Journal of Baltic Science Education, 12*(5), 692–703.

Said, Z., Summers, R., Abd-El-Khalick, F., & Wang, S. (2016). Attitudes toward science among grades 3 through 12 arab students in Qatar: Findings from a cross-sectional national study. *International Journal of Science Education, 38*(4), 621–643. doi:10.1080/09500693.2016.1156184

Salta, K., &Koulougliotis, D. (2015). Assessing motivation to learn chemistry: Adaptation and validation of science motivation questionnaire II with Greek secondary school students. *Chemistry Education Research and Practice, 16*, 237–250. doi:10.1039/c4rp00196f

Schumm, M. F., & Bogner, F. X. (2016). Measuring adolescent science motivation. *International Journal of Science Education, 38*(3), 434–449. doi:10.1080/09500693.2016.1147659

Semsar, K., Knight, J. K., Birol, G., & Smith, M. K. (2011). The Colorado learning attitudes about science survey (CLASS) for use in biology. *CBE Life Sciences Education, 10*(3), 268–278. doi:10.1187/cbe.10-10-0133

Sha, L., Schunn, C., & Bathgate, M. (2015). Measuring choice to participate in optional science learning experiences during early adolescence. *Journal of Research in Science Teaching, 52*(5), 686–709. doi:10.1002/tea.21210

Sjaastad, J. (2013). Measuring the ways significant persons influence attitudes towards science and mathematics. *International Journal of Science Education, 35*(2), 192–212. doi:10.1080/09500693.2012.672775

Summers, R., & Abd-El-Khalick, F. (2018). Development and validation of an instrument to assess student attitudes toward science across grades 5 through 10. *Journal of Research in Science Teaching, 55*(2), 172–205. doi:10.1002/tea.21416

Tee, O. P., & Subramaniam, R. (2018). Comparative study of middle school students' attitudes towards science: Rasch analysis of entire TIMSS 2011 attitudinal data for England, Singapore and the U.S.A. as well as psychometric properties of attitudes scale. *International Journal of Science Education, 40*(3), 268–290. doi:10.1080/09500693.2017.1413717

Tosun, C., & Genç, M. (2015). Adaptation of science attitude scale developed for elementary school students to turkish: Validity and reliability study. *Elementary Education Online, 14*(3), 946–960. doi:10.17051/io.2015.08787

Tuan, H. L., Chin, C. C., & Shieh, S. H. (2005). The development of a questionnaire to measure students' motivation towards science learning. *International Journal of Science Education, 27*(6), 639–654. doi:10.1080/0950069042000323737

Tyler-Wood, T., Knezek, G., & Christensen, R. (2010). Instruments for assessing interest in STEM content and careers. *Journal of Technology and Teacher Education, 18*(2), 341–363. doi:10.1016/j.tate.2005.03.006

Unfried, A., Faber, M., Stanhope, D. S., & Wiebe, E. (2015). The development and validation of a measure of student attitudes toward science, technology, engineering, and math (S-STEM). *Journal of Psychoeducational Assessment, 33*(7), 622–639. doi:10.1177/0734282915571160

van Aalderen-Smeets, S., &Walma van der Molen, J. (2013). Measuring primary teachers' attitudes toward teaching science: Development of the dimensions of attitude toward science (DAS) instrument. *International Journal of Science Education, 35*(4), 577–600. doi:10.1080/09500693.2012.755576

Velayutham, S., Aldridge, J., & Fraser, B. (2011). Development and validation of an instrument to measure students' motivation and self-regulation in science learning. *International Journal of Science Education, 33*(15), 2159–2179. doi:10.1080/09500693.2010.541529

Villafañe, S. M., & Lewis, J. E. (2016). Exploring a measure of science attitude for different groups of students enrolled in introductory college chemistry. *Chemistry Education Research and Practice, 17*(4), 731–742. doi:10.1039/c5rp00185d

Wang, T., & Berlin, D. (2010). Construction and validation of an instrument to measure Taiwanese elementary students' attitudes toward their science class. *International Journal of Science Education, 32*(18), 2413–2428. doi:10.1080/09500690903431561

Wang, M. Te, Fredricks, J. A., Ye, F., Hofkens, T. L., & Linn, J. S. (2016). The math and science engagement scales: Scale development, validation, and psychometric properties. *Learning and Instruction, 43,* 16–26. doi:10.1016/j.learninstruc.2016.01.008

Wendt, J. L., &Rockinson-Szapkiw, A. (2018). A psychometric evaluation of the English version of the dimensions of attitudes toward science instrument with a U.S. population of elementary educators. *Teaching and Teacher Education, 70*, 24–33. doi:10.1016/j.tate.2017.11.009

Wilcox, B. R., & Lewandowski, H. J. (2016). Students' epistemologies about experimental physics: Validating the colorado learning attitudes about science survey for experimental physics. *Physical Review Physics Education Research, 12*, 1–11. doi:10.1103/PhysRevPhysEducRes.12.010123

Xu, X., & Lewis, J. E. (2011). Refinement of a chemistry attitude measure for college students. *Journal of Chemical Education, 88*(5), 561–568. doi:10.1021/ed900071q

Yasar, S., &Anagün, S. S. (2009). Reliability and validity studies of the science and technology course scientific attitude scale. *Journal of Turkish Science Education, 6*(2), 43–54.

You, H. S. (2016). Rasch validation of a measure of reform-oriented Science teaching practices. *Journal of Science Teacher Education, 27*(4), 373–392. doi:10.1007/s10972-016-9466-3

You, H. S., Kim, K., Black, K., & Min, K. W. (2018). Assessing science motivation for college students: Validation of the science motivation questionnaire II using the Rasch-Andrich rating scale model. *Eurasia Journal of Mathematics, Science and Technology Education, 14*(4), 1161–1173. doi:10.29333/ejmste/81821

Zhang, D., & Campbell, T. (2011). The psychometric evaluation of a three-dimension elementary science attitude survey. *Journal of Science Teacher Education, 22*, 595–612. doi:10.1007/s10972-010-9202-3

DESIGN AND VALIDATION OF A TEACHER SURVEY ON SPECIAL NEEDS EDUCATION

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Teachers are increasingly challenged in inclusive classrooms as more children are being diagnosed with special education needs (SEN). Teachers teaching disciplinary-based lessons in inclusive classrooms have to give conceptual, epistemic, and social considerations. Additionally, they have to adapt according to the needs of learners with SEN at the same time. However, inservice and preservice teacher preparation programmes rarely discuss the topic of SEN in science pedagogies and assessment. The science education research literature is not well-established in the area of special needs science education. This paper addresses the gap in the literature and teacher education programmes by designing and validating the Views and Practices in Special Needs Science Education (VPSeNSE) survey to measure: (a) teachers' views about students with SEN, (b) teachers' self-efficacy views in teaching students with SEN, and (c) science teaching practices in inclusive science classrooms. These constructs are important because teachers' views about their students and self-efficacy views have been reported to shape teaching practices. In this paper, I describe the design and validation process of VPSeNSE. Specifically, a literature search on teacher survey instruments related to special needs education was conducted and 51 papers were found. Survey item related to the three constructs were selected and compiled. Qualitative validation via interviews with one current primary (Grade 6) science teacher teaching in inclusive science classrooms, and a former primary science teacher who was recently seconded to lecture in primary science teacher education courses, were conducted. Based upon the qualitative validation process, the items were revised, deleted, or added. The final teacher survey comprised 35 items. The survey responses gathered from 108 Singapore science teachers were subjected to Rasch analysis and the results were reported here. The survey has been validated for our research purpose.

Keywords: design and validation, teacher survey, special needs science education

SCIENCE EDUCATION AND SPECIAL EDUCATION NEEDS

Students with special education needs[1] (SEN) are increasingly included in mainstream science classrooms and are expected to demonstrate academic proficiency on standardised assessments (McLeskey, Landers, Williamson, & Hoppey, 2012). Advocates for inclusive education have emphasised the importance of quality science experiences for *all* students including SEN students (Lederman, & Stefanich, 2004), even arguing that it is a moral imperative (McGinnis, 2003). Research have suggested that science lessons, when designed to accommodate students with special needs, can afford effective learning (McGinnis, 2013). While the inclusion of SEN students in regular classrooms confers many benefits in terms of socialization and curricular access (Baker, Wang, & Walberg, 1994), it presents challenges to teachers who may not be prepared to teach students with learning disabilities. Previous studies have reported on science

[1] Different terms have been used in the literature to refer to learners with diverse learning needs that can be emotional, cognitive, development, or physical. In this proposal, we use the term special education needs (SEN) for consistency.

teachers who feel unprepared to teach students with SEN and special education teachers feel unprepared to teach science (Irving, Nti, & Johnson, 2007; Norman, Caseau, & Stefenich, 1998). Teacher preparation and attitudes have been cited as the major factors contributing to the success or failure of students with disabilities in science learning (Elhoweris & Alsheikh, 2006; Jobe, Rust, & Brissie, 1996; Van Reusen, Shoho, & Barker, 2001). A mixed methods study conducted by Kahn and Lewis (2014) on 1,088 K-12 science teachers in the U.S. revealed that they received little formal training and felt unprepared to teach SEN students. Yet, a paucity of studies about special needs science education, especially about science teachers remains.

GOAL OF THIS PAPER

This paper reports on the design and validation of a teacher survey instrument that is used to measure the following three constructs: (a) teachers' views about students with SEN, (b) teachers' self-efficacy views about teaching students with SEN, and (c) science teaching practices in inclusive science classrooms. There is no specific programme or course about special needs science education in Singapore. There is also no survey instrument specifically for investigating teachers' views in the context of special needs science education. The survey reported in this study is used to conduct a baseline inaugural study of science teachers in Singapore so as to identify specific support for them to teach science in classrooms, which are all inclusive. As most teacher surveys focus on teachers' views about inclusiveness, which is the policy for Singapore education, they are not relevant to the context of the study. Hence, a new teacher survey was developed for this study with a disciplinary focus in SEN.

THEORETICAL CONSTRUCTS

The three theoretical constructs examined in the survey are: (a) teachers' views about students with SEN, (b) teachers' self-efficacy views in teaching students with SEN, and (c) science teaching practices in inclusive classrooms. These three constructs are being studied because it has been well-established in the literature that teachers' views about students will impact what they do in the classroom. Their successfulness in the classroom will in turn affect their self-efficacy views and then impact students' achievements (Goddard, Hoy, & Hoy, 2000).

METHODS

This research is part of a larger one year study involving a quantitative scan of science teachers' views about special needs science education and qualitative case study of three teachers to obtain a more in-depth view. The quantitative component of the research involves a survey design that entails: (1) literature review on the three theoretical constructs, (2) qualitative validation using interviews, and (3) Rasch analysis (Wright, 1993).

The design of the survey instrument began with a literature search on peer-reviewed journal articles related to surveys about teachers in special education needs. A total of 51 papers were found and all the theoretical constructs studied and survey items were compiled. Three theoretical constructs that were relevant to the goal of research were identified. Qualitative validation via interviews with one current primary (Grade 6) science teacher teaching in inclusive science classrooms, and a former primary science teacher who was recently seconded to lecture in primary science teacher education courses, were conducted. Based upon the qualitative validation process, the items were revised, deleted, or added. The final teacher survey comprised 35 items. The survey was administered to Singapore primary science teachers and the responses were analyzed using Rasch modeling.

In Singapore, science is taught only from Grades 3 (aged 9) onwards. As such, primary science teachers, who have had taught Grades 3-6 classes with at least one student with SEN (autism spectrum disorders, ADHD, intellectual disabilities, and learning disabilities), were recruited via email to complete the online survey. The email was sent to all Singapore public and independent primary schools. The survey could be completed within 20 minutes and teachers could access it via a webpage link or QR code. A total of 108 science teachers, who met the selection criteria, completed the survey. All institutional guidelines related to human ethics clearance had been obtained prior to the start of the study. Only responses from teachers who had submitted the consent forms were included in the analysis.

FINDINGS AND DISCUSSION

Fit statistics

The infit and outfit mean squares, *and* standardized residuals from the Rasch analysis outputs showed that no items appear misfitting. That means that no items were found to be confusing and not performing well in determining the teachers' responses. The results also showed that no persons were misfitting (i.e., no teachers were "misbehaving" on the survey).

Item and Person Reliability

Person and Item reliabilities were achieved. The values were at least 0.70 for all three constructs. This means that if the survey was readministered to another sample of the same size, the persons and items placement on the survey pathway would remain consistent.

Item Maps

Based on the Wright map on science teachers' views about students with SEN, the mean of the person "ability" is about 1 logit higher than the mean of the item "difficulty" (see Figure 1 in the Appendix). This means that most of the teachers found it easier to agree with the items in this construct. On the other hand, the Wright maps on science teachers' self-efficacy views in teaching students with SEN (see Figure 2 in the Appendix) and science teaching practices in inclusive science classrooms (see Figure 3 in the Appendix), showed that mean of the person "ability" is about 1 logit lower than the mean of the item "difficulty". This means that most of the teachers found it harder to agree with the items in these two constructs. Typically, instruments (e.g., cognitive tests) that are used to collect data about specific areas of competencies (e.g., analytic skills, computation skills) should ideally have the two means (person "ability" and item "difficulty") in close proximity. This means that the difficulty of the items matches the abilities of the participants taking the test. However, in our survey validation, the separation of the two means by approximately 1 logit is acceptable (i.e., not excessively positive or negative) as the instrument is intended to gather their explicit and implicit views about students with SEN and the types of adaptive teaching practices that use in their inclusive science classrooms.

IMPLICATIONS AND CONCLUSION

This paper has reported on the design and validation process of a survey instrument (available upon request) to investigate science teachers' views about students with SEN. The three constructs—namely, science teachers' views about students with SEN, science teachers' self-efficacy views in teaching students with SEN and science teaching practices in inclusive science classrooms—were included in the survey. The constructs and relevant items were qualitatively and quantitatively validated using interviews and Rasch modeling. Based on the Rasch analysis results, we conclude that the survey instrument has been validated. To date, we have translated and administered the survey to science teachers of similar demographics in Taiwan and South Korea. The instrument will be validated further and international comparisons based on the results will be reported elsewhere.

ACKNOWLEDGEMENT

This study was funded by Singapore Ministry of Education (MOE) under the Education Research Funding Programme (OER 25/17 TTW) and administered by National Institute of Education (NIE), Nanyang Technological University, Singapore. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author and do not necessarily reflect the views of the Singapore MOE and NIE.

REFERENCES

Baker, E. T., Wang, M. C., & Walberg, H. J. (1994). The effects of inclusion on learning. *Educational Leadership, 52,* 33-35.

Elhoweris, H., & Alsheikh, H. (2004, Nov 14). *Teachers' attitudes toward inclusion*. Paper presented at the New York State Federation of the Council for Exceptional Children, Albany, NY.

Goddard, R., Hoy, W., & Hoy, A. (2000). Collective Teacher Efficacy: Its Meaning, Measure, and Impact on Student Achievement. *American Educational Research Journal, 37*(2), 479-507.

Irving, M. M., Nti, M., & Johnson, W. (2007). Meeting the needs of the special learner in science. *International Journal of Special Education, 22,* 109-118.

Jobe, D., Rust, J. O., & Brissie, J. (1996). Teacher attitudes toward inclusion of students with disabilities into regular classrooms. *Education, 117,* 148-153.

Kahn, S., & Lewis, A. R. (2014). Survey on teaching science to K-12 students with disabilities: Teacher preparedness and attitudes. *Journal of Science Teacher Education, 25*, 885-910.

Lederman, J. S., & Stefanich, G. (2004). Addressing disabilities in the context of inquiry and nature of science instruction. In L. Flick & N. G. Lederman (Eds.), *Scientific Inquiry and Nature of Science: Implications for Teaching, Learning, and Teacher Education* (pp. 55-74). Dordrecht, The Netherlands: Kluwer

McGinnis, J. R. (2003). The morality of inclusive verses exclusive settings: Preparing teachers to teach students with developmental disabilities in science. In D. Zeidler (Ed.), *The role of moral reasoning on socio-scientific issues and discourse in science education* (pp. 195-216). The Netherlands: Kluwer.

McLeskey, J., Landers, E., Williamson, P., & Hoppey, D. (2012). Are we moving toward educating students with disabilities in less restrictive settings? *The Journal of Special Education, 46,* 131-140.

Norman, K., Caseau, D., & Stefanich, G. P. (1998). Teaching students with disabilities in inclusive science classrooms: Survey results. *Science Education, 82,* 127-146.

Van Reusen, A. K., Shoho, A. R. & Barker, K. S. (2001). High school teacher attitudes toward inclusion. *High School Journal, 84*, 7-20.

Wright, B.D. (1993). Logits? Rasch Measurement Transactions, 7(2), 288.

Figure 1. Wright map for the construct on science teachers' views about students with SEN. The number of responses is 108.

```
MEASURE    PERSON - MAP - ITEM
               <more>|<rare>
    5            ##  +
                     |
                     |
                     |
                     |
                     |
    4                +
                     |
                     |
                     |
                     |
                  #  |
    3               T+
                  .  |
                 .#  |
                     |
                 .#  |
                ###  |
    2               S+
                 ##  |
               ####  |
                ###  |
              #####  |
              .#### M|  A9
    1          .###  +T
                 ##  |
          .########  |  A1
                  #  |S
                  #  |  A2
               .### S|  A10    A3
    0                +M A11
                .##  |  A4
                 .#  |
                  .  |S A7     A8
                     |  A5     A6
                 .# T|
   -1             .  +T
               <less>|<frequent>
EACH "#" IS 2: EACH "." IS 1
```

Figure 2. Wright map for the construct on science teachers' views on their self-efficacy views in teaching students with SEN. The total number of responses is 105.

```
MEASURE    PERSON - MAP - ITEM
               <more>|<rare>
    3                +
                     |
                     |T
                     |
                     |  B9
    2                +
                     |
                     |
                     |
                  .  |S
    1            ## T+
                     |  B10    B2     B7
                     |  B3
               .###  |
                 ##  |  B1
    0            .# S+M
                 .#  |
              .####  |
            #######  |  B4
               .###  |  B5
   -1         ##### M+
               .###  |S
             ######  |
                .##  |
                     |  B6
   -2           ### S+
                ###  |  B8
                  .  |
                     |T
                 .#  |
   -3               T+
                     |
                     |
                     |
                     |
   -4             #  +
                     |
                  .  |
                     |
                     |
   -5                +
               <less>|<frequent>
EACH "#" IS 2: EACH "." IS 1
```

Figure 3. Wright map for the construct on science teachers' teaching practices in inclusive science classroom(s). The total number of responses is 99.

```
MEASURE  PERSON - MAP - ITEM
             <more>|<rare>
    2              +
                   |
                   |
                   |
                   |
                   |
                   |T
                X  |
    1           X  +  C14
                   |  C9
                   |
                  T|S C13
                   |  C10    C12
                X  |
              XXX  |
                   |  C1     C5     C6
    0           X  +M C7
                X S|  C11
           XXXXXX  |  C8
         XXXXXXXX  |  C3
      XXXXXXXXXXX  |
          XXXXXXX  |S
        XXXXXXXXX  |
           XXXXXX  |  C15
   -1      XXXXXX M+
          XXXXXXX  |  C2
              XXX  |T C4
              XXX  |
         XXXXXXXX  |
              XXX  |
                X S|
                   |
   -2        XXXX  +
               XX  |
                   |
             XXXX  |
                  T|
                X  |
                   |
                   |
   -3              +
               XX  |
                   |
                   |
                   |
                   |
                   |
                   |
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DEMONSTRATION EXPERIMENTS IN THE CONTEXT OF COGNITIVE PSYCHOLOGY RESEARCH

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In this article, our project team examines the question: Under which conditions are students in a position to perceive presented experimental phenomena in such a way that these phenomena can best be used throughout the course of the learning process?

The theoretical inspiration for this research project came from the Gestalt psychology motivated research of Schmidkunz during the 1980s and 1990s. In addition to this, new cognitive psychology methods were adapted from the field of "eye tracking research." A total of 135 students from six classes grade 8 of two grammar schools took part in the study. The participants were divided into four groups, before each of which one of four different versions of a video documented experiment was played on a computer. While the students each observed their version of the experiment, the movements of their gaze and fixation were recorded. After the presentation of the experiment, the students were asked to complete a pre-structured laboratory report. The assessment of these reports and the results of the eye tracking analysis presented unexpected findings.

Keywords: Gestalt psychology laws, demonstration experiments, eye tracking analysis

THEORETICAL FRAMEWORK

The Gestalt psychology motivated works and recommendations from Schmidkunz for the presentation of chemistry-related demonstration experiments form the theoretical starting point for our project (Schmidkunz, 1983; 1990; 1991; 1992; 1997; 2007). In addition, we oriented ourselves on newer cognitive psychology works, especially in the field of eye-tracking research (Rayner, 1992; 1998; Havanki & VandenPlas, 2014). Studies using the eye-tracking method offer the prospect of shedding some light into the black box of the cognitive processing and perception of visual stimuli.

Works motivated by chemistry education and Gestalt psychology from Schmidkunz

In the 1980s, Schmidkunz had already proved that elements from Gestalt psychology theory could contribute to the explanation of chemistry-related learning processes with his case studies oriented on chemistry education (Wertheimer, 1985 [1925]; Fitzek, 2014). In the course of his studies, Schmidkunz dealt with various laws of Gestalt psychology; among others the law of continuity (2007; cf. Treatment 1), the law of figure-ground contrast (1991; cf. Treatment 2), and the law of symmetry (1992; cf. Treatment 4). The results of these studies suggest that disregarding the principles described in the Gestalt laws during the presentation of chemistry demonstration experiments leads to impaired learning success on the part of the pupils involved – at least in comparison to the learning of the pupils to whom the optimum possible experimental arrangement (here: Treatment 3) was presented (Schmidkunz, 1983; 1990; 1991; 1992; 1997; 2007).

Subject-specific teaching and cognitive psychology in eye tracking research

In the field of neuropsychology and cognitive psychology, studies are increasingly being conducted by means of the eye tracking method (Ravner, 1992; 1998; Auer et. al., 2005; Havanki & VandenPlas, 2014). With the help of special software and hardware, visual fixations are recorded in the millisecond range enabling the reconstruction and visualization of the corresponding movements of gaze. In this way, attention and concentration as well as perception processes can be quantitatively analyzed. This in turn allows conclusions to be drawn about the triggered cognitive processes and the learning of selected facts. For some time, eye tracking studies have found their way into more and more studies motivated by science education and specifically chemistry education (Sumfleth & Gnoyke, 1995; Gnoyke, 1997; Fäth, Watzka & Girwidz, 2013; Hofmann, 2011; Richtberg & Girwidz, 2013; Rohde et al., 2013; 2015).

RESEARCH QUESTIONS

Following the two research strains outlined above, our project group addressed the following research questions:

1. To what extent can the findings presented by Schmidkunz be replicated?

2. What causes for successful and/or unsuccessful chemistry-related learning can be derived from the results of our eye tracking analysis?

METHOD

To answer the research questions, we decided to plan and conduct an *experimentally designed study in the Treatment Control Group design*. The large number of case studies presented by Schmidkunz concerning the eight Gestalt psychology laws, as well as the large number of attached recommendations necessitated that we make a selection for the upcoming investigation. Our choice landed on the "law of the straight and continuous line" (Schmidkunz, 2007, 406; Treatment Group 1: Line), the "law of figure-ground contrast" (Schmidkunz & Büttner, 1991, 338; Treatment Group 2: Contrast), and the "law of symmetry" (Schmidkunz, 1992, 12; Treatment Group 4: Symmetry) as conciseness-governing factors in chemical experiments. The experimental design which avoided the violation of the three laws mentioned, and thus corresponded to the "state-of-the-art" didactic example of recommendable experimental practice, served as a control variant (control group: state of the art; see Fig. 1 and Image 4 in Fig. 4).

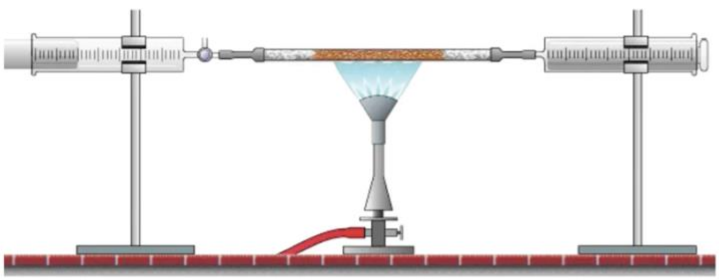

Figure 1. Experimental apparatus for the quantitative determination of the oxygen content in ambient air (Source: Lehrwerk Online - Prisma Chemie, Ernst Klett Verlag GmbH. URL: https://static.klett.de/software/shockwave/prisma_chemie_ol/pc_pcni02an202/index.html)

Fig. 2. Basic equipment setup of an eye tracking laboratory space

Fig. 3: Workspace in the eye tracking laboratory of the FU Berlin

We invited six school classes from year 8, accompanied by their teachers, to a project day in the student-laboratory of the Department of Chemistry Education at the FU Berlin. The project day was planned and executed by the members of this project group. From the classes that took part in the project day, four groups were formed by random sampling, each of which in turn was randomly assigned to one of the four experimental treatments (see Fig. 3).

First, the students were familiarized with the experimental setting of the eye tracking laboratory in the workspace of the Neuropsychology Department at the FU Berlin. Afterwards, one of the four taped chemistry experiments was shown on the computer. During the introduction, students were instructed to observe the experiment carefully in order to be able to complete a pre-structured lab report afterwards.

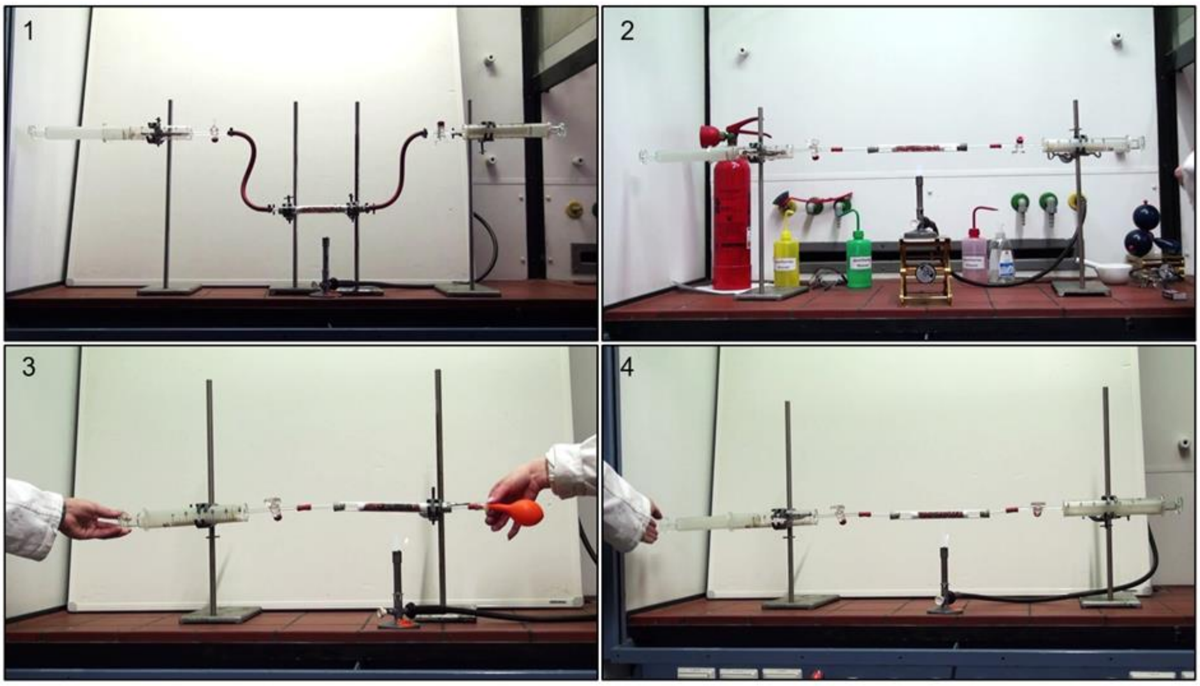

Figure 4. Four variants of the video-documented demonstration experiment. Image 1: Violation of the law of the continuous straight line (Treatment Group 1); Image 2: Violation of the figure-ground contrast law (Treatment Group 2); Image 3: Violation of the law of symmetry (Treatment Group 4); Image 4: "State of the Art" (Treatment Group 3, Control Group)

After being filled out by the test subjects, the lab reports were evaluated according to specially developed evaluation criteria. In the course of this grading process, cumulative and relative solution frequencies were calculated. As long as the necessary subsample size was reached, a group-specific statistical significance test was performed (Eid, Gollwitzer & Schmitt, 2015) and the obtained results were compared with those from the Schmidkunz studies.

In this regard, we expected (in agreement with Schmidkunz; see above) that the students which could recall the experimental procedure that followed the Gestalt laws (Treatment Group 3:

representing the Control Group), compared to the other three treatment groups would achieve the best comparable results with regard to recording (logging) the experiment. In addition, eye fixations and eye movements of the participants were recorded and analysed using eye tracking software and hardware during the four different sets of experiments (see Fig. 1 and 2).

Theory-compliant results from the analysed lab reports, as well as those which deviated from Schmidkunz's findings (contrary to our expectations), were examined and discussed in detail, using the eye tracking findings that we generated and analysed.

With regard to our eye tracking analyses, we expect statistically significant differences that indicate differences in perception and/or attention differences when considering the four different experimental demonstrations.

EMPIRICAL RESULTS

The sample of our study consisted of 135 pupils from year 8, which came out of six classes from two different schools. The students were assigned to the four experimental sub-samples (treatment groups) and distributed as follows: Treatment 1 (solid line): 34; Treatment 2 (basic figure contrast): 33; Treatment 3 (Control and "State of the Art" Group): 32; Treatment 4 (Symmetry): 36.

The results of the analysis of the pre-structured test protocols prepared by the students can be found in Table 1, differentiated according to the experimentally different sub-samples or settings. Selected findings from the eye tracking analysis – differentiated by treatment group– are summarized in Table 2.

Table 1: Results from the analyses of the pupils' completed pre-structured lab reports - differentiated according to treatment groups

Treatment	N	Sketch Experiment Setup	Describe Experiment Procedure	Note Observations	Explain Observations	Answer Research Question	**Average Overall Score**
#1: Continuity	34	10.26	2.26	1.88	0.62	0.26	15.29
#2: Contrast	33	9.06	1.91	1.55	0.67	0.27	13.45
#3: Standard	32	8.53	1.63	1.72	0.69	0.22	12.78
#4: Symmetry	36	10.19	1.67	1.28	0.08	0.08	13.31
∑	**135**	**14**	**5**	**6**	**7**	**6**	**38**

Table. 2: Selected findings (mean dwell time) from the eye tracking analyses - differentiated by treatment group and observation sector

Treatment	N	Gas Syringe ls	Reaction Tube	Gas Syringe (or Object) rs	Bunsen Burner	Neutral Sector	Distracting Sector	∑ ***(off)***	∑ **(on)**
#1: Continuity	34	29.6	28.7	21.6	2.1	*17.9*	*1.1*	***19.0***	**82.0**
#2: Contrast	33	19.3	30.0	19.0	3.3	*28.0*	*6.5*	***34.5***	**71.8**
#3: Standard	32	26.7	29.8	19.1	4.1	*20.2*	*/*	***20.2***	**79.7**
#4: Symmetry	36	36.1	11.3	29.9	1.9	*20.6*	*/*	***20.6***	**79.2**
∑	**135**								

INTERPRETATION

The performance-based findings from the Schmidkunz case studies could not be replicated in our investigation. This may be due to the varying experiment designs and evaluation processes as well as the different sample groups, but the termination of the testing process may also be to blame. These findings alone speak for the conducting of further experiments of this kind.

The results of the analyses related to content and learning growth, based on the pre-structured lab reports of the pupils, suggest that the pupils involved were evidently capable of compensating for didactic shortcomings in the presentation of the demonstration experiments. Contrary to expectations, the best results were not achieved by the treatment group to which the supposedly best trial demonstration was presented (see Table 1). Indeed, the findings of our eye tracking analyses (see Table 2) suggest that the planned violations of the principles of Gestalt psychology were not as attention-grabbing as the previous case studies of Schmidkunz from the 1980s and 1990s would have us assume.

CONCLUSION

Apart from the abovementioned limitations, the overall design of our study has proven itself. Although eye tracking studies are time consuming and demand much organization, the method offers many interesting, scientifically valid and subject-relevant insights into the learning of scientific facts. Therefore, further and even more systematic and nuanced studies should be undertaken promptly, while the study presented here should provide suggestions for such studies in order to gain in-depth and differentiated insights in this field.

ACKNOWLEDGEMENTS

A very special thank you goes out to Dr. Sascha Tamm (from the eye tracking laboratory in the Department of Neuropsychology at the Freie Universität Berlin) for his support throughout our survey and evaluation of the eye tracking data. We would also like to thank all the students who participated and their teachers who supported us during our tests. Furthermore, we sincerely thank Dr. Sabine Streller and Anke Ayyasky (from the Chemistry Education Department of the FU Berlin), for their support in the planning and implementation of the project days for the participating school classes.

REFERENCES

Minstrell, J., & Zee, E.H. (2000). Inquiring into Inquiry Learning and Teaching in Science. AAAS [American Association for the Advancement of Science]

Astleitner, H. (2010). Methodische Rahmenbedingungen zur Entdeckung der Wirksamkeit von pädagogischen Interventionen. In T. Hascher & B. Schmitz (Ed.), *Pädagogische Interventionsforschung. Theoretische Grundlagen und empirisches Handlungswissen* (1. ed., 48-62). Weinhein und München: Juventa Verlag.

Auer, M., Gruber, G., Mayring, H. & Wimmer, H. (2005). *SLS 5-8, Salzburger Lese-Screening für die Klassenstufen 5-8. Bern*: Verlag Hans Huber, Hogrefe AG.

Barke, H.-D., & Harsch, G. (2001). *Chemiedidaktik kompakt- Lernprozesse in Theorie und Praxis*. Berlin, Heidelberg: Springer Verlag.

Becker, H.-J., Glöckner W., Hoffmann, F., & Jüngel, G. (1992): *Fachdidaktik Chemie*. Köln: Aulis Verlag Deubner.

Duchowski, A.T. (2017) *Eye Tracking Methodology: Theory and Practice*. Berlin, Heidelberg: Springer-Verlag.

EC [European Commission] (2007). Science Education Now: A Renewed Pedagogy for the Future of Europe. http://ec.europa.eu/research/science-society/document_library/pdf_06/report-rocard-on-science-education_en.pdf (26/04/2014)

Eid, M., Gollwitzer, M., & Schmitt, M. (2015). *Statistik und Forschungsmethoden*. Basel: Beltz.

Fäth, J., Watzka, B. & Girwidz, R. (2013). Eye-Tracker-Untersuchung zu Gestaltungsprinzipien einer Animation. In S. Bernholt (Ed.), *Inquiry-based Learning - Forschendes Lernen,* (746-748). Kiel: IPN-Verlag.

Fitzek, H. (2014). *Gestaltpsychologie kompakt. Grundlinien einer Psychologie für die Praxis*. Wiesbaden: Springer Fachmedien

Fries, E., & Rosenberger, R. (1973). *Forschender Unterricht*. Frankfurt a. M.: Diesterweg.

Gnoyke, A. (1997). *Das Lernen mit Bildern in der Chemie - Aktion und Interaktion von Wahrnehmen und Denken.* Frankfurt a. Main: Lang (zugleich: Universität Essen (Dissertation 1995).

Graf, E. (2000). Stationenlernen – ein Beitrag zur Weiterentwicklung des Chemieunterrichts. *NiU Chemie*. *11*(58/59) S. 6-9.

Häußler, P., Frey, K., Hoffmann, L., Rost, J., & Spada, H. (1980). *Physikalische Bildung: Eine curriculare Delphi-Studie. Teil I: Verfahren und Ergebnisse*. Kiel: IPN-Arbeitsbericht 41.

Havanki, K.L., & VandenPlas, J.R. (2014). Eye Tracking Methodology for Chemistry Education Research. In D.M. Bunce & R.S. Cole (eds.) *Tools of Chemistry Education Research* (191-218). Washington D.C.: American Chemical Society (ACS Series 1166).

Holmqvist, K., Nyström, M. Andersson, R., Dewhurst, R., Jarodzka, H., & van de Weijer,J. (2010). *Eye tracking: A comprehensive guide to methods and measures*. Oxford: Oxford University Press.

Hofmann, B. (2011). Analyse von Blickbewegungen von Schülern beim Lesen von physikbezogenen Texten mit Bildern. Eye Tracking als Methodenwerkzeug in der physikdidaktischen Forschung. In H. Niedderer, H. Fischler, E. Sumfleth (Eds.): *Studien zum Physik- und Chemielernen*. Band 119. Berlin: Logos Verlag Berlin GmbH.

Jarodzka, H., Holmqvist, K., & Gruber, H. (2017). Eye tracking in Educational Science: Theoretical frameworks and research agendas. *Journal of Eye Movement Research*, *10*(1), 1-18.

Just, M.A, & Carpenter, P.A. (1980). A theory of reading: From eye fixations to comprehension. *Psychological Review*, 329 – 354.

KMK [Kultusministerkonferenz] (2005). *Bildungsstandards im Fach Chemie für den mittleren Schulabschluss (Jahrgangsstufe 10).* Wolters Kluwer.

Nehring, A., Springfeld, H., & Taubert, Ch. (2017). Gestaltgesetze für Demonstrationsexperimente unter der Lupe. Ein Forschungsbericht über den Einsatz von Eye-Tracking. *MNU*, *70*(6), 422-427.

NRC [National Research Council] (2000). *Inquiry and the National Science Education Standards. A Guide for Teaching and Learning*. Washington DC: National Academy Press.

Osborne, J. F., Ratcliffe, M., Collins, S., Millar, R., & Dusch, R. (2003). What "Ideas –about-Science" Should Be Taught in School Science? A Delphi Study of the Expert Community. *Journal of Research in Science Teaching*, *40*(7), 692-720.

Pfeifer, P., Lutz, B., & Bader, H.J. (2002): *Konkrete Fachdidaktik Chemie*. München: Oldenburg Schulbuchverlag.

Raab-Steiner, E. & Benesch, M. (2008). *Der Fragebogen. Von der Forschungsidee zur SPSS-Auswertung.* Wien: facultas.wuv Universitätsverlag.

Rayner, K. (1992, Ed.). *Eye Movements and Visual Cognition: Scene Perception and Reading*. Berlin, Heidelberg: Springer-Verlag.

Rayner, K. (1998) Eye movements in reading and information processing: 20 years of research. *Psychol. Bull. 124*(3), 372-422.

Richtberg, S. & Girwidz, R. (2013). Livebild & Funktionsgraph – Echtzeitüberlagerung beim Experimentieren. In S. Bernholt (Ed.), *Inquiry-based Learning - Forschendes Lernen* (S. 323-325). Kiel: IPN-Verlag.

Rohde, N., Opfermann, M., Schmuck, C. & Rumann, S. (2013). Lernwirksamkeit von Illustrationen zum Orbitalmodell in der Organischen Chemie. In S. Bernholt (Ed.), *Inquiry-based Learning - Forschendes Lernen* (S. 752-754). Kiel: IPN-Verlag.

Rohde, N., Winterink, K., Opfermann, M. & Rumann, S. (2015). Blickbewegungen Studierender beim Betrachten von Fotografien chemischer Versuchsaufbauten. In: S. Bernholt (Ed.), *Hetero¬genität und Diversität - Vielfalt der Voraussetzungen im naturwissenschaftlichen Unterricht*. (S. 666-668). Kiel: IPN.

Schmidkunz, H. (1983). Die Gestaltung chemischer Demonstrationsexperimente nach wahrnehmungspsychologischen Erkenntnissen. *NiU – Physik/Chemie*. 31, 10, S. 360 – 367.

Schmidkunz, H. (1990). Die Bedeutung der visuellen Wahrnehmung für den Aufbau und die Durchführung chemischer Demonstrationsexperimente. *Chemie und Schule*. H. 2, S. 1 – 4.

Schmidkunz, H. (1992): Die Symmetrie als prägnanzbildender Faktor bei chemischen Experimenten. *NiU – Chemie*. 3, H. 11, S. 12 – 16.

Schmidkunz, H. (1997). Gestalt Theory within Chemical Education. In W. Gräber, C. Bolte (Eds.), *Scientific Literacy. An international symposium.* (S. 391 – 398). Kiel: IPN.

Schmidkunz, H. & Büttner, D. (1991). Chemische Experimente und visuelle Wahrnehmung – eine Fallstudie zu den Gesetzen des Figur-Grund-Kontrastes und der Einfachheit. *Sachunterricht und Mathematik in der Primarstufe*. 19, H. 8, S. 338 -346.

Schmidkunz, H. & Büttner, D. (1992): Aufbau und Durchführung chemischer Demonstrationsexperimente – Die Wirkungsweise gestaltpsychologischer Faktoren, dargestellt an einem konkreten Beispiel. *NiU – Chemie*. 3, H. 11, S. 7 – 11.

Schmidkunz, H. (1992): Die Symmetrie als Prägnanz-bildender Faktor bei chemischen Experimenten. *NiU – Chemie*. 3, H. 11, S. 12 – 16.

Schmidkunz, H. (2007). Die Wahrnehmung chemischer Experimentieranordnungen, zum "Gesetz der glatt durchlaufenden Linie". In D. Höttecke (Ed.), *Naturwissenschaftlicher Unterricht im internationalen Vergleich.* (S. 406 – 408). Berlin: LIT Verlag.

Schmidkunz, H., & Lindemann, H. (1992). *Das forschend-entwickelnde Unterrichtsverfahren: Problemlösen im naturwissenschaftlichen Unterricht*. Essen: Westarp Wissenschaften.

SMI Instruments (2016): BeGaze Manual. Version 3.7.

SMI Instruments (2016): Experiment Center Manual. Version 3.6.

SMI Instruments (2012): RED-m Eye Tracking System Manual. Version 3.2.

SPSS Statistics 24 Programm. https://spss.en.softonic.com/ (Zugriff: 2017-04-21)

Stäudel, L. (2000). Lernen an Stationen. *NiU Chemie*. 11(58/59) S. 2-5.

Sumfleth, E. & Gnoyke, A. (1995). Ich sehe was, was Du nicht siehst! - Die Bedeutung bildlicher Symbolsysteme in Wahrnehmung und Erinnerung in der Chemie. In H. Behrendt (Ed.), *Zur Didaktik der Physik und Chemie: Probleme und Perspektiven*. (S. 187–189). Alsbach: Leuchtturmverlag.

Sumfleth, E., Schmidkunz, H., Schoel, S. & Körner, H.-D. (1993). Der Experimentaufbau – Zeichnen und Verstehen. *NiU Chemie*. 3, H. 11, S. 4 – 8.

Wertheimer, M. (1985 [1925]). Über Gestalttheorie. *Gestalt Theory*, 7, 99-120. Berlin, Heidelberg: Springer Verlag.

AUTOMATIC CONTENT ANALYSIS IN COLLABORATIVE INQUIRY-BASED LEARNING

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In the field of science education, content analysis is a popular way to analyse collaborative inquiry-based learning (CIBL) processes. However, content analysis is time-consuming when conducted by humans. In this paper, we introduce an automatic content analysis method to identify the different inquiry-based learning (IBL) phases from authentic student face-to-face discussions. We illustrate the potential of automatic content analysis by comparing the results of manual content analysis (conducted by humans) and automatic content analysis (conducted by computers). Both the manual and automatic content analyses were based on manual transcriptions of 11 groups' CIBL processes. Two researchers performed the manual content analysis, in which each utterance of the groups' discussions was coded to an IBL phase. First, an algorithm was trained with some of the manually coded utterances to prepare the automatic content analysis. Second, the researchers tested the ability of the algorithm to automatically code the utterances that were not used in the training. The algorithm was a linear support vector machine (SVM) classifier. Since the input of the SVM must be a numerical vector of constant size, we used a topic model to build a feature vector representation for each utterance. The correspondence of the manual and automatic content analyses was 52.9%. The precision of the classifier varied from 49% to 68%, depending on the IBL phase. We discuss issues to consider in the future when improving automatic content analysis methods. We also highlight the potential benefits of automatic content analysis from the viewpoint of science teachers and science education researchers.

Keywords: Collaborative learning; Inquiry-oriented learning; Quantitative methods

INTRODUCTION

In the field of science education, content analysis is a popular method for analysing collaborative inquiry-based learning (CIBL) processes (e.g., Lämsä et al., 2018, 2020; Wang et al., 2014). Typically, researchers have pre-defined codes, such as the phases of inquiry-based learning (IBL), on which the content analysis is based. Identification of different phases of IBL is needed when designing scaffolds for CIBL processes. For instance, previous research has shown that students need support, especially in the first phases of IBL (Lämsä et al., 2018; Wang et al., 2014). However, it is known that optimal scaffolding is context-specific, so there is a need to study CIBL processes in various contexts. Due to the vast human resources that content analysis of CIBL processes requires, in this study, we illustrate the potential of automatic content analysis for analysing CIBL processes. In the following, we briefly present how automatic content analysis has been applied in learning sciences so far.

Automatic content analysis in learning sciences

A major challenge in building a practical tool that supports teachers in the classroom is the need to analyse students' discussions in each group. Hence, we need novel methods to process and analyse massive amounts of data. This is not only time-consuming when performed by humans, but also requires the analysis of parallel speech produced in each group of students. Moreover, the analysis needs to be done in real time in order to be useful to the teacher. Furthermore, it is not straightforward to produce a robust diagnosis, as trained human raters must agree on coding. Specifically, in order to provide a robust analysis, it is necessary to have at least two raters and ensure sufficient inter-rater and intra-rater agreement.

So far, studies have investigated the potential for automatic content analysis in developing a better understanding of computer-mediated student–student interaction as well as teacher–student interaction. In the context of student–student interaction, Rosé et al. (2008) presented an overview of work on automatic analysis of computer-supported collaborative learning (CSCL) in which the authors stated, 'Our specific goal has been to extend and apply current text classification technology to CSCL, exploring which classification techniques are most effective for improving the performance on different types of coding dimensions used in the CSCL community.' They found that some discourse processes in educational psychology could be automatically detected in text messages at a level of agreement comparable to that between human coders. Dowell et al. (2018) also developed a group communication analysis by combining automated computational linguistic techniques with analyses of the sequential interactions of online group communications to detect emergent roles in group interactions.

Text analysis also allows the study of the effect of questions posed by the teacher. This is a subject of great importance in teaching practice and in the preparation of teachers. More than a century ago, Stevens (1912) emphasised the realisation of questions as a fundamental component in teacher training. Araya et al. (2018) analysed written responses to open-ended questions of students from various elementary school classes and built an automatic predictor of the length of the answers of each student based on the presence of keywords in the teacher's questions. Donnelly et al. (2017) used an automatic speech recognition (ASR) algorithm to automatically detect teachers' questions, and Caballero et al. (2017) used an ASR algorithm to automatically provide teachers with a visualisation of the structure of concepts present in their discourse in science classrooms. Araya et al. (2012) built an automatic classifier of estimations of teacher practices using ratings of a subset of transcriptions made by trained raters. The agreements between the automatic classifiers and the corresponding raters that were computed for transcriptions from an independent subset were better than the agreements between the human raters. More recently, Kelly et al. (2018) compared human coding and semi-automated computer coding of the authenticity of teacher questions. They concluded that the correlations were sufficiently high to provide a valuable complement to human coding in research efforts.

These examples show that automatic content analysis has been applied to the study of computer-mediated communication between students and teachers in CSCL classrooms. CSCL research could benefit from the opportunities afforded by technological and methodological development. So far, the results of automatic content analysis have been encouraging. In this paper, we apply automatic content analysis to authentic student face-to-face interactions taking place in computer-supported settings in order to identify the different IBL phases in students' discussions. We address the research question (RQ): How similar are the results of the proposed automatic and manual content analyses in a CIBL context?

METHODS

Our study was conducted in introductory university physics courses on thermodynamics at a Finnish university. The participants were divided into groups of five students at the beginning of the course. Here, we focus on face-to-face discussions as the groups solved problems collaboratively in a technology-enhanced learning environment with shared laptop computers. Eleven groups screen-captured and audio-recorded their group-work sessions. First, we manually transcribed these sessions as they solved an inquiry problem (on average, 180 utterances per group). The inquiry problem was a study of how the displacement of an atom in a two-dimensional gas depends on time. The groups had a Python programme that calculated the displacement of an atom with different values of the number of collisions and then plotted the atom's path. Based on the output of the Python programme, the groups inferred the relationship between the displacement and time.

Second, we conducted theory-driven content analysis (Neuendorf, 2002) in which two researchers coded the transcriptions based on the IBL framework presented by Pedaste et al. (2015), i.e., each utterance was coded to one of the IBL phases (orientation, conceptualisation, investigation, conclusion, and discussion). In the orientation phase, the students became familiar with the given assignment, its main variables, and technological resources (in this case, the Python programme). In the conceptualisation phase, the students identified the dependent and independent variables of the problems and proposed research questions or hypotheses. In the investigation phase, the students planned the data collection and collected, analysed, and interpreted the data. In the conclusion phase, the students drew conclusions and offered solutions to the research questions or hypotheses. In the discussion phase, the students could communicate and reflect on the process at the end of the inquiry or in relation to an IBL phase. The inter-rater agreement was 67.7%, and any disagreements were discussed and resolved.

After this manual content analysis, we performed automatic content analysis to identify the IBL phase from a given utterance. All the analysed transcriptions were written in Finnish. We approached this task as a text classification problem—finding a characterisation of utterances (vector representation) and building an automatic classifier. Figure 1 shows the four stages of the automatic content analysis that we conducted, describing the process for each stage and the corresponding input and output.

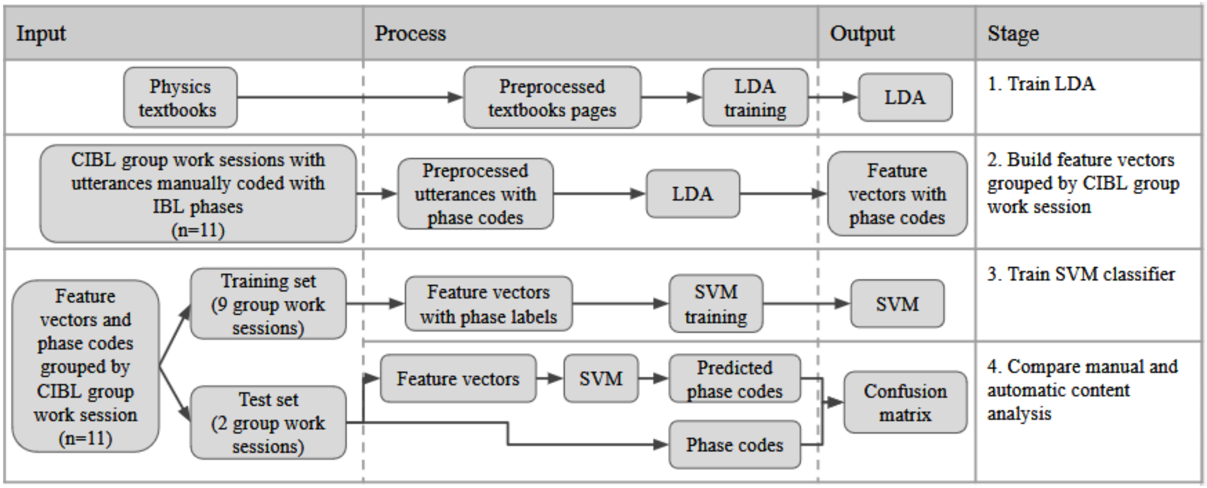

Figure 1. Stages for training and assessing the automatic content analysis.

Stage 1: Train an LDA

In order to build a characterisation of utterances, we trained a latent Dirichlet allocation (LDA) topic model (Blei et al., 2003). Topic models are statistical models that are used to find topics in large document collections in a wide range of applications, e.g., analysing historical documents, understanding scientific publications, or machine translation (Boyd-Graber et al., 2017; Dowell et al. 2018). The term *topic*—in the topic models context—is used to refer to groups of words that usually appear together in a document collection. The assumption behind topic models is that documents have a mixture of topics, and the words in a single document will depend on the topics that comprise the document. Applying a topic model to a large collection of documents allows the identification of topics and the description of documents in terms of the topics present in each document.

Table 1. Example of seven topics found by applying the LDA model to physics textbooks. These topics were common in the CIBL group-work sessions. For each topic, the top four words are shown.

Topic 8	Topic 13	Topic 17	Topic 19	Topic 27	Topic 33	Topic 39
[number]	v	=	so	T	?	[proportional to]
a	R	+	for example	l	a	measurement
b	voltage	R	same	o	how	increase
m	l	o	or	R	b	measure

Topic models need a large collection of documents to find topics that are formed by coherent groups of words. In learning sciences, there are usually learning materials available for different contexts, subjects, and languages. Our assumption was that we could use relevant topics from upper secondary school physics textbooks if we wanted to describe the discussions of undergraduate physics students. Thus, the first stage consisted of using 31 Finnish physics textbooks to train the LDA model. We trained the model to identify 60 topics, which allowed us to represent an utterance as a mixture of 60 topic proportions. Table 1 shows the words most relevant to seven of the topics. We have translated the words from Finnish to English. Topic

19 relates to words used in explanations. Topic 39 relates to words describing measurements. The other topics refer to numbers, units, name of variables and symbols.

Stage 2: Build feature vectors grouped by CIBL group-work session

In the second stage, we built a feature vector, or an enhanced representation of each utterance in the CIBL group-work sessions. The feature vector was used to train the automatic classifier in the next stage. Each utterance of the CIBL sessions was pre-processed (removing stopwords, symbols, and infrequent words). The LDA model was then used to obtain, for each utterance, a vector of 60 topic proportions. The output of this stage was a 182-dimensional feature vector representing each utterance: 60 components of the topic proportions for the utterance, 60 for the previous utterance, and 60 for the following utterance. The two additional dimensions corresponded to the number of words and the relative position of the utterance in the group-work session. It is important to note that each feature vector was related to the corresponding human-coded phase.

For the third and fourth stages, we grouped the feature vectors into two sets: a training set with the feature vectors from nine group-work sessions and a test set with the feature vectors from two group-work sessions. The training set would be the input for the third stage and the test set would be the input for the fourth stage.

Stage 3: Train the SVM classifier

In the third stage, we trained a linear support vector machine (SVM) classifier (Burges, 1998). SVMs are one of the most popular automatic classifiers (e.g., Araya et al., 2012; Rosé et al., 2008). The training of the SVM consisted of adjusting a function to optimise the number of utterances in the training set that were automatically coded to be the same as the manual code. By the end of Stage 3, a workflow had been created that allowed automatic coding of an utterance with an IBL phase. The following are examples of utterances coded with the SVM classifier:

> Yes, it was something like 20, approximately [the number of collisions $N = 300$ in the Python programme]. Then it was a little bit more than 30. Let's now try when it [N] is 500. I'll try a couple of times: 11, 15, 25, 21, 15 … [manual coding: investigation; automatic coding: investigation]
>
> ...
>
> Would someone else like to tap [run the Python programme]? [manual coding: discussion; automatic coding: orientation]

Stage 4: Compare the manual and automatic content analyses

In the fourth stage, we used the test set to compare the manual coding with the phase automatically assigned by the SVM (see the previous examples). The output of the fourth stage was a confusion matrix, i.e., a 5×5 matrix that summarises the number of utterances that were manually coded as the phase indicated by the row and automatically coded as the phase indicated by the column.

As the dataset was small, the results were highly dependent on the test set selected. To get a more robust estimation of the SVM classifier's errors, we independently ran the third and fourth stages while varying the input with all the possible combinations of nine and two group-work sessions in order to build the training and test sets. With 55 combinations in total, we obtained 55 confusion matrices. As different test sets had different numbers of utterances, each matrix was standardised to total 100. The output of the overall process was then an average confusion matrix of the 55 standardised matrices. This procedure allowed us to answer the RQ, as the confusion matrix described how well the IBL classifier was performing for each IBL phase.

Baseline

To test whether the classifier was gaining information from the text features, we defined two baselines that did not require the extraction of information from the utterances. The first baseline was a classifier that classified all the utterances as the more frequent phase. In this study, the discussion phase was the most frequent and represented 36.1% of the utterances in the CIBL sessions. The second baseline was a classifier that, in the first part of the sessions, classified the utterances as orientation, and, in the second part of the sessions, classified them as discussion. To define where in the transcription the baseline classifier should start to classify utterances as discussion, we used the training dataset to find the optimal threshold for each run of the third and fourth stage. The average threshold used for the second baseline was to classify the first 40% of the session as orientation and the remainder as discussion. The second baseline had an accuracy of 42.7%.

RESULTS

A comparison of the results of the manual and automatic content analyses is presented in the confusion matrix (Table 2). Each cell $C_{i,j}$ in the confusion matrix is the average number of utterances that were manually coded to IBL phase i and automatically coded to IBL phase j. Each cell $C_{i,j}$ represents an average across all the independent runs of the third and fourth stages of the automatic content analysis. The accuracy of the classifiers are the coincidences between the manual and automatic content analyses. As the resulting matrix in Table 2 is standardised to a total of 100, the accuracy is obtained by adding up the diagonal. The overall accuracy was 52.9% (SD = 4.8%). The precision of the classifier for each phase is the number of times that the automatically coded phase was the same as the manually coded phase. The precision of automatic coding of different IBL phases varied from 49% to 68% (orientation 50%, conceptualisation 49%, investigation 68%, conclusion 49%, and discussion 51%).

Table 2. Comparison of the results of the manual and automatic content analyses. The rows refer to the manual content analysis, and the columns refer to the automatic content analysis.

	Predicted Orientation	Predicted Conceptualisation	Predicted Investigation	Predicted Conclusion	Predicted Discussion
Orientation	16.3	0.4	1.1	0.0	6.8
Conceptualisation	2.8	2.2	0.8	0.0	5.7
Investigation	5.8	0.3	9.6	0.0	8.6
Conclusion	0.1	0.6	0.2	0.4	2.5
Discussion	7.6	0.9	2.5	0.4	24.4

In addition to the precision of the classifiers, there are other indexes that can be used to measure the reliability of the automatic coding. For example, the recall for each phase is the number of times that the automatic coding agreed with the manual coding, divided by the frequency of the phase. The recall of the automatic coding varied from 10% to 68% (orientation 66%, conceptualisation 19%, investigation 39%, conclusion 10%, and discussion 68%). These results show that the recall was rather low in the investigation phase compared to the orientation and discussion phases. This demonstrates that utterances manually coded to the investigation phase were automatically coded to the orientation and discussion phases many times, as shown in Table 2.

The results show that the precision of the automatic coding varied depending on the IBL phase. In particular, the precision of the investigation phase was higher than the precision of the other phases, i.e., when the utterance was automatically coded to the investigation phase, the utterance was also manually coded to the investigation phase with 68% probability (even though the recall was 39% for the investigation phase). The following is an utterance that was coded to the investigation phase both manually and automatically:

> Yes, it was something like 20, approximately [the number of collisions $N = 300$ in the Python programme]. Then it was a little bit more than 30. Let's now try when it [*N*] is 500. I'll try a couple of times: 11, 15, 25, 21, 15 … [manual coding: investigation; automatic coding: investigation]

In the investigation phase, the students had to, amongst other things, collect data to address the inquiry problem. The previous utterance shows an example of the data collection. During that collection, students collected the values of the displacement of an atom with different values of the number of collisions so they could infer the relationship between the displacement and time. Numbers were thus a characteristic of the investigation phase (cf. Topic 8 in Table 1). The following utterance demonstrates a challenge for the automatic coding: the utterance was manually coded to the discussion phase but automatically coded to the orientation phase.

> Would someone else like to tap [run the Python programme]? [manual coding: discussion; automatic coding: orientation]

Even though the classifier on which the automatic coding is based accounts for the previous and subsequent utterances as well as the relative position of the utterance in the whole discussion, the consideration of the overall context of the utterances is difficult to automatise. This specific utterance was manually coded to the discussion phase as it is about communicating and suggesting a new way to proceed with the inquiry problem (changing the student in charge of working with the Python programme). As can be seen from Table 2, the conceptualisation and conclusion phases were rare in the students' discussions compared to the other IBL phases, and there is thus not a representative example that illustrates inter-rater agreement between the manual and automatic coding in these phases.

DISCUSSION AND CONCLUSION

This study was a novel attempt to automate content analysis in authentic CIBL contexts in which students were working face-to-face in computer-supported settings. We compared the results of the manual and automatic content analyses, which were based on an SVM classifier.

The average accuracy of the SVM classifier (52.9%, SD = 4.8%) was 15% lower than the agreement between human coders (67.7%). Regarding the baselines, the first classified all the utterances as discussion and had an accuracy of 36.1% (SD = 5.8%). The second baseline classified the first part of the IBL sessions as orientation and the rest as discussion and had an accuracy of 42.7% (SD = 5.3%). The SVM classifier performed significantly better than the baselines; therefore, the topic description of the sentences provided information that enabled the SVM classifier to distinguish the IBL phases. Overall, these results highlight the potential for using automatic content analysis both in CIBL contexts and in face-to-face interaction in general.

There are still issues that future research should consider. First, the results for the recall and precision per phase indicate that the SVM classifier was biased against the most frequent phases. This is known as an unbalanced dataset problem. In our study, the precision was notably higher in the investigation phase than in the other phases. The recall of investigation was 39%, and the classifier frequently confused the investigation phase with orientation or discussion. When the classifier correctly coded investigation, topics 8 (numbers and units), 19 (so, for example, same, or, …) and 33 (question mark, units, how, large, calculate, ...) were present. In the future, this bias could be addressed by gathering more examples of the less-frequent phases (conceptualisation and conclusion).

Second, we treated the results of the manual content analysis as reliable so they could be compared with the results of the automatic content analysis. However, inter-rater agreement in the manual content analysis indicated that the codes for many utterances were not unambiguous, but were decided after careful joint consideration. In future, research could check whether disagreement between computer coding and human coding appears more frequently in utterances in which there is disagreement between the human coders. Third, to build the numerical representation of the utterances, we used an LDA model. As our dataset was small (11 group discussions), we trained the LDA model with physics textbooks, which contained only some of the language that appears in authentic face-to-face discussions. In the future, we will integrate transcriptions from student discussions into the LDA training.

Combining emerging automatic content analysis methods with ASR applications could be beneficial for both researchers and teachers. Automatic content analysis could support researchers with preliminary coding so they can focus more on tasks that cannot be automated, such as designing experiments and the interpretation of results, instead of time-consuming data transcription and coding. As productive CIBL activities do not necessarily emerge without assistance (Alfieri et al., 2010; Kobbe et al., 2007), a tool that can detect the stage of group discussions in real time could help in adapting support to the needs of different groups. An advantage of building the feature vectors based on LDA and using the SVM classifier is that the analysis is not necessarily language-specific. Even though we trained the LDA model using Finnish textbooks, our novel methodological approach is applicable to automatising content analysis in any language in which there are available textbooks (or other similar materials to train the LDA model) matching the language and subject of the CIBL activities.

ACKNOWLEDGEMENTS

We would like to express our gratitude for the financial aid provided by Basal Funds for Centers of Excellence Project BF 0003 from CONICYT in Chile and the Academy of Finland [grant numbers 292466 and 318095, the Multidisciplinary Research on Learning and Teaching profiles I and II of JYU].

REFERENCES

Alfieri, L., Brooks, P. J., Aldrich, N. J., & Tenenbaum, H. R. (2011). Does discovery-based instruction enhance learning? *Journal of Educational Psychology, 103*(1), 1–18. doi: 10.1037/a0021017

Araya, R., Plana, F., Dartnell, P., Soto-Andrade, J., Luci, G., Salinas, E., & Araya, M. (2012). Estimation of teacher practices based on text transcripts of teacher speech using a support vector machine algorithm. *British Journal of Educational Technology, 43*(6), 836–846.

Araya R., Jiménez A., & Aguirre C. (2018). Context-based personalized predictors of the length of written responses to open-ended questions of elementary school students. In Sieminski A., Kozierkiewicz, A., Nunez, M., & Ha, Q. (eds.), *Modern Approaches for Intelligent Information and Database Systems. Studies in Computational Intelligence*, vol. 769, pp. 135–146. Cham, Switzerland: Springer.

Blei, D. M., Ng, A. Y., & Jordan, M. I. (2003). Latent Dirichlet allocation. *Journal of Machine Learning Research, 3*(Jan.), 993–1022.

Boyd-Graber, J., Hu, Y., & Mimno, D. (2017). Applications of topic models. *Foundations and Trends in Information Retrieval, 11*(2–3), 143–296.

Burges, C. J. (1998). A tutorial on support vector machines for pattern recognition. *Data Mining and Knowledge Discovery, 2*(2), 121–167.

Caballero, D., Araya, R., Kronholm, H., Viiri, J., Mansikkaniemi, A., Lehesvuori, S., Virtanen, T., & Kurimo, M. (2017) ASR in classroom today: Automatic visualization of conceptual network in science classrooms. In Lavoué, É., Drachsler, H., Verbert, K., Broisin, J., & Pérez-Sanagustín, M. (eds.), *Data driven approaches in digital education. EC-TEL 2017. Lecture Notes in Computer Science*, vol. 10474, pp. 541–544. Cham, Switzerland: Springer.

Donnelly, P., Blanchard, N., Olney, A., Kelly, S., Nystrand, M., & D'Mello, S. (2017). Words matter: Automatic detection of teacher questions in live classroom discourse using linguistics, acoustics, and context. In *Proceedings of the Seventh International Learning Analytics and Knowledge Conference*, pp. 218–227. New York, NY: Association for Computing Machinery.

Dowell, N., Nixon, T., & Graesser, A. (2018). Group communication analysis: A computational linguistics approach for detecting sociocognitive roles in multi-party interactions. *Behavior Research Methods, 51*, 1007–1041.

Kelly, S., Olney, A. M., Donnelly, P., Nystrand, M., & D'Mello, S. K. (2018). Automatically measuring question authenticity in real-world classrooms. *Educational Researcher, 47*(7), 451–464.

Kobbe, L., Weinberger, A., Dillenbourg, P., Harrer, A., Hämäläinen, R., Häkkinen, P., & Fischer, F. (2007). Specifying computer-supported collaboration scripts.

International Journal of Computer-Supported Collaborative Learning, 2(2/3), 211–224.

Lämsä, J., Hämäläinen, R., Koskinen, P., Viiri, J., & Mannonen, J. (2020). The potential of temporal analysis: Combining log data and lag sequential analysis to investigate temporal differences between scaffolded and non-scaffolded group inquiry-based learning processes. *Computers & Education, 143*.

Lämsä, J., Hämäläinen, R., Koskinen, P., & Viiri, J. (2018). Visualising the temporal aspects of collaborative inquiry-based learning processes in technology-enhanced physics learning. *International Journal of Science Education*, *40*(14), 1697–1717.

Neuendorf, K. A. (2002). *The content analysis guidebook* (1st ed.). Thousand Oaks, CA: Sage Publications.

Pedaste, M., Mäeots, M., Siiman, L. A., de Jong, T., van Riesen, S. A. N., Kamp, E. T., . . . Tsourlidaki, E. (2015). Phases of inquiry-based learning: Definitions and the inquiry cycle. *Educational Research Review, 14*, 47–61.

Rosé, C., Wang, Y., Cui, Y., Arguello, J., Stegmann, K., Weinberger, A., & Fischer, F. (2008). Analyzing collaborative learning processes automatically: Exploiting the advances of computational linguistics in computer-supported collaborative learning. *Computer-Supported Collaborative Learning, 3*, 237–271

Stevens, R. (1912) The question as a measure of efficiency in instruction: A critical study classroom practice. *Teachers College Contributions to Education, 48*.

Wang, H., Duh, H., Li, N., Lin, T., & Tsai, C. (2014). An investigation of university students' collaborative inquiry learning behaviors in an augmented reality simulation and a traditional simulation. *Journal of Science Education and Technology, 23*(5), 682–691.

DESIGN BASED RESEARCH AND THE MODEL OF EDUCATIONAL RECONSTRUCTION – A COMBINED APPROACH TO DESIGN SUCCESSFUL SCIENCE INSTRUCTION

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One of the main challenges that science educators face is to develop teaching-learning sequences that both engage students and convey the science content successfully. In particular, new curriculum topics such as topics of modern physics pose challenges for teachers and educators because of a scarcity of teaching experience and learning resources. What is needed is a powerful and flexible methodological framework that can guide the design of new instructional material. We argue that a combination of Design Based Research and the Model of Educational Reconstruction provides such a framework. To exemplify the efficacy of such a combined approach, we present two educational projects that have leveraged the Model of Educational Reconstruction and Design Based Research successfully to bring topics of modern physics to science classrooms.

Keywords: Design Based Research, Instructional Design, Secondary Education

INTRODUCTION

Developing teaching-learning sequences that engage students and that convey science content successfully is one of the main challenges that science educators face in their research and practice. This challenge has become more urgent as new learning domains such as modern physics, nano-science, or climate change have started to enter science curricula (Henriksen et al., 2014; Laherto, 2012; Niebert & Gropengießer, 2013). To guide educational design processes, researchers routinely draw on frameworks and methodological support structures. Often, these frameworks integrate perspectives of scientists, practitioners, and students to develop research-based instructional activities (Méheut & Psillos, 2004).

This work seeks to support educators in the gradual process of synthesising perspectives and designing successful science instruction by showing how two well-established methodological frameworks, the Model of Educational Reconstruction (MER) and Design-Based Research (DBR), can be fruitfully combined. While MER serves as an overarching framework to reconstruct novel scientific topics from an educational perspective (Duit, Gropengießer, Kattmann, Komorek, & Parchmann, 2012), it does not explicitly specify the research methods to do so. However, the framework offers a design-oriented research approach. Thus, we argue that it is natural to complement a research design based on MER with methods of DBR (Anderson & Shattuck, 2012). To guide our explorations, we ask: **How does a combination of DBR and MER offer new opportunities to design teaching and learning sequences?**

In the following, we present MER and DBR in more detail before turning to two case studies that illustrate the merits of combining both frameworks in the learning domain of modern physics. We use these two cases to show how a combined approach MER-DBR allows bridging the gap between theoretical perspectives on teaching and learning and the actual science classroom practices.

METHODOLOGICAL FRAMEWORK

In this section, we briefly outline Design Based Research and the Model of Educational Reconstruction as two methodological approaches to develop solutions to educational problems. In the next section, we present two cases that exemplify how both approaches can fruitfully be combined to design successful science instruction.

Design Based Research

Design Based Research (DBR) aims to solve educational problems by designing new educational solutions that work in the "messy" setting in which day to day education takes place. To this end, educators who use this framework not only want to know if an educational solution works, but also why it works (Bakker, 2018, pp. 3-18). In DBR, the design is guided by certain design principles or design hypotheses (provided by a learning or design theory) to generate certain learning outcomes in a certain context. The design is then tested in real educational settings and practitioners contribute to the design over multiple design cycles (Plomp, 2013, pp. 20-25). Eventually, methods of DBR result in new learning resources (the design) and a local theory that describes if and how the design works. These local theories are humble in the sense that they cannot be generalized over populations per se, but usually they are general enough to be also applicable in other classrooms settings.

Redraw picture of DBR and insert it here.

Model of Educational Reconstruction

The Model of Educational Reconstruction (MER) aims to make novel learning domains accessible to students by offering a methodological framework that integrates three strands of educational research: curriculum development, design of learning environments, and assessment of learning processes. To this end, MER provides guidance for science educators on how to integrate empirical research on teaching and learning in the development of learning resources. MER comprises the basic idea that "science subject matter issues as well as student learning needs and capabilities have to be given equal attention in attempts to improve the quality of teaching and learning" (Duit et al., 2012, p. 13). The holistic approach of MER serves as a useful and flexible tool to scrutinize the educational relevance of learning domains that have not entered mainstream science education yet. Eventually, methods of MER result in an educational reconstruction of a learning domain that contains a content structure for instruction, learning resources, based on that content structure and findings on student perspectives.

Insert picture of Magdalena's article of MER.

CASE STUDIES

In the previous section, we introduced DBR and MER as two frameworks to develop design solutions in educational settings. Both Special Relativity (SR) and General Relativity (GR) are new physics topics that have found their way to secondary school curricula in many countries (Kamphorst, Vollebregt, Savelsbergh, & van Joolingen, 2019; Kersting, Henriksen, Bøe, & Angell, 2018; Kim & Lee, 2018) . Yet, field-tested and research-based educational material is rare in this emerging learning domain of relativity education. In this section, we present two specific cases from the Netherlands and Norway in which we have combined the frameworks of MER and DBR to design teaching-learning sequences for secondary school students.

Relativity Education

Our modern scientific understanding of the universe rests on the special and the general theory of relativity. These theories present Albert Einstein's revolutionary description of space, time, light, and gravity. According to Einstein, space and time are dynamic entities that dynamically interact with matter and light. In contrast to classical physics where space and time are absolute and separate from the laws of physics, SR and GR thus ask us to let go of absolute space and universal time, concepts that seem integral to our experiential understanding of the world (Woodhouse, 2014). The abstract character of these physical insights seem counter-intuitive or even contradictory to the common-sense understanding of students (Kamphorst et al., 2019; Kersting et al., 2018). Moreover, the formulation of SR and GR necessitated philosophical changes in the world view of many scientists (Kersting & Steier, 2018). Consequently, there is potential to design learning resources that have a specific emphasis on the history and philosophy of science (Levrini, 2014).

In response to the conceptual challenges of SR and GR and acknowledging the need to convey historical and philosophical perspectives as well as content knowledge, the following two case-studies combined methods of MER and DBR to develop research-based learning resources.

Example 1 – Special Relativity

Special relativity was introduced in the Dutch upper level secondary physics curriculum in 2013. This curriculum reform placed a bigger emphasis on scientific literacy and the process of knowledge formation in physics as well. The curriculum goal of SR reflects this change: 'The candidate can explain the phenomena of time dilation and length contraction in thought experiments and applications, using the concepts of lightspeed, simultaneity and reference frame.' (ref to curriculum document) Although the big ideas in this goal are clear, it is not known how they can be achieved.

Drawing on the model of educational reconstruction we were able to design a teaching and learning sequence in which students can experience the prototypical thinking and reasoning that introduces the concepts of SR for themselves. The teaching and learning sequences takes students' spontaneous reasoning with light propagation (ref. Kamphorst) as a starting point. Through subsequent reasoning activities students introduce and explain new relativistic concepts and phenomena. A first experimental exploration in small groups with multiple versions of the design offered a proof of principle and insights to improve the task design (ref GIREP&derde artikel). However, the design was not yet suitable to use directly in the classroom. To that end we involved teachers as co-designers, informed by the DBR framework. The teachers offered a deeper understanding of students' difficulties with some aspects of the initial designs and adapted the task design so the proposed learning could be fostered in the classroom context. Furthermore, this close collaboration with teachers ensured the intended performance of the educational design.

Combining the frameworks of MER and DBR stimulated us to create a detailed view on student learning processes and the content structure of SR on the one hand and look for design guidelines that can inform future educational design on the other hand. The result is an educational design that takes both students' conceptual difficulties and the classroom reality into account.

Example 2 – General Relativity

As part of the school reform introduced in 2006, GR became part of the Norwegian curriculum for upper secondary physics. However, the specific curriculum goal for GR remained vague: "The aims of the studies are to enable pupils to give an account of the postulates that form the basis for the special theory of relativity, discuss qualitatively some of the consequences of this theory for time, momentum and energy, and give a qualitative description of the general theory of relativity" (The Norwegian Directorate for Education and Training, 2006). This broad curriculum goal left scope for different interpretations of what a qualitative description of GR might look like.

Using MER as overarching framework, the Norwegian project ReleQuant unpacked the curriculum goal by attempting an educational reconstruction of GR (Kersting et al., 2018). This reconstruction entailed the development of a content structure for instruction, the development of a digital learning environment that is freely available in English and Norwegian (www.viten.no/relativity), and in-depths studies of students' conceptual understanding of key ideas in GR (Kersting, 2019; Kersting & Steier, 2018). A key feature of the design process related to the methodological issue of combining MER and DBR. To develop the content structure of instruction, which characterises MER, we drew on DBR methods to supplement this content structure with design hypotheses. We tested these hypotheses in iterative rounds and eventually formulated design principles that encapsulate successful ways of teaching relativistic concepts based on the empirical evidence from the classrooms (Figure ?). The design principles encompass overarching themes that characterise appropriately designed learning resources and specific recommendations that promote successful instruction in GR (Kersting et al., 2018).

CONCLUSION - DBR & MER COMBINED

We live in a changing world where science educators are continuously invited to integrate new domains to the curriculum. The difficulty for this particular challenge is that for these kinds of topics, little is known on student learning and teachers lack practical experience teaching these topics. This faces the science educator not only with the question what to teach, but also how to teach. The combined framework of MER&DBR offers a guide to answer to these types of challenges science educators face.

DBR and MER are two complementary methodological frameworks. MER provides a framework that includes a broad perspective on theory, teaching and learning perspectives. DBR provides a structure to include practitioners and design hypotheses. The common denominator in both frameworks is the iterative approach in which field testing informs the improvement of the design. We have added features of both frameworks to this the common iterative approach. Of the MER framework we incorporated the analysis of the theory and student perspective to create a content structure for instruction. DBR added design hypotheses and involve practitioners as co-designers to the framework. The combination of these two frameworks has shown its benefits for the subjects of SR and GR.

Although this framework offers guidance in the design process, it is still an open process. First of all on what aspects of MER and DBR one wants to integrate into the design process. But second of all, in the process itself. The design process brings forward a lot of choices that may be taken one way or the other, based on the views on teaching and learning the designer holds. However, we expect that structuring the design with the combined framework of DBR and MER, will result in common features in the eventual design. It are these features, design hypotheses or design principles, in addition to the content structure that are the scientific outcome of design research.

REFERENCES

Anderson, T., & Shattuck, J. (2012). Design-Based Research: A Decade of Progress in Education Research? *Educational Researcher*, *41*(1), 16–25. DOI: 10.3102/0013189X11428813

Bakker, A. (2018). What is design research in education. In A. Bakker, *Design Research in Education* (pp. 3-18). New York: Taylor and Francis.

Blair, D., & Kersting, M. (Eds.). (in preparation). *Teaching Einsteinian Physics in Schools*. Allen & Unwin.

Duit, R., Gropengießer, H., Kattmann, U., Komorek, M., & Parchmann, I. (2012). The Model of Educational Reconstruction - A Framework for Improving Teaching and Learning Science. In D. Jorde & J. Dillon (Eds.), *Science Education Research and Practice in Europe: Retrospective and Prospective* (pp. 13–37). Rotterdam: Sense Publishers.

Dutch College for Exams. (2014). Syllabus for the central exam 2016 (for the new exam programme) Physics Upper level secondary education. Retrieved from https://www.examenblad.nl/examenstof/syllabus-2016-natuurkunde-vwo/2016/vwo/f=/natuurkunde_vwo_2016_def_voor_hervaststelling_versie_2.pdf

Henriksen, E. K., Bungum, B., Angell, C., Tellefsen, C. W., Frågåt, T., & Vetleseter Bøe, M. (2014). Relativity, quantum physics and philosophy in the upper secondary curriculum: challenges, opportunities and proposed approaches. *Physics Education*, *49*(6), 678–684. DOI: 10.5617/nordina.2043

Kamphorst, F., Vollebregt, M. J., Savelsbergh, E. R., & van Joolingen, W. . (2019). Students' preinstructional reasoning with the speed of light in relativistic situations. *Physical Review Physics Education Research*, *15*, 020123. DOI:10.1177/001316446802800216

Kamphorst, F., Savelsbergh, E. R., Vollebregt, M. J., & van Joolingen, W. R. (2018). A meaningful introdcution to the light postulate for secondary education students. GIREP-MPTL conference, San Sebastian.

Kersting, M. (2019). Free fall in curved spacetime - how to visualise gravity in general relativity. *Physics Education*, *54*(3), 035008. DOI:10.1088/1361-6552/ab08f5

Kersting, M., Henriksen, E. K., Bøe, M. V., & Angell, C. (2018). General relativity in upper secondary school: design and evaluation of an online learning environment using the model of educational reconstruction. *Physical Review Physics Education Research*, *14*(1), 010130-1-010130–18. DOI: 10.1103/PhysRevPhysEducRes.14.010130

Kersting, M., & Steier, R. (2018). Understanding curved spacetime - the role of the rubber sheet analogy in learning general relativity. *Science & Education*, *27*(7), 593–623. DOI: 10.1007/s11191-018-9997-4

Kim, H., & Lee, G. (2018). Reflection and Outlook on Special Relativity Education from the Perspective of Einstein: Focusing on Research Papers Published in Korea. *Journal of the Korean Physical Society*, *73*(4), 422–435. DOI:10.3938/jkps.73.422

Laherto, A. (2012). *Nanoscience education for scientific literacy : Opportunities and challenges in secondary school and in out-of-school settings*. University of Helsinki. DOI:10.5617/nordina.537

Levrini, O. (2014). The role of history and philosophy in research on teaching and learning of relativity. In M. R. Matthews (Ed.), *International Handbook of Research in History, Philosophy and Science Teaching* (pp. 157–181). Dordrecht: Springer.

Méheut, M., & Psillos, D. (2004). Teaching–learning sequences: aims and tools for science education research. *International Journal of Science Education*, *26*(5), 515–535. DOI: 10.1080/09500690310001614762

Niebert, K., & Gropengießer, H. (2013). The model of educational reconstruction: A framework for the design of theory-based content specific interventions. The example of climate change. In T. Plomp & N. Nieveen (Eds.), *Educational design research – Part B: Illustrative cases* (pp. 511–532). Enschede.

Plomp, T. (2013). Educational Design Research: An Introduction. In J. v. Akker, B. Bannan, A. E. Kelly, N. Nieveen, & T. Plomp, *Educational Design Research - Part A: An introduction* (pp. 20-25). Enschede: Netherlands Institute for Curriculum Development (SLO).

The Norwegian Directorate for Education and Training. (2006). Physics - programme subject in programmes for specialization in general studies. Retrieved from http://www.udir.no/kl06/fys1-01/Hele/Kompetansemaal/fysikk-2/?lplang=eng

Woodhouse, N. M. J. (2014). Relativity Today. In V. Petkov & A. Ashtekar (Eds.), *Springer Handbook of Spacetime*. Berlin.