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Editorial

The PBE 2021 conference, again, managed to gather a considerably wide spectrum of contributions. As it is with many conferences nowadays, some authors choose not to publish their presentations as conference proceeding papers. The authors who did, however, focused on teaching science content such as soft drinks' content, the sense of smell or nanoscience in a student-activation way – project-based, inquiry or problem-based education. Other papers were focused on broader aspects such as 21st century skills' fostering, students' ability to formulate research questions, using lapbooks, promoting modelling competence, teachers' attitude towards IBSE, the role of interactive animations, investigation of student ability to identify misinformation or girls' attitudes towards STEM. Authors also aimed at student testing and quality of the data science educators receive from them. With the tradition student-activation oriented courses have, research on such courses' evaluation provides a valuable contribution to the contemporary discourse.

As the PBE conference creates room for a wider discussion, the PBE 2021 proceedings also contains results of a research on the Hamlet-like issue of science disciplines' integration. As a sign of the conference's overreach, an interdisciplinary visit was paid by colleagues showing an example of history education which carried remarkable parallels with problems science education needs to deal with too.

This proceeding opens the doors to the anniversary 20th year of the conference. Let us hope it will find a lot of satisfied readers, proud authors and eager "quotees".

Martin Rusek

Soft drinks' composition as a theme of educational experiments for upper-secondary schools

Petr Obořil, Rafael Doležal, Martin Bílek, Karel Kolář

Abstract

The article is focused on development of thin-layer chromatographic methods for analysis of soft drinks (*N* = 11) with the aim to propose novel didactical aids for introduction of suitable chemical experimental tasks in teaching chemistry at general secondary schools. These tasks are oriented to analytical identification of four common chemical substances: L-ascorbic acid, caffeine, sorbic acid and taurine. The selected compounds induce specific effects in the human body such as stimulation of the central nervous system and are also broadly utilized as taste additives, antioxidants, or stabilizers in various foods. The proposed experiments are designed for further didactical evaluation.

Key words

Soft drinks; thin-layer chromatography; educational experiments

INTRODUCTION

Consumption of soft drinks is a natural part of everyday life. This is also reflected in extensive offer of these drinks on the market. Drinks differ in their appearance, consistence, colour, but also in taste or smell, which is related to their composition (Odstrčil & Odstrčilová, 2006). Importantly, the basic component of these soft drinks is water. The drinks also contain flavour additives, like sucrose, which sweetens, or citric acid, providing a sour taste. Taste additives can be of natural origin or may be synthetic, like saccharin or cyclamate. Dyes used in drinks can also be natural (e.g. anthocyanins) or synthetic (e.g. azo dyes). An essential component of these drinks are stabilizers, a typical representative being sorbic acid. Drinks can also contain vitamins, e.g. water-soluble vitamins of the B series, and are often modified by substances with multiple functions, such as L-ascorbic acid (i.e. vitamin C), which is both a taste additive and antioxidant. Another group of additives consists of substances with a specific function in the body like stimulation of the central nervous system (e.g. caffeine). An essential part of these drinks are also various inorganic salts, such as carbonates, sulphates, chlorides, but also fluorides or iodides, containing mainly cations of sodium, potassium, magnesium, calcium, or iron. Mineral waters have a high content of these salts and carbon dioxide. It is clear that soft drinks are complex mixtures and their analysis, revealing the presence of the contained substances, can become an object of interest for grammar school pupils within the framework of school experiments or specialized workshops for pupils and other interested parties.

The present study is focused on the analysis of energy drinks, in which the presence of selected additives, namely L-Ascorbic acid, caffeine, sorbic acid and taurine, was proven. The drinks were analysed using thin-layer chromatography (TLC), which is a suitable method for application in teaching chemistry at secondary schools due to the simplicity of execution and evaluation of the results. As such, these four TLC experiments are well prepared for further evaluation in education.

CHARACTERISTICS OF THE SELECTED ADDITIVES IN SOFT DRINK SAMPLES

In this chapter, basic characteristics of the selected additives, which are usually contained in energy soft drinks, are listed. The first of them is L-ascorbic acid, known as vitamin C. The structural formula of L-ascorbic acid and its molecular model displaying electron density colored by electrostatic potential (red color – negative potential, blue color – positive potential) are shown in Fig. 1.

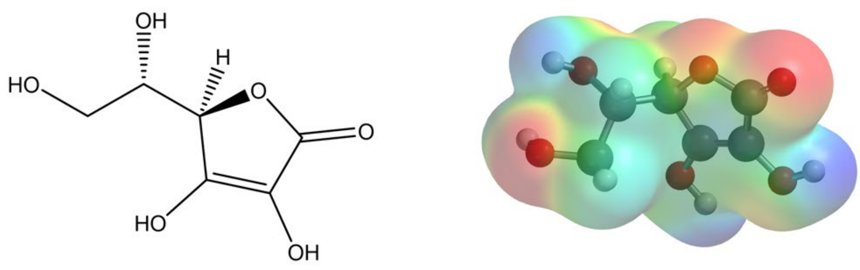


Fig. 1 Structural formula of L-ascorbic acid and its molecular model (from own resources).

Vitamin C can be understood 2,3-endiol-γ-lactone of 2-oxo-L-gulonic acid. Of note, vitamin C shows acidic and reductive properties although the molecule does not contain any classical acid or oxidizable functions such as carboxylic or aldehyde groups. For the human body, reducing capacity of this chemically interesting substance is especially important, enabling it to act as an antioxidant (Velíšek and Hajšlová, 2009). It captures and scavenges free radicals such as reactive oxygen species (ROS), reacts with the oxidized forms of vitamin E, etc. L-ascorbic acid is added to food products as an antioxidant, it also gives food products a sour taste. In nature, it is found in fruits (e.g. kiwi, rosehip, black currant) and vegetables (e.g. peppers, broccoli, Brussels sprout).

Second substance selected for investigation in this study is caffeine as an example of the commonest alkaloids sought by a considerable number of people for its stimulation effects on the central nervous system. Structural formula and geometrically optimized molecular model of this adenine related organic compound are given in Fig. 2.

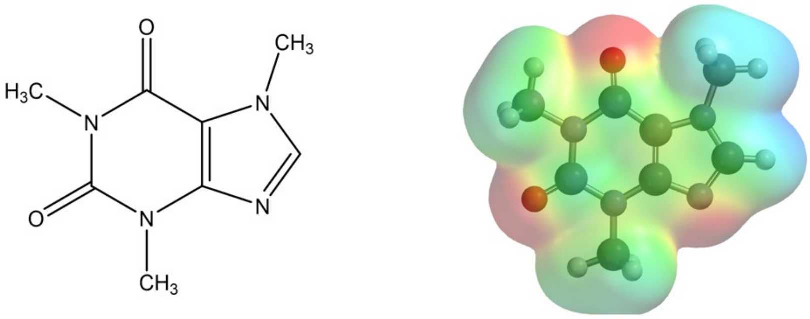


Fig. 2 Structural formula of caffeine and its molecular model (from own resources).

Caffeine is a polar substance that belongs to purine alkaloids, like the structurally related substances theophylline and theobromine. The caffeine fundamental structure is formed by the xanthine molecule, in which a methyl group is attached to each of the three nitrogen atoms. This molecule is less polar than L-ascorbic acid. The semi-systematic name of caffeine is 1,3,7-trimethylxanthine and, contrary to vitamin C, it contains no chiral carbon atoms. Caffeine is found in various types of coffee, but also in tea and cocoa. This substance has a bitter taste and is part of several soft drinks where it procures stimulation impact on the central nervous system (Velíšek, 1999). It removes drowsiness, feelings of fatigue, and induces an invigorating effect on the body. The mechanism of action of caffeine on the human body consists mainly in the antagonistic blockage of the adenosine receptors A_{2A} in the central nervous system. Based on the similarity of the structures, caffeine is able to bind to the adenosine receptor active site and thus competes with the binding of adenosine. Overall, caffeine accelerates the spread of nerve signals and elicits contraction of cerebral vessels. Because dopamine receptors become slightly sensitized, caffeine also improves mood. The structure of caffeine is close to the structure of uric acid, which causes the diuretic effects of this substance.

The third compound, which was involved into this study, is a monocarboxylic aliphatic acid with two conjugated double bonds in the middle of the molecule. The substance contains six carbon atoms, and it is called sorbic acid. The structural formula of this compound and its molecular model are shown in Fig. 3.

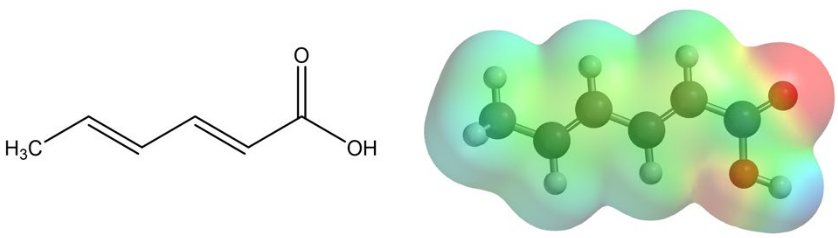
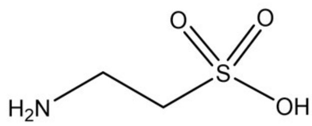


Fig. 3 Structural formula and molecular model of sorbic acids (from own resources).

Besides various additives, soft drinks include also substances called stabilizers or preservatives that inhibit the growth of mold, yeast, and some bacteria. Stabilizer cause inhibition of enzymes and also prevent oxidation of fatty acids, which plays an important role in the rancidity of fats. A very common stabilizer is sorbic acid, which was firstly found in red berries of *Sorbus aucuparia*. For its antibacterial activity, it has been used for suppression of *Clostridium botulinum*, which can produce extremely toxic substances especially in spoiled foods. Sorbic acid is a white crystalline compound, slightly soluble in water that easily sublimes. Sorbic acid (pK_A = 4.76) is of the same acidic strength as L-ascorbic acid, which both can be compared with acetic acid. Sorbic acid with systematic name (2*E*,4*E*)-hexa-2,4-dienoic acid can cause browning of food (Velíšek, 1999), the essence of which is the interaction of sorbic acid oxidation products with amino acids and proteins.

The last compound chosen for this study is also an organic acid, derived from ethane. The trivial chemical name of this substance is taurine, as a remainder of its first identification in bull's bile (ταῦρος = bull). Its structural formula and molecular model are given in Fig. 4.



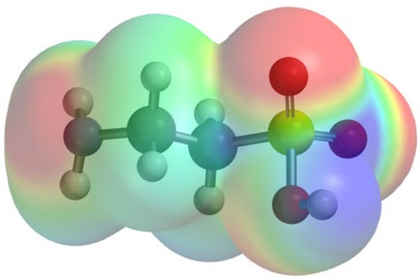


Fig. 4 Structural formula of taurine and its molecular model (from own resources).

2-Aminoethane-1-sulfonic acid, which is the systematic name of taurine, is a substance that is the only amino sulfonic acid commonly found in the human body. Taurine is a stronger acid (pK_A = 1.5) than sorbic or L-ascorbic acids and thanks to the presence of primary amino group it forms a zwitterion in aqueous medium. Taurine is formed by decarboxylation of cysteine and subsequent oxidation of the sulfanyl group to the sulfonic acid group. It occurs in the brain, gallbladder and muscles. In the body, it mainly supports digestion of lipids. It reacts with cholic acids, which are formed by oxidation of cholesterol, to form bile acids. Cholic acid reacts with taurine to form taurocholic acid, which, due to having a structure of surfactants, acts as a lipid emulsifier in the small intestine. Moreover, taurine has a number of other functions in the body. For instance, it is involved in some stimulation processes in the central nervous system, affects the transmission of nerve impulses, can participate in the removal of heavy metals from the body.

EXPERIMENTAL DESING FOR ANALYSIS OF SOFT DRINKS USING THIN-LAYER CHROMATOGRAPHY

Within this study, thin-layer chromatography (TLC) was used to analyse several selected soft drinks available on the Czech market (Gasparič & Churáček, 1981; Fried & Sherma, 1994). The choice of this method is based on the accessibility of materials and chemicals, the simplicity of the analysis and the easy evaluation of the results, accordingly to the possibilities of the secondary general education school and the manual skills of students (Engler, 1983; Kolář, 1996). TLC was used to separate individual additives in samples of the selected soft drink, as well as to assess semi-quantitatively the whole content of samples. Chromatographic analysis of individual additives has been reported by a number of authors, for example, L-ascorbic acid (Trineeva et al., 2018), caffeine and other purine alkaloids (Pavlik, 1973; Torres et al. 2015; Kolář et al., 2001), sorbic acid (Ríos, 1972), taurine (Oberle & Griesinger, 2018). Based on this experience, a convenient composition of the elution agent was proposed. All TLC analyses were performed on silica gel aluminium TLC plates, using different mobile phases as described in Tab. 1.

Tab. 1 Mobile phases, detection methods and retardation factors RF of the selected additives.

ADITIVE	MOBILE PHASE	DETECTION	RETARDATION FACTOR (R_F)
L-ASCORBIC ACID	cyclohexane : acetone : acetic acid (1:2:1)	1% $AgNO_3$ in 25% NH_3 (aq)	0.70
CAFFEINE	chloroform : butan-1-ol : 25% NH_3 (aq) (3:3:4)	UV radiation, λ = 254 nm	0.78
SORBIC ACID	chloroform : butan-1-ol : 25% NH_3 (aq) (3:3:4)	UV radiation, λ = 254 nm	0.19
TAURINE	propan-1-ol : water (8:2)	0.2% ninhydrin in ethanol	0.51

The results of TLC analyses for the selected analytical standards (ST) (e.g. L-ascorbic acid, caffeine, sorbic acid, taurine) as well as for the soft drink samples are (VZ) displayed in Fig. 5.

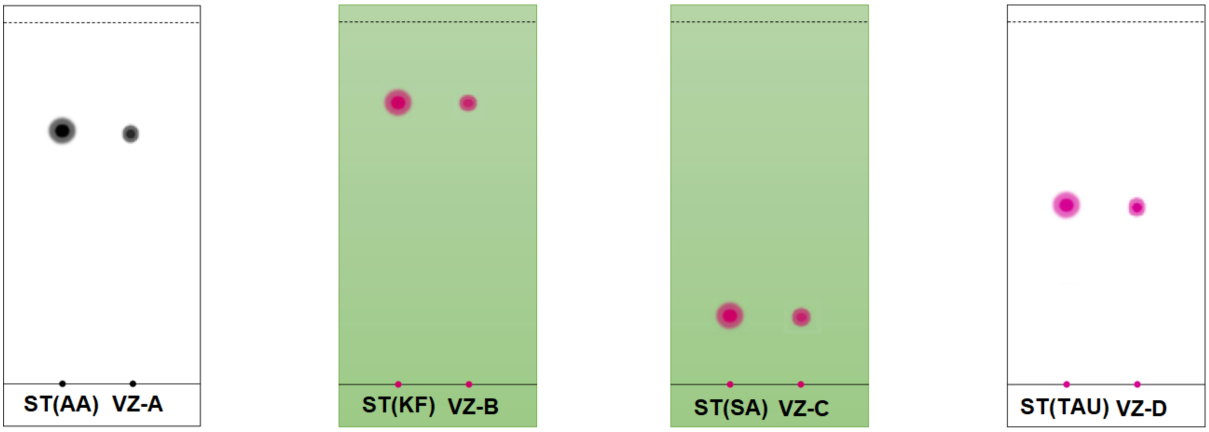


Fig. 5 TLC analyses of L-ascorbic acid (AA), caffeine (KF), sorbic acid (SA), and taurine (TAU). VZ-A, VZ-B, VZ-C, VZ-D represent different samples of soft drinks (from own resources).

FOOD ADDITIVES IN CHEMISTRY AT THE SECONDARY GENERAL EDUCATION SCHOOLS

For the purposes of didactical judgement of the proposed teaching experiments, some legislative documents and textbooks for secondary general education schools in the Czech Republic were examined, focusing on the intentional involvement of key information on L-ascorbic acid (vitamin C), caffeine, sorbic acid and taurine in the chemistry curriculum. These materials contain certain information about vitamin C and caffeine, but only rarely in direct relation to food. In the Czech textbook Základy chemie 2 [trans.: Fundamentals of Chemistry 2] (Beneš et al., 2010), vitamins are discussed on pages 68-69 in the chapter devoted to biocatalysts. There is a part on a simple proof of vitamin C by reaction with silver nitrate. On page 76, caffeine is shown within the part focused on the drug abuse and drug prevention. Based on the curriculum for the upper grades of grammar schools, pupils should encounter information about caffeine in thematic units dealing with heterocyclic compounds. Knowledge about caffeine is further developed in the thematic units of the subject matter on drugs, where pupils can learn the effect of caffeine on the human body (Balada et al., 2007). Basically, pupils are introduced to vitamins within the framework of the biochemistry curriculum. The textbook Chemie organická a biochemie pro gymnázia [trans.: Organic Chemistry and Biochemistry for Grammar Schools] (Kolář et al., 2005) introduces the topic of vitamins on pages 82, 86, 97 and 117. Herein, the structural similarity of L-ascorbic acid with carbohydrates is recalled, structural formulas of a number of natural substances are mentioned as well, including cofactors of enzymes. At the end of the textbook, there are formulas of vitamins and caffeine. The textbook Chemie pro studijní obory SOŠ a SOU nechemického zaměření [trans.: Chemistry for the Study Fields of Secondary Schools and Vocational Schools of Non-Chemical Focus] (Blažek & Fabini, 1999, p. 195) mentions vitamins as natural substances and components of enzymes. Vitamins are divided into two groups according to the solubility in fats and water. Vitamins as cofactors are mentioned also in the book Chemie v kostce pro SŠ [trans.: Chemistry in a Box for Secondary Schools] (Růžičková & Kotlík, 2009). An extensive treatise on vitamins can be found in the book Odmaturuj z chemie [trans.: Graduate in Chemistry] (Benešová & Satrapová, 2002). This textbook introduces also a comprehensive overview of vitamins, including their function in the body, their classification, properties information about the foods in which they are contained, information about the manifestations of the vitamin deficiency in the human body, including the recommended daily dose. A certain drawback of this textbook is that chemical formulas of the compounds are not given in the text. On the other hand, caffeine is mentioned in the topic of heterocyclic compounds and in the subject matter focused on alkaloids.

CHROMATOGRAPHY IN CHEMISTRY AT SECONDARY GENERAL EDUCATION SCHOOLS

Czech pupils encounter chromatography already at primary schools. Especially, experiments with coloured markers are favoured for demonstration of simple chromatographic analyses. The filling of the markers may be analysed by chromatography on chalk or filter paper using ethanol as an elution agent. These are simple presentations of the use of chromatography as a separation method. In the textbook Chemie obecná a anorganická pro gymnázia [trans.: General and Inorganic Chemistry for Grammar Schools] (Flemr & Dušek, 2001), the relevant information on chromatography is given on pages 96 and 97. It describes the principle of the method, its classification and use. In the textbook Odmaturuj z chemie [trans.: Graduate in Chemistry] (Benešová & Satrapová, 2002), a note on chromatography is given in the introductory chapter on page 7. The method is briefly described and its essence is explained. Concerning thin-layer chromatography, information about the method is practically absent in the Czech curriculum for the secondary general education school.

IDENTIFICATION OF FOOD ADDITIVES BY THIN-LAYER CHROMATOGRAPHY

In the following part, a brief description of the necessary steps for TLC analyses of the selected soft drink is presented. At first, a start line is marked with a soft pencil on a thin sorbent layer. On the start line, using glass micro-capillaries, the same volumes of samples of soft drinks and standard are applied to a thin layer. The chromatogram is then placed into the chromatographic chamber containing layer of the elution agent and the chamber is covered with a glass lid. In this way, the chromatogram starts to develop. When the front of the chromatogram reaches a distance of several mm from the upper edge of the thin layer, the development should be stopped. After drying, the chromatogram can be detected by spraying with a detection agent and then heated in the oven (at 80 °C) or visualized under an ultraviolet radiation source (UV lamp). After detection, the individual spots on the chromatogram should be traced with a soft pencil for next evaluation of the chromatogram and calculation of R_F

values. Finally, the presence of individual additives in the analysed samples of the selected soft drinks is assessed by comparison with chromatographic behaviour of the analytical standards, including a semi-quantitative assessment of the presence of substances in the sample.

CHROMATOGRAPHIC ANALYSIS OF THE SELECTED SAMPLES OF SOFT DRINKS

Before carrying out the TLC chromatographic analyses, all available information sources about these food products were studied, taking into account the presence of these food additives: L-ascorbic acid, caffeine, sorbic acid and taurine. The reported content of studied substances in the selected food products is outlined in tables Tab. 2.

Tab. 2 Declared content of L-ascorbic acid, caffeine, sorbic acid, and taurine in the selected soft drinks (N = 11).

NAME OF THE SOFT DRINK	CONTENT [MG / 100 ML]			
	L-ASCORBIC ACID	CAFFEINE	SORBIC ACID	TAURINE
1. RELAX ORANGE	6	-	-	-
2. HAPPY DAY POMERANČ	32	-	-	-
3. PFANNER ORANGE	25	-	-	-
4. CAPRISUN MULTIVITAMIN	15	-	-	-
5. RED BULL	-	32	-	-
6. BIG SHOCK	-	32	-	-
7. KONG	-	30	-	-
8. CLEVER ENERGY	-	32	-	-
9. SEMTEX	-	32	-	Listed only*
10. MONSTER	-	-	Listed only*	Listed only*
11. BIG SHOCK	-	-	Listed only*	Listed only*

*The presence of the additive was only qualitatively declared on the packing etiquette or in other supplementary soft drink material.

In the all above mentioned soft drinks, the relevant additives were identified by TLC in accordance with the information given on the etiquette or in other information sources. The results of the TLC chromatographic analyses showed that the soft drinks contain the supposed food additives that are declared on the packaging of these beverages. The reproducibility of TLC identification of the food additives in the selected soft drinks has also been confirmed. The experience from the TLC analyses was subsequently utilized in proposition of four didactically optimized experimental tasks aimed at proving the presence of L-ascorbic acid, caffeine, sorbic acid and taurine in soft drink samples. These educational tasks are intended for practical exercises at secondary general education schools as well as for chemistry workshops for pupils and other interested persons. Due to the fact that some experimental steps use chemicals that are not suitable for work in the laboratory at a secondary school according to the legislative documents (Nařízení vlády č. 361/2007 Sb., [trans. Czech Republic Government Regulation No. 361/2007 Coll.]), the respective operations should be performed by the teacher or the leading practitioner (Holzhauser & Matuška, 2019). Since the critical substances are components of, for example, the elution agent, the preparation of the chromatogram can be carried out by the pupils, the development of the chromatogram should be then carried out by the teacher, the detection is again carried out by the pupils.

CONCLUSION

Based on the results of our preliminary experimental research, four novel educational tasks were designed for proving the presence of L-ascorbic acid, caffeine, sorbic acid and taurine in the selected common soft drinks by TLC. Since the consumption of these drinks is a matter of everyday life, it is advisable, and certainly more didactically rewording in chemistry education, to try to examine the composition of these drinks by oneself employing an appropriate research method than receiving simply the information about these drinks from the etiquettes or from the literature. This approach paves the way to immediate chemical understanding of the soft drinks that we consume on different occasions and under different circumstances on a daily basis, and can also bring strong impulses motivating and deepening the interest in chemistry and other natural sciences. We hope that the proposed TLC tasks follow the learning objectives, which will be further evaluated in education.

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Evaluation of Student Teachers' Perceived Quantitative Workload and Usefulness of an On-line Elementary Science Education Course Unit

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Abstract

We have designed a 1 ECTS on-line science pedagogy unit as a part of a 6 ECTS science education course for elementary school student teachers. To improve the unit, we asked 169 participants to estimate their use of time and the usefulness of the themes and contents in it. We analysed the responses in the framework of students' perceived workload. The Basics of School Science was perceived as the most useful section, followed by Science Teaching and Learning Methods and Basics of Science and Scientific Knowledge in Schools, respectively. This in mind, we discuss the rescaling of the workload and the respective weights student perception and teacher expertise should have in the process.

Key words

Perceived quantitative workload; perceived usefulness; on-line science pedagogy course unit

INTRODUCTION

Curricula need to be reformed or reviewed every now and then, in order to respond to the dynamic visions and changes in the intended outcomes, learning environments and pedagogy. The curriculum of our Department of Teacher Education at the University of Jyväskylä in Finland was last reformed two years ago. In this reform, the resource of the courses of pedagogy of natural and environmental sciences decreased from 8 to 6 credits of the European Credit and Transfer and Accumulation System (ECTS). This loss, but also the changes in the operational environment due to the multiple global and local incidents, required us to enhance and intensify our digital services in education. We designed a new course of Environmental and Science Education and split it into three units: Active learning in small groups, Text-book exam and On-line science pedagogy studies (On-line unit) (3, 2 and 1 ECTS, respectively). In this report we describe the student teachers' perceived subjective workload and compare it with their perceived usefulness of the themes and the materials in the On-line unit. This case study is a part of design-based research (DBR) to further develop the whole designed course.

In the On-line unit, we ended up with 15 themes, which can be seen in Table 1. The teaching and learning materials were designed by 6 experts in our team. Each of the experts designed materials for 1-5 themes, according to their own specialty. The unit was implemented on-line in Moodle learning management system. The learning materials of the themes varied between texts, videos and interactive contents. Most of the tasks were automated multiple choice control questions, with exceptions of one productive task of curriculum analyses and two discussion boards for the themes of differentiating and science in society.

Theoretical Framework

Workload has been recognised as the major factor in a teaching and learning environment that influences the quality of learning (Kyndt et al., 2011). The European commission defines ECTS credits as the volume of learning. One credit corresponds to 25 to 30 hours of student's work. However, this is just an overall estimation of the objective time that learners may need to complete the activities to achieve the curricular learning outcomes. It is obvious that having too little time to study does not lead to good learning. On the other hand, linear increase of the ratio of working hours to learning objectives does not continuously improve the quality of learning and teaching. As Karjalainen et al. (2006, p. 13) formulated: "Even an infinite amount of time does not guarantee learning, although the existence of time is an essential condition to learning, it is not sufficient itself, other factors are needed as well".

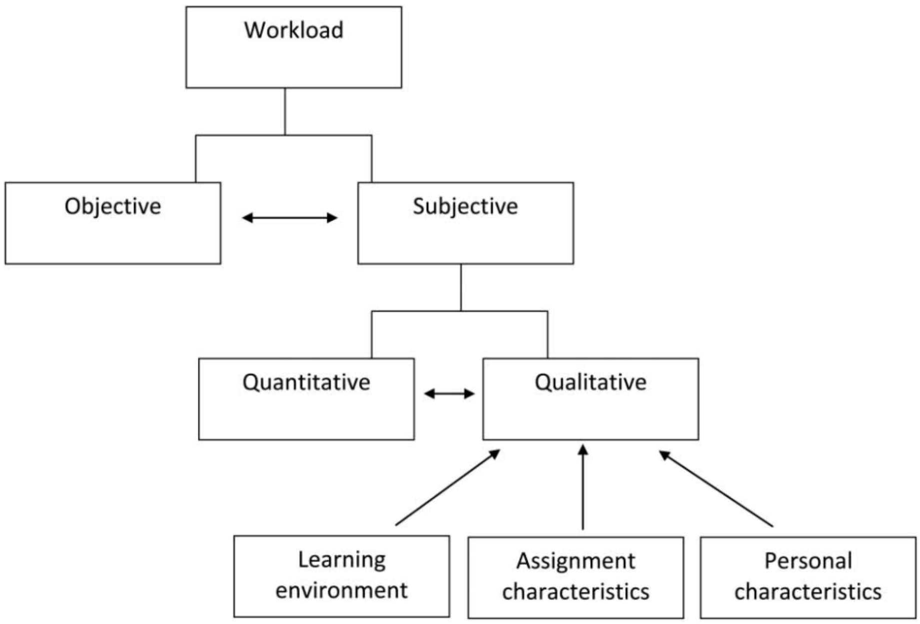

Fig. 1 The conceptual framework by Kyndt (2014), and Kemper and Leung (2006) for objective and quantitative and qualitative subjective workloads was used in this study.

These other factors comprise students' subjective, or perceived, workload (see Figure 1). Kember and Leung (1998) found that the objective workload explained only 4% of the variance of students' perceived workload. Research has shown that high perceived workload leads to a surface type of learning (Entwistle and Ramsden, 1983; Kember et al., 1996; Kember and Leung, 1998 and Beaten et al. 2010). High demands may or may not correlate with that, depending on the teacher (Kemper

& Leung, 2006). Also, the teaching and learning environments are only weakly related to perceived workload. However, Kemper and Leung (2006) described a teaching and learning environment that can be organized to produce good quality learning while perceived workload is still considered reasonable, minimizing the extraneous workload (Sweller et al., 2011). All the above suggests strongly to study students' perceived workload to optimize course designs, learning environments and outcomes for deep and effective learning.

Kyndt et al. (2014) formulated ideas of Kemper and Leung (2006) into a conceptual framework of students' workload. Figure 1 outlines, how subjective, or perceived, workload can further be divided into quantitative and qualitative workloads. Quantitative perceived workload differs from the objective workload, being the student's effective time used for learning (Marsh, 2001). The components of qualitative workload covers the course design and student's personal characteristics. The course design has an effect on the students' perceived qualitative workload via pedagogy and curriculum. Lectures are seen as ineffective teaching (Kember, 2004). Active learning, such as project-based education and real-life contexts are seen as effective and motivating, integrating theory and practice by means of problem-solving related to working life issues (Blumenfeld et al., 1991). Both the content and difficulty of the assignments influence the perception of workload (Kember, 2004). The content of an assignment is defined by its theme and materials. The personal characteristic has a self-strenghtening feedback between learning and interest and vice versa (Karjalainen, 2006). The students' views about the usefulness of the studies can be considered as a factor in this positive feed-back loop. We have not seen any earlier reports comparing student teachers' perceived workload with their perceived usefulness of different themes and materials of science pedagogy.

To study the student teachers' perceived workload in the designed 1 ECTS on-line unit within our Environmental and Science Education course, we first wanted to know if the essential precondition of 25 to 30 hours time being enough time to complete the unit is fulfilled. After that, we mapped the qualitative workload of the unit under the measure of the student teachers' perceived usefulness of the themes of the unit as well as the contents of study materials and tasks for learning them. For this, we set a research question: How do student teachers perceive their quantitative workload and the usefulness of the different themes of the elementary science education on-line unit?

METHOD

A questionnaire was designed to survey student teachers' perceived quantitative workload in studying each of the 15 themes and the usefulness of the materials and tasks designed for learning them. The perceived time used for studying the materials and the tasks were estimated as the time slots of < 30 min., 30-60 min., 60-90 min., 90-120 min., >120 min. for studying materials and <15 min., 15-30 min., 30-45 min., 45-60 min., >60 min., for tasks. The perceived usefulness was evaluated by 5 step Likert ordinal scale with categories from *not useful (1)* to *extremely useful (5)*. In addition, the questionnaire requested open feedback or other ideas considering the content, material and task of the theme in question. The questionnaire was embedded into the tasks of each 15 themes.

The data was collected during the pilot of the On-line unit, with 169 elementary student teachers mostly in the second year of their academic studies, in the period of autumn 2020 - spring 2021. Answering was voluntary and took place after the completion of the tasks of each theme.

RESULTS

The first column in the Table 1 shows the themes of the unit. Student teachers assessed their use of time for studying by the materials and carrying out the tasks in each of these themes. The median intervals of the assessments are listed in the following columns respectively.

Tab. 1 Medians of the time intervals used for the learning by the materials and the tasks assessed by the student teachers. The themes were designed under 3 sections, 5 themes in each: Basics of School Science (red), Basics of Science and Scientific Knowledge in Schools (green) and Science Teaching and Learning Methods (blue). The performances perceived as extremely quick are highlighted with bold typeface.

Themes	Materials	Tasks
1. Curriculum design	30-60 min.	30-45 min.
2. Objectives, methods and assessment	30-60 min.	15-30 min.
3. Classroom interaction	**<30 min.**	**<15 min.**
4. Differentiation and learning difficulties in science education	30-60 min.	15-30 min.
5. Working safely and safety education	**<30 min.**	**<15 min.**
6. Nature of science	30-60 min.	15-30 min.
7. Science in society	30-60 min.	15-30 min.
8. Concepts, conceptual structures and conceptions	**<30 min.**	15-30 min.
9. Knowledge structures of experts and novices, knowledge organization in teaching and learning	**<30 min.**	**<15 min.**
10. Developing thinking skills in science teaching	30-60 min.	15-30 min.
11. Phenomenon based learning	30-60 min.	15-30 min.
12. Project based education	30-60 min.	**<15 min**
13. Simulations in environmental and science education	**<30 min.**	**<15 min.**
14. Games and gamification in environmental and science education	**<30 min.**	**<15 min.**
15. Tips for herbarium	30-60 min.	15-30 min.

The student teachers perceived the usefulness of the different sections of themes differently. On average, the student teachers considered the first section *Basics of School Science* and its theme of *Differentiation and learning difficulties in science education* (Differentiating) very useful (the median value). This theme was followed by the themes of *Working safely and safety education* (Safety); *Objectives, methods and assessment* and *Curriculum design*. The *Science Teaching and Learning*

Methods section and the theme *Project-based education* (PBE) within, the student teacher audience perceived also as very useful (median value). The least, but still moderately, useful ranked themes were *Knowledge structures of experts and novices*, *knowledge organization in teaching and learning* (Novice-Expert), and *Developing thinking skills* in science teaching in the section of *Basics of Science and Scientific Knowledge in Schools*. This trend of the perceived usefulness by student teachers can be noticed in Figure 2., where the distributions have been plotted combining their assessments in the categories of “Not useful and Somehow useful” (1 and 2 in the Likert scale), “Moderate useful” (3) and “Very useful and Extremely useful” (4 and 5).

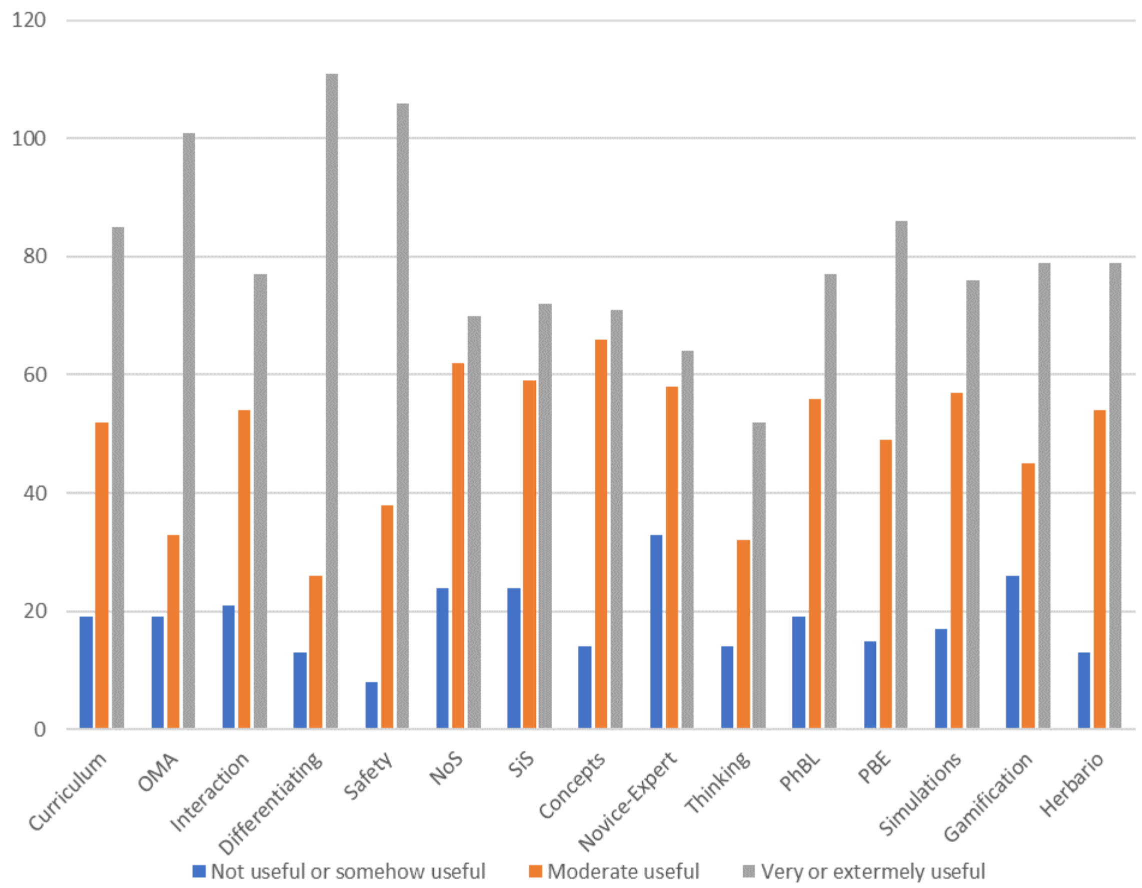

Fig. 2 Student teachers’ perceived usefulness of the themes of the unit.

A similar trend and the median values apply with the perceived usefulness of the teaching and learning materials in Figure 3. The study materials of exactly the same themes were perceived most useful as the themes themselves in the section of *Basics of School Science*. In the section of *Science Teaching and Learning Methods*, the study materials of Simulations in environmental and science education (Simulations) and Herbarium exceeded the usefulness of that for the theme PBE. The study material of Developing thinking skills in science teaching in the section of *Basics of Science Pedagogy* was perceived the least useful by the student teachers.

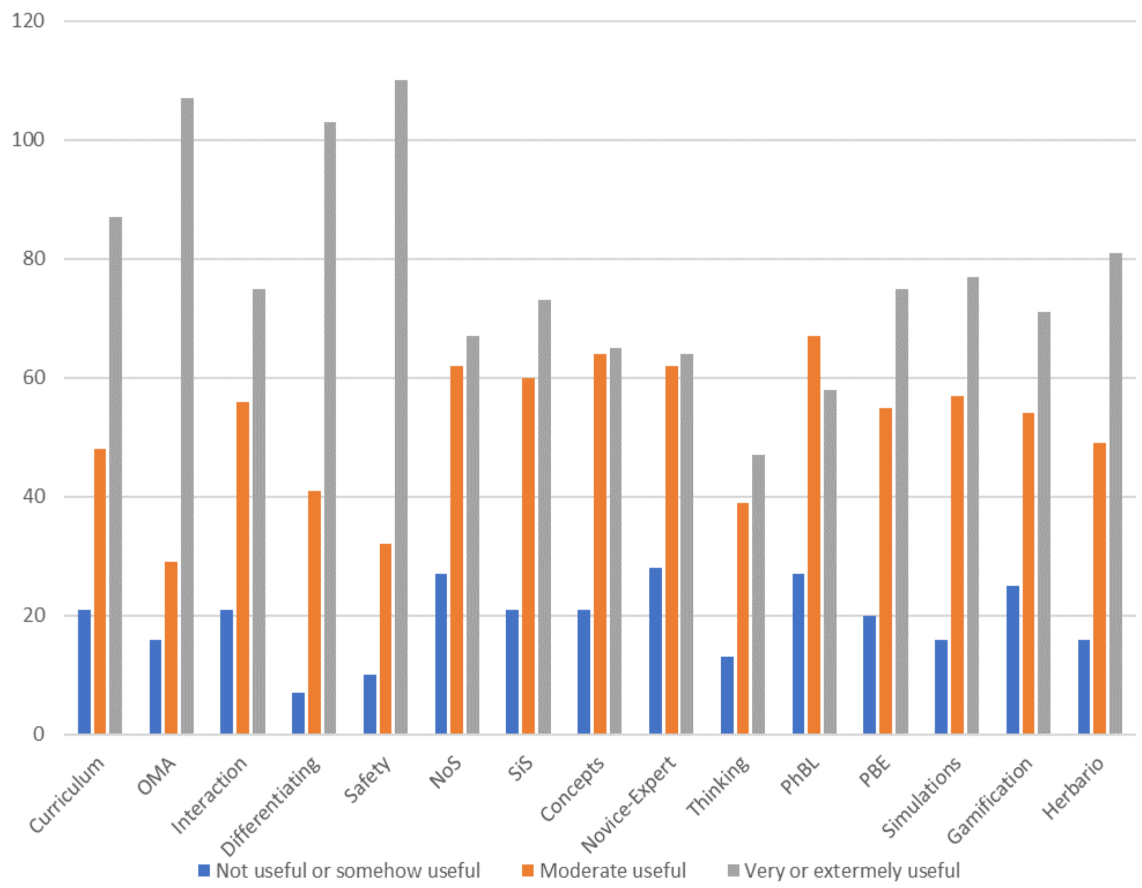

Fig. 3 Student teachers' perceived usefulness of the study materials prepared for each of the themes of the unit.

CONCLUSIONS

As the sufficient time to study is an essential condition to learning, (Karjalainen et al., 2006), the students' perceived quantitative workload should not exceed the intended workload. In this 1 ECTS on-line unit of Environmental and science education, the median categories of the student teachers' perceived quantitative workload of each of the 15 themes settled on 30-60 minutes for studying the materials and 15-30 minutes for accomplishing the tasks. As the 1 ECTS means 25 to 30 hours of objective qualitative work for students, these perceptions of quantitative workload seem equitable and the design of the themes of the units reasonable. The highest median for the perceived workload of the tasks was the theme curriculum design i.e. production of a table comparing the competences of a selected topics across the curricula of school grades (30-45 minutes). This may be considered as the upper limit of quantitative workload of one theme. Increasing the workload of a theme bigger than this this should be well-grounded and reasonable to the teacher students. The other end of the quantitative perceived workload was in the themes of Classroom interaction, Safety, Novice -experts, Simulations and Games and gamification in Environmental and science education (median categories of <30 and <15 minutes each). The objective quantitative workload of these kind of themes may be considered to be increased, if needed.

Student teachers' perceived usefulness of themes and their study materials may be connected to the measures of contents and assignment of the course design in the construct of quantitative perceived workload (Kemper & Leung, 2006). Both the themes and the study materials of *Basics of Science and Scientific knowledge in Schools* were perceived the least useful by the student teachers, which may increase their perceived workload in this section. However, it should be kept in mind that the student teachers' perceived usefulness of the themes and materials serves only as an indicator of their subjective quantitative workload. It does not tell anything about objective usefulness of the themes of the materials. It is the teachers' and course designers' professionality, which defines the implementation of both the contents and methods of curricula. However, the less useful the students perceive a theme, the more activating methods (Kemper, 2004) and materials with smaller workload need to be considered in teaching them to ensure greater part of the working memory capacity to issues germaine to learning (Sweller et al., 2011). In our pilot version of this On-line unit of the new course of Environmental and Science Education, our intent is to teach such themes in the Active learning in small groups -unit of the course.

The next step in our design-based research of developing the On-line unit and the whole course of Environmental and science pedagogy is analysing the student teachers' open responses in the questionnaire. Those will be analysed along with the results reported here together with the designers of each of the themes in the unit. The contents under the themes will be modified, if needed, to take into account the student teachers' perceived qualitative workload, the perceived usefulness of the theme and the study materials, the open responses, and the ideas from the designers and the teachers of the course. To restrain the perceived workload with recommendations of a coherent programme of courses or subjects with a transparent relationship between them (Kemper, 2004), also the instructors of the course will be asked about the connections between the different units of the course.

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Fostering 21st century skills of prospective elementary, technics, and biology teachers during the COVID -19 induced university closure

Kosta Dolenc, Mateja Ploj Virtič, Andrej Šorgo

Abstract

Promoting 21st century skills and teaching them to prospective teachers became a challenge during the closure. The main problem was the lack of didactics for practical exercises, of which practical and hands-on activities are an essential part. Based on previous experiences, three activities were systematically planned and evaluated. The case studies presented were conducted as practitioner research. Final evaluation was done using SWOT analysis. Asynchronous activities supported by problem-based learning were an approach in the right direction. Students were engaged, active, and successfully acquired knowledge and skills under the otherwise passive conditions of forced emergence education.

Key words

Active teaching methods; course evaluation; creativity; remote teaching; science and technology; technical education

INTRODUCTION

The Covid 19 pandemic and its follow-up measures significantly affected the education of prospective teachers. Students and their teachers were confined to their homes and forced online distance learning/teaching became the norm to bridge an academic year (Ploj Virtič et al., 2021; Dolenc et al., 2022). However, like almost every tool, online distance education had many unwanted and unintended side effects (Dolenc et al., 2021). A particularly significant problem arises in education of elementary and subject teachers of technics and technology, biology, physics and chemistry, collectively known as STE subjects, where practical and hands-on activities form a significant part of their training. This training normally takes place in university laboratories and workshops, which were not accessible during the closure. In response to the new situation, the authors developed several practical activities in lively online debates to provide students with the opportunity to combine practical and problem-solving skills with a touch of creativity and to present their work to their peers. Such an approach can be seen as operationalising the so-called 21st century skills (Chalkiadaki, 2018) and the cross-cutting transformative competences (OECD, 2019). This is especially true, when outcomes of the active educational forms are compared to the outcomes of traditional expository teaching practices (Chlebounova, & Šmejkal, 2020; Rusek, 2021).

Fostering 21st century skills and teaching them to prospective teachers is already a major challenge in 'normal' times (Kaplan, 2019; Mulyono, 2018; Nordstrom & Korpelainen, 2011; Soh, 2017; Zemljak & Ploj Virtič, in press) and became even greater during the closure. The lack of didactics for practical exercises in remote online distance education was the first problem that led to improvisation and the introduction of untried strategies. Even more difficult to solve was the lack of laboratory equipment and materials at students' homes, when teaching practise through video experiments or animations was not considered an adequate substitute that would allow students to acquire higher order psychomotor and cognitive skills. A problem that should not be neglected was also the inequality of working conditions for both students and staff in areas of study where much emphasis is placed on practical work. After the first wave of the pandemic, there was a brief pause that allowed for an assessment of the practises that had emerged to sustain the study process, which led to the elaboration of strategies for a possible re-closure of the faculty or retention based on plausible outcomes in blended forms. Based on previous experiences, active problem- and inquiry-based activities were systematically planned and evaluated. They are presented individually in the section "Case studies".

METHODOLOGY

All case studies presented were conducted as practitioner research (Zinskie & Rea, 2016), which means that the roles of a teacher and a researcher are integrated (Binder, 2012). Collaborative practitioner research was chosen (Elliot, 2015) because teacher learning communities provide an excellent opportunity to discuss important research issues and dilemmas (Binder, 2012; Cochran-Smith & Donnell, 2006). Three teacher educators, all specialists in STE (science, technology, engineering) didactics, planned, reflected and evaluated remote classes in a form of active teaching. For a detailed description of the content, the learning activities, the sample of each group and the results, see the chapter "Case studies with household appliances".

Qualitative evaluation involving self-reflection, multiple participants and triangulation enabled the authors to gain a deeper understanding of the teaching and learning process (Cochran-Smith & Donnell, 2006; Zinskie & Rea, 2016). Based on the authors' group discussions on learning activities, the conclusions were prepared that can be used to answer two research questions for STE lecturers in remote online teaching, using activating teaching strategies: RQ1: Is it possible to successfully use active forms combining hands-on activities in distance education? and RQ2: What are the limitations for doing so?

The final evaluation was done by using the SWOT analysis.

CASE STUDIES WITH HOUSEHOLD APPLIANCES

The students carried out a range of learning activities that can be done remotely online. The case studies show as examples three active learning methods that combine practical activities and creativity in remote online distance learning. The titles and basic information about the activities and courses can be found in Table 1:

Tab. 1 Basic information about the learning activities

TITLE	STUDY PROGRAM:	YEAR OF STUDY:	THE TITLE OF THE COURSE:	NOST:
MAGIC TREE	Elementary education (PeF)	4th	Didactics of Science and Technics II	88
SMARTPHONE-BASED LABORATORY EXERCISES	Subject teacher (FNM)	4th	Biological didactical practicum II	8
DEVELOPING A CREATIVE IDEA	Subject teacher (FNM)	5th	Creativity in the school	12

Learning goals of all three activities were similar, and directed students to:

- apply problem solving techniques;
- apply design thinking;
- develop creativity thinking; and
- combine the acquired knowledge to produce final products.

Therefore, learning goals are not repeated in description of each activity.

Description of the case studies

Magic tree

Objective. The aim of the activity was to create a magic tree from household materials and using hand tools. **Background**. The content of the course was adapted and designed to focus on technical creativity and design thinking. The exercises were conducted as an asynchronous project-based activity supported by problem-based learning. Students had to solve real-world problems and apply design thinking methods to produce the desired product. The exercises consisted of a one-month project in which students had to solve real-world problems to meet given requirements and produce the desired product. The solutions and products developed were presented and showcased at the end of each project. The basic information about the presented magic tree project can be found in Table 1. **Method**. The students had to design and make a magic tree with roots, boot and crown that is between 50 and 150 cm tall. They were free to choose the material to be used for the magic tree. The students could use waste (reuse), natural materials (collected on a long healthy walk), homemade materials (collected when tidying the room) or all together, the choice was free. The magic tree had to be meaningfully integrated into any primary school curriculum. It needed to be cross-curricular and could become an activity day task, part of the competition, a project that spanned the whole school year, or any other part of the lesson. **Conclusion**. We found that a project-based activity supported by problem-based learning was an approach that emphasised higher levels of technical creativity. We have indeed exceeded students' expectations in terms of the course and the knowledge acquired and, most importantly, balanced inequalities and enabled everyone to successfully fulfil all commitments.

Fig. 1 Examples of produced magic trees

Smartphone-based laboratory exercises

Objective. The aim of the activity was to create a laboratory activity using a smartphone. **Background**. The reason for this activity was the realisation that most students own smartphones. A smartphone can be considered as a powerful portable computer that can be connected to the internet and allows synchronous and asynchronous communication. An important reason for inclusion in STE practical work is the documentation with the camera and the ability to measure a range of variables (e.g. sound) with a range of built-in sensors supported by applications. As the students did not have access to the school labs, such sensors can in some ways replace the sensors that would otherwise be used with data loggers in a school lab. **Method**. Students were given the task of inventing or redesigning an existing lab activity to include smartphone-based data collection. They were free to choose the topic as long as it could be recognised as supporting one or more objectives in lower or upper secondary school biology curriculum. At the end of the process, which included individual and group work, they were expected to produce a lab manual that followed a structure commonly used in lab workbooks. **Conclusion**. The students have successfully completed their work and created several labs, preferably using a light sensor. Their work can be considered innovative and the production of a lab has sparked new ideas like a snowball. It can be recommended to use the activity in the preparation of prospective teacher preparation not only as an online activity but as a regular lab work and to incorporate it into regular classes to promote multidisciplinarity.

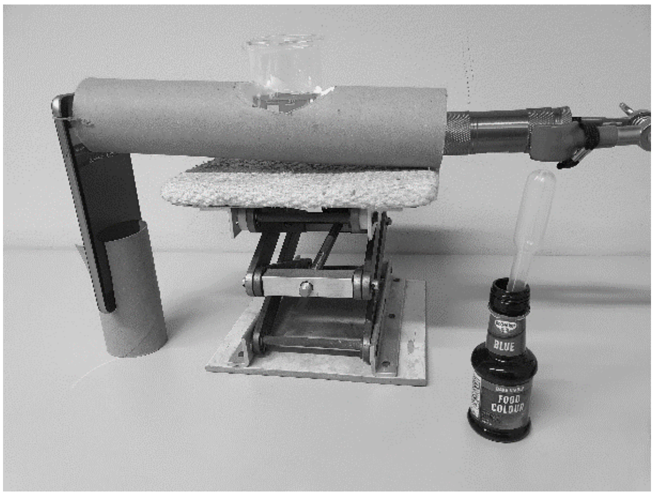

Fig. 2 A dynamic, smartphone-based improvised colourimeter (photo Vida Lang).

Developing a creative idea

Objective. The aim of the activity was to develop a creative idea, focusing on the process using the methods of creative thinking. **Background**. Creativity in school is a final year elective course for all students in the education degree programmes, which means that the group of students is interdisciplinary and heterogeneous. In this course students learn different techniques of creative thinking and develop creativity both in the individual and in the group. The biggest challenge of the distance learning course was to teach how to develop creativity in a group. Under normal circumstances, students would work face-to-face in small groups to develop a creative product that they produce in a workshop, and in the distance learning setting, the activity had to be adapted. **Method**. Students were divided into groups of six and given the task of developing and improving a creative idea by using techniques that promote creativity step by step and through the creative process. Each group first chose a leader who organised the process and their virtual meetings and distributed the tasks that the group members had to complete on an ongoing basis. The instructions given to the students were very loose and allowed for many self-initiated adjustments, but the final goal was clearly defined: Each group had to keep an activity diary recording the process that led to the final creative idea. **Conclusion**. We found that despite the distance learning, the students' group work was very successful. Each group conducted five virtual sessions in the online classroom MS Teams. The activity diary shows that they incorporated very different techniques into the process, and it also shows the time they took for each stage. Let us highlight two creative ideas developed by the students: Zero Waste School (with a detailed concept of reusing individual wastes) and Smart Classroom (with a detailed description of the interior and exterior design, allowing for various experiments and including the use of renewable energy sources). This was followed by a presentation of the individual group tasks and a joint evaluation. An interesting finding of all student groups was that the process took place on an unconscious level according to Wallase's (1926) four-stage model of the creative process: preparation, incubation, illumination and verification. They emphasised the incubation stage, which they experienced much more intensely because of the distance learning. When they had almost given up, they started to develop very creative ideas.

DISCUSSION

During and after the semester, the authors had many group discussions and formative assessments on the learning activities. The final evaluation was done by using the SWOT analysis:

Strengths

- Activate the creative potential of students.
- Even out inequalities and enable everyone to successfully fulfil all obligations.
- Encourage individual and group work.

Weakness

- Lack of control over student work and prevention of cheating.
- Practical work assigned to the asynchronous part of the course can be done by others.

Threads

- Due to the formalisation of tasks, procedures and contents of such activities, creative moments may decrease in the future.
- Decrease in motivation level due to lack of social relations.

Opportunities

- Activating students to use hours set aside for individual work in the ECTS scheme.
- Creating an environment and conditions for blended learning.

The evaluation of the adapted course showed that the course design fully met and even exceeded the students' expectations. They spent significantly more time on the exercises than there were contact hours in the curriculum. A positive pattern seems to appear as also shown by Mattila, Huovinen and Lundell (2022). Most importantly, these activities evened out inequalities and enabled each individual to successfully fulfil the obligations. The didactic concept of group work (Rajsiglova & Škarkova 2019) enabled the students to divide the tasks according to their individual abilities and taking into account the available computer equipment.

CONCLUSION

Forced emergence education has caused many problems that we already know (Dolenc et al., 2021) and many more problems that we have not yet defined. At the University of Maribor, the majority of teachers delivered lectures online as synchronous activities, which were passive activities from the students' perspective (Ploj Virtič et al., 2021). However, we recognised a unique opportunity to introduce active methods, which was not possible in regular classes due to the fixed places and times in the curricula. Asynchronous activities supported by problem-based learning were an approach in the right direction. Students were engaged, active and successfully acquired knowledge and skills under the otherwise passive conditions of forced emergence education.

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How do students formulate a research question and conclusions in science research?

Adam Nejedlý, Karel Vojíř

Abstract

Inquiry skills are an essential part of scientific literacy. The research aimed to map students' ability to correctly formulate a research question and an answer to a research question. Four inquiry-based biology tasks were used, which were solved by 58 Czech lower-secondary school students (ISCED 2) in seventh grade. Based on qualitative-quantitative analysis, it was found that more than half of the students was not able to formulate the research question correctly and more than one third of the students was unable to formulate the correct answer to the research question. Insufficient inquiry skills can limit student's science understanding. Development of targeted intervention therefore seems desirable.

Key words

Inquiry-based science education; scientific thinking; lower-secondary education; inquiry-based learning

INTRODUCTION

The rapid changes of society as well as the extensive development of human activities create several new challenges for education, as confirmed by the anchoring of new competencies. To maintain the current standard of living and for further development, it is also necessary to increase the understanding of natural sciences and their knowledge and the ability to use them in (everyday) life. Therefore, several steps are being taken to change education in this direction (cf. Council recommendation of 22 May 2018). It is desirable not only to acquire specific scientific knowledge, but also to understand scientific principles and procedures, i.e. to develop the scientific thinking. An integral part of it are inquiry skills, which together with other aspects contribute to scientific literacy. Moving towards developed scientific literacy in a broad sense is an important factor for the full application of person in society (see OECD, 2019a).

The analysis of data from PISA and TIMMS testing shows that the trend of long-term deterioration of the results of Czech students at the end of lower-secondary school and the beginning of secondary school in scientific literacy is still ongoing (Prokop & Dvořák, 2019). A possible reason is also the insufficient development of scientific literacy of students at the second level of lower-secondary schools (Prokop & Dvořák, 2019). From the study by Rokos and Holec (2019) is clear that Czech science teachers should focus on the development of scientific literacy through activation methods. Many authors focus their attention on creating teaching materials to support these efforts (see Rusek & Vojíř, 2018). Nevertheless, just over 10% of Czech students have experience with teaching in which they can independently design experiments, interpret data, form hypotheses, or formulate conclusions (Brusenbauch Meislová et al., 2018).

Inquiry-based science education is implemented in teaching as a key educational method aimed at developing inquiry skills (see Bybee, 2013). This method of teaching simulates the principle of real scientific research in its various phases. These are often described through a *5E learning cycle,* consisting of five phases - engagement, exploration, explanation, elaboration, and evaluation (Carpineti et al., 2015). As it turns out, the inquiry process involves several partial steps. Their detailed analysis is provided, for example by Pedaste et al. (2015). However, as noted by Riga et al. (2017), the use of the inquiry cycle alone is not sufficient for the successful implementation of inquiry-based education. Besides the efforts to develop tasks that respect the various steps of scientific inquiry (e.g. Vojíř et al., 2019), attention is also paid for example to the evaluation of students' results in solving inquiry tasks (e.g. Trčková & Bujok, 2019). For the possibility of understanding the (un)success of students in solving inquiry tasks, and especially the possibility of targeted intervention, it is desirable to analyse the inquiry process of students at the level of individual steps. However, only a limited number of research findings are currently available in the Czech environment in terms of specific inquiry skills.

RESEARCH AIM AND QUESTIONS

This contribution presents the results of research carried out in the master thesis by Nejedlý (2021). An integral part of the nature of science is finding information through scientific reasoning. Mastering the principles of scientific reasoning is a necessary prerequisite for the actual study of (scientific) facts and events, as well as a condition for understanding the nature of scientific information obtained from various sources and the possibility of their relevant assessment. For the effective development of inquiry skills in the school environment, it is then necessary to map the current situation with regard to the possible implementation of adequate interventions. For these reasons, the research focused on mapping the inquiry skills of students in the second stage of lower-secondary school. The research plan was concretized through two research questions:

- *What is the students' ability to formulate a research question in solving inquiry-based tasks?*

- *What is the students' ability to properly formulate the answer to a given research question in solving inquiry-based tasks?*

Subsequently, two hypotheses about the existence of a statistically significant association between the solved task and the correctness of the formulation of the research question or the answer to the research question were also tested.

The research question is the basic determining principle of scientific reasoning and together with the answer corresponding to its formulation and the nature of the research activity, forms the framework of the scientific method of obtaining information. Examining student' skills in these areas provides insight into their acquisition of scientific thinking and their ability to use it. Finding out the skill levels of lower-secondary school students show a starting point for further science education, together with possible problems that need to be addressed.

METHODOLOGY

A quantitative-qualitative approach was chosen to answer the research questions. The research was carried out during May and June 2021 at a Czech lower-secondary school. It consisted of four inquiry-based tasks individually solved by students. Students independently formulated a research question based on the assigned laboratory equipment, material, and inquiry procedure. Subsequently, the set question was checked by the teacher. Afterwards, based on a correctly formulated question and their own inquiry, students formulated the answer to the research question.

In the analysis phase, the solutions formulated by the students were coded regarding the quality of the formulation of the research question and answer. Typical formulation problems were identified by qualitative analysis.

Tasks design

Four inquiry tasks designed by the authors were used in the research. The structure of the tasks corresponded to the individual phases of the inquiry cycle (cf. Pedaste et al., 2015). Two tasks used an experiment in the exploratory phase (tasks focused on yeast multiplication and osmotic phenomena in the cell) and two observations (tasks focused on fibres comparison and flower analysis).

All tasks had a uniform structure. The tasks were presented to the students in the form of worksheets. In each task, an introduction to the topic, laboratory equipment, material, and the procedure of one's own inquiry were given. The tasks were then solved in the following steps: 1) The students read the inquiry procedure described in task and looked at the laboratory equipment and material. Based on this they formulated their own RQ. 2) Students presented their formulations of RQs, and these formulations were reflected by the teacher. 3) With respect to the corrected RQ students realize the inquiry procedure. Teacher acted as a guide. 4) Students formulated an answer to a RQ set with the teacher. The used tasks were published by Nejedlý (2021).

Research sample

The assignments were given in the 7th year of one lower-secondary school in the Central Bohemia Region. The research was carried out within the subject *Man and the World of Work*, which is designed as a laboratory practice (cf. Poupová et al., 2019). 41-50 students solved individual tasks (yeast multiplication: 45, osmotic phenomena in the cell: 50, fibres comparison: 41, flower analysis: 50). The teaching of natural sciences at this school takes place separately by individual scientific disciplines (physics, biology, etc.). According to all science teachers, the practical use of inquiry-based learning was not specifically included in the teaching of students in the research sample.

Analysis procedure

A system of codes was used to evaluate students' formulations of RQs and answers. The evaluation was based on a comparison with an expert solution. The formulation of students' RQs assessed the extent to which the student formulated the RQs correctly with respect to the assigned solution procedure and aspects of the assigned inquiry problem. The general characteristics of the evaluation codes are given in Table 1.

Tab. 1 General characteristics of the coding system for the students' formulation of research questions evaluation.

Code	Code characteristics
N	The student did not mention any formulation of the research question in the task.
0	The student stated in the task an incorrect formulation of the research question, which did not correspond to the stated solution procedure and did not reflect aspects of the given research problem.
1	The student stated in the task the formulation of a research question, which only partially corresponds to the given solution procedure, it reflects aspects of the given research problem, but it cannot be answered in full, or it omits some of the essential features of the problem.
2	The student wrote a formulation of a research question that fully corresponds to the solution procedure and reflects aspects of the assigned research topic.

The students' answers to the jointly modified RQ were evaluated to the extent to which the student formulated the answer based on data obtained from the solution and also if the answers respect the nature of RQ with all its aspects. The general characteristics of the evaluation codes are given in Table 2.

Tab. 2 General characteristics of the coding system for the students' responses to the research questions evaluation

Code	Code characteristics
N	The student in the task did not write any formulation of the answer to the research question.
0	The student did not answer according to the obtained data from the solution, in his answer did not respect the nature of the set research question and did not consider any aspect of the research question.
1	The student answered according to the data obtained from the solution but did not respect the nature of the research question and considered only some aspects of the research question.
2	The student answered according to the data obtained from the solution, respected the nature of the research question, and considered all aspects of research question in the answer.

To verify the accuracy of the evaluation, a randomly selected third of the RQs and the formulations of the answers were coded by the second researcher. The data obtained by coding were descriptively evaluated. In the individual categories, typical variants of students' answers were subsequently identified, including typical problems.

Data analysis

The data were processed and evaluated using MS Excel. As the correctness of the student formulations of the RQs and answers was assessed in the verified hypotheses, the codes N and 0 were unified as incorrect formulations in the confirmatory analysis. Pearson's chi-squared test of independence was used to assess the validity of the hypotheses. Post hoc analysis was performed using z-test on the adjusted residuals with Bonferroni correction. To assess the effect size of the association Cramer's *V* coefficient was used. The values of this coefficient were interpreted according to Cohen (1988).

RESULTS AND DISCUSSION

A chi-square test of independence showed that there was no significant association between solved task and the correctness of students' RQ formulations ($\chi^2 = 10.598$; $p = .102$). In the tasks using both experiment and observation in the exploration phase, it was found that more than half of the students were unable to formulate the RQ correctly. In all the tasks, approximately one third of the students were unable to formulate the question even partially correctly based on the given procedure, laboratory equipment and material (see Figure 1 and 2). In the case of partially correct answers, students typically did not report all relevant factors - for example, the inclusion of only the temperature factor in the case of a yeast multiplication task, although the concentration of solutions was included as a factor in the inquiry process.

Figure 1 Proportion of students according to the correctness of their RQ formulations in experimental tasks.

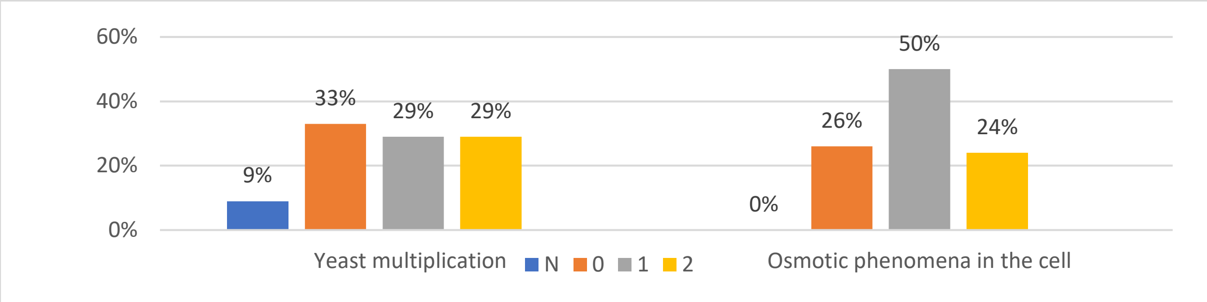
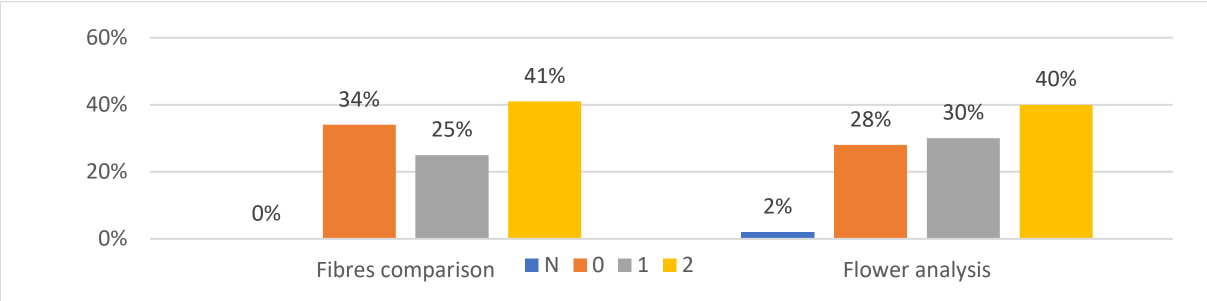


Figure 2 Proportion of students according to the correctness of their RQ formulations in observational tasks.



The similarity in the students' success in formulating the RQ suggests that this is a general competence that does not depend entirely on the specific content. Designing scientific enquiry, including RQs, is one of the essential competencies included in scientific literacy as defined by PISA (OECD, 2019a). The high failure rate of students in determining the RQ corresponds in this sense to the PISA findings, which show a significant group of students with a low-level performance in science (OECD, 2019b). As the RQ is one of the basic concepts determining the framework of scientific reasoning, students' lack of skills in this area can be a significant limit to their understanding of how science discovers new information and how its validity is determined.

Although there is no significant difference in the proportions of the correct formulations for the particular tasks, there are some differences from a qualitative point of view. The tasks with the described experimental procedure led students to one specific RQ. On the contrary, there is more general and broader possibility of formulating RQ in tasks with observational inquiry procedure – e.g.: *"What are the differences between the fibres?"* or *"What group of fibres do these fibres belong to?"*, etc.

It was found that there was a significant association between solved task and the correctness of students' formulation of the answer to the determined RQ (χ^2 = 28.648; p < .001). The effect size of this association was medium (df = 2; V = .278). However, post-hoc z-test on the adjusted residuals with Bonferroni correction revealed that only in task *flower analysis* there was a significant difference (see Figure 3 and 4). In this task, an above-average proportion of partially correct formulations of answers to the RQ was found at the expense of completely correct ones. Only 20% of students formulated response to the RQ in this task quite correctly. Instead of correct answering the RQ, students typically listed only the observed elements (e.g.: *"In colour, stamens, inflorescence, pistil and calyx.").* It seems, that it could be easier for students to formulate an answer based on experimental exploration than observation in some cases. The experimental nature of the research seems to direct students to specific variables and the research framework is clearer to them.

Figure 3 Proportion of students according to the correctness of their formulation of answer to the RQ in experimental tasks.

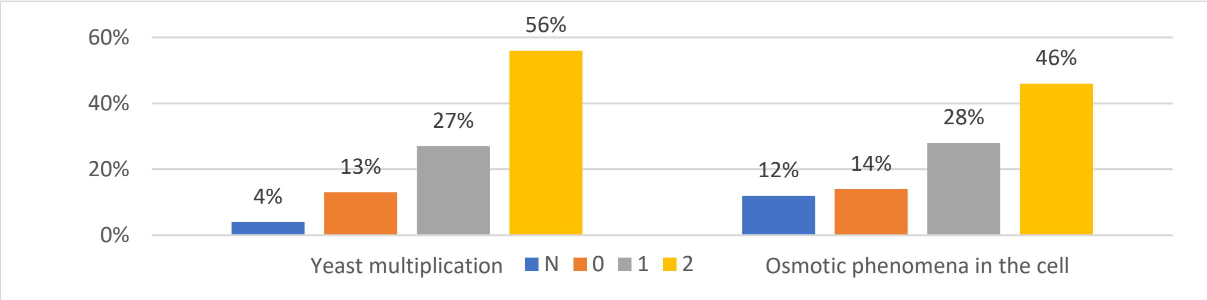
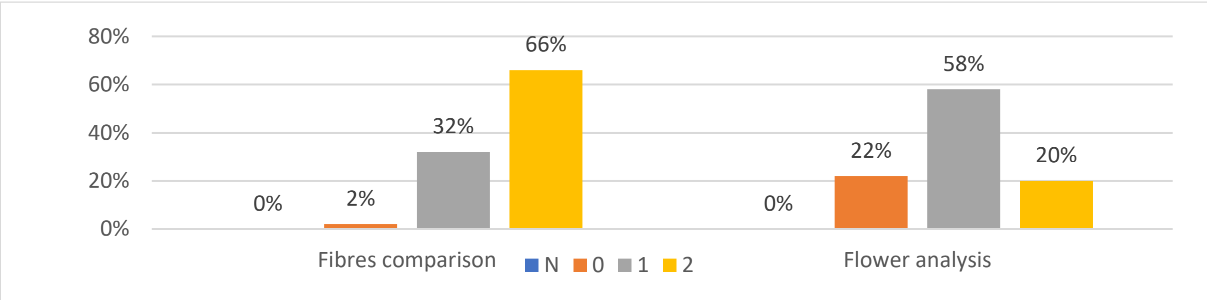


Figure 4 Proportion of students according to the correctness of their formulation of answer to the RQ in observational tasks.



Although in other tasks the students' success in responding to the RQ was higher, on average also only approximately half of the students responded quite correctly to the RQ based on the nature of RQ and their inquiry. Although students actively conducted their own inquiry, insufficient scientific reasoning skills led to a poor understanding of the information obtained. Thus, the actual implementation of research activities without targeted development of inquiry skills does not seem to lead to an understanding of the educational content (cf. Riga et al., 2017).

The development of individual skills is closely related to the nature of the assigned tasks. Therefore, to support the development of students' ability to interpret observed and researched phenomena, innovation of activities used in science education seems desirable (cf. Tóthová et al., 2020). It is also necessary to change the concretization of the intended curriculum, including textbooks. Textbooks play an important role not only in the lesson realization, but also in the teachers' own preparation for teaching (Vojíř & Rusek, 2021). However, the tasks contained in current textbooks do not seem to support the development of inquiry skills and scientific reasoning in general (see Vojíř, 2021; Vojíř & Rusek, 2021).

CONCLUSIONS

The conducted pilot research provided a basic insight into the inquiry skills of lower-secondary schools students. It was found that more than half of the students were unable to formulate a relevant RQ and a significant proportion of students also had difficulty formulating a question-based answer to the simple inquiry. This confirms that students' scientific reasoning skills cannot be a priori expected. Insufficient internationalization of the method of scientific cognition can significantly reduce students' understanding of the nature of science and their decision-making based on the obtained information. The fact, that students fail in these skills requires systematic attention to identify the causes and to design appropriate interventions.

In the conducted research was proven methodology for compiling inquiry-based biology tasks and an evaluation tool for two selected inquiry skills. The proven process of compiling observational and experimental inquiry-based tasks can also serve as a template for creation of tasks by teachers. As the results are limited by the number of tasks and the sample available, this issue requires further investigation. Moreover, only the skill state was mapped. Following research projects should be therefore focused to the possibilities of developing students' inquiry skills.

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Impact of metacognitively designed teaching on 7th graders' metacognitive monitoring and reading comprehension development in the subject of history

Jaroslav Říčan, Vlastimil Chytrý, Ondřej Pešout

Abstract

The aim of the quasi-experimental survey was to determine the impact of metacognitively oriented learning in history. An intervention battery was created (13 hours). Experimental group (N = 57 students) and control group (N = 52 students) was established. The results of the survey did not bring any significant conclusions in the experimental ($p_{exp.}$ = .198, $d_{exp.}$ = .234) or control ($p_{con.}$ = .719, $d_{con.}$ = .062) group for both the reading comprehension area and the metacognitive monitoring ($p_{exp.}$ = .213, $d_{exp.}$ = .195; $p_{con.}$ = .396, $d_{con.}$ = .167). The results are discussed in the context of reliability, domain-general approach and way of measurement.

Key words

History instruction; metacognitive monitoring; reading comprehension; quasi-experiment

INTRODUCTION

Contemporary Science education has been dealing with a challenge how to motivate students to pursue science careers. One of the biggest obstacles is being seen in the low-relevance students ascribe to the topics they learn in science (Schmidt et al., 2019) as well as scientists as individuals (Erten et al., 2013). The latter study showed the importance of stories which is a phenomenon naturally not unique to science education. In order to truly convey history in its full meaning to students in schools, we need to show them how real historians work and think, which is a typical attitude across domains (Shreiner, 2014). In the context of history teaching, it means to form individuals who not only study the science but also apply it and participate in its creation in the context of relevant ways of thinking. The aim of metacognitive teaching is to highlight the content for students as well as the process of their own thinking and encourage them to analyse this thinking and to adapt their thoughts and behaviour to achieve their own goal or the learning goal (Dole et al., 2009). It can be said that metacognitively conceived teaching brings the teacher's attention to the students'' thought process and activity instead of the results of their thinking.

HISTORY INSTRUCTION

Curriculum perspective

Expert contributions show tensions in the concept of history teaching between historians and researchers in the field of history teaching on the one side and politicians on the other (Puustinen & Khawaja, 2020). While researchers emphasize critical thinking, multiperspectivity and understanding the past as a comprehensive set of information with a strong bound to history as science, political leaders emphasize democratic responsibility, patriotism, integration of the individual into existing traditions, and building of national narrative (Van Drie & Van Boxtel, 2008). The second approach often causes a content overload in the curriculum and one's own lessons, "in which students take notes and search through textbooks to remember the facts" (Fogo, 2014, p. 153). This approach, characterized by the central role of the teacher and focus on facts, is dominant in the Czech environment (ČŠI, 2016). From an ontological nature, however, history is an idiosyncratic, soft, and multiparadigmatic science (Muis et al., 2006) which is built on the interpretive nature of the discipline in a social context (Beneš, 2011). This fact necessarily leads to a situation where historians subjectively shape what they interpret. Many researchers form frameworks of historical thinking supported by cognitive research embedded in the social constructivist approach and use them to conceptualize theoretical models (e.g., Big Six – Seixas & Morton, 2013) and diagnostic tools (overview – Reisman et al., 2019) addressed to students. These efforts and tools, however, are often in opposition to testing in history lessons by teachers or the ministry in which recalling of facts, a description of a historical event, or focus on the constructs that may support historical thinking (reading comprehension, but it is not its explicit component – Smith, 2017) are often required. There is a consensus among experts that it includes the complex cognitive processes that historians use to think about the past (Smith, 2017).

Teachers' teaching approach and students' learning approach

Studens' preconceptions often reflect the ideas of collective memory and historical culture (Wineburg et al., 2007) and correspond to the belief that history is "accepted" (the past is fixed and certain – it is not subject to time, space, or participants). Smith (2017) states that the perception of historical sources as windows into to the past and the evaluation of these sources on the basis of whether they are in accordance with the individual's preconceptions is considered "crucial delusions in historical thinking" (p. 1279). Wineburg (2001) states, in summary, that historical thinking is unnatural for studens. However, the ability to examine the past in the intentions of historical science is not available from personal experience. Therefore, it is essential for the teacher to be able to model historical thinking in front of the students (Fogo, 2014). If teachers do not perceive historical knowledge as an interpretive matter, they cannot accept that knowledge is constructed, which clearly affects the way they teach (Wansink et al., 2017). The central cuticular question in history teaching remains the balance between content knowledge and procedural skills (VanSledright, 1996).

METACOGNITION

Metacognition is part of Self-regulated learning models (SRL, i.e., a certain level at which the individual is an active participant of his or her own learning processes) either implicitly (Pintrich, 2000) or with an explicit emphasis (Zimmerman, 2002). Many authors demonstrate that it is a domain-specific construct, i.e., it is tied to the relevant discipline but also to the topic and task (Poitras & Lajoie, 2013). Metacognition is the ability to think about our cognition of ourselves and the world around us. The first significant researchers of this time, Brown (1987) already divided metacognition into two components, even though with different descriptions. This practical double division consists of: (a) knowledge and beliefs about one's own cognitive phenomena (content part) and (b) management and checking of one's own cognitive actions (processual part). This dual concept, despite the terminological inconsistency, is still accepted across professional discourse. According to Winne and Hadwin (1998), the metacognitive aspect of monitoring is at the centre of the self-regulated learning model and for this reason the area is the focus of this paper (similarly: Říčan & Chytrý, 2020).

METACOGNITION AND HISTORY INSTRUCTION

Meijer et al. (2006) suggested a taxonomy of metacognitive activities for studying historical texts (6 constructs with 70 categories), while the authors state that 60% of categories can be realized in both history and physical education The authors, nevertheless, add that the application of the relevant category differs depending on the context of the discipline. Poitras and Lajoie (2013) demonstrated that students who successfully built a deep conceptual understanding of historical events were more likely to apply complex domain-specific strategies (self-questioning and corroboration). The same authors proposed a three-phase model CMHI (Cognitive and Metacognitive Activities in Historical Inquiry) synthesizing theoretical frameworks of historical reasoning and problem solving. The model consists of 7 superior and 36 subordinate strategies (asking appropriate questions, formulating an explanation, evaluating the trustworthiness of sources, using concepts, as well as gathering, corroborating, and contextualizing evidence). Some of these strategies are already interfering with the construction of epistemic beliefs. An analysis of this issue would be beyond the scope of this study.

MATERIALS AND METHODS

History lesson plans

13 history lesson plans were created (topics from 16th century history based on the national curriculum). These included: (i) reading task based on historical text, (ii) cognitive strategy task (prediction, questioning, summarization, comprehension monitoring) and (iii) metacognition-activation task. Each plan consists of 4-6 activities.

Reading comprehension

Texts followed by 12 multiple-choice comprehension items were used to measure reading comprehension. Two historical texts (395 and 472 words) related to the topic of overseas discoveries were selected (Kašpar, 1992). The difficulty of the items in both texts was reviewed twice by three reading comprehension experts.

Metacognitive monitoring

Confidence judgements (CJ) were chosen as an approach for measuring metacognitive monitoring. After each reading comprehension item, the students evaluated on a 100mm scale from 0% to 100% to what extent they were sure that their answer to the previous question was correct (range from 0 to 100). In the context of change in metacognitive monitoring, the bias index was used. Item bias indicates the degree of overestimation or underestimation of correctness of their own answers. The index takes values from -1 to +1 and can be interpreted as determining the direction and size of the error in judgment (Bol & Hacker, 2012).

INSTRUMENT PILOTING

Research sample

There were 8 different schools addressed in the Ústí region. Students from the seventh (N = 182) and eighth (N = 168) grades took part in the preliminary research (10-11/2018). The average evaluation in History (7 = 1.81; 8 = 2.43) and in the Czech language and literature (7 = 2.13; 8 = 2.43). The aim of the pilot survey was to examine the psychometric methods of the instruments used on a sample that has similar characteristics to the target population.

Reading comprehension

The test items were assessed in terms of their difficulty (p). Chráska (1999) identifies tasks with a difficulty level index p > 80 as suspicious, but those with p < 20 as forbidden. The difficulty index determines the percentage of the total number of students who solved the task correctly. It is calculated according to the formula $p = 100 * \frac{n_s}{n}$, where p is the difficulty index, ns are the students who answered correctly, and n represent the total number of tested students.

Tab. 1. Difficulty index values for both texts

Text title	**Pirates and Buccaneers**	**Pizzaro and Incas**	**Text title**	**Pirates and Buccaneers**	**Pizzaro and Incas**
Item order	Difficulty	Difficulty	Item order	Difficulty	Difficulty
1	68	58	7	50	60
2	70	72	8	79	45
3	33	49	9	84	29
4	55	33	10	33	37
5	56	62	11	33	52
6	56	52	12	32	31

None of the items can be marked as forbidden, only task number 9 in the first text is considered suspicious. However, it was necessary to address another issue and that is equivalence of the items of both tests. Items 8, 9, and 11 showed very different difficulty values and were, therefore, excluded. Moreover, the order of items 3 and 4 in the first text was changed to be more equivalent in relation to the items in the second text. After this adjustment, the order of some other items was changed. For further analysis, 9 items were used. The difficulty index was supplemented by a sensitivity value (ULI). For suitable tasks, it should be d > 0.25 for p = < 30;70 > and d > 0.15 for p = < 20;30 > and < 70;80 >. The prohibited tasks are those with a negative value (d < 0). ULI sensitivity coefficient was calculated according to the following formula: $d = \frac{n_{L-} n_H}{0{,}5n}$, where d is the sensitivity coefficient, nL is the number of students with higher scores (better half of the total number of the tested students) who solved the task correctly, nH is the number of students with worse scores (the worse half of the total number of the tested students) who solved the task correctly, and 0.5n represents half of all tested students.

In terms of sensitivity, it was also not possible to mark any of the items as prohibited, however, in the new arrangement, item 8 (text 1) and items 3, 6, and 9, can be seen as suspicious (Chráska, 1999). Only those respondents who filled in all items were included in the reliability calculation. The KR21 model (Kudera, Richardson, 1937) was used to calculate reliability. The reliability of test 1 for N = 280 was $\alpha = 0.523$. The reliability of test 2 (N = 261) was $\alpha = 0.521$. Sekaran (1992) set the acceptable minimum of reliability coefficient at .60. The low level of reliability which is given by the nature of the data (dichotomous items) and the number of items of the tool was acknowledged. The correlation between the instruments (in this case the sum of items) is $r = 0.5$, $p < 0.001$, $r^2 = 0.25$.

Tab. 2. Difficulty and sensitivity index values for each of the 9 items in both texts, including the standard deviation.

Item	Pirates and Buccaneers (text 1)		Pizzaro and Incas (text 2)	
	Difficulty	Sensitivity	Difficulty	Sensitivity
1	70	0.406	72	0.337
2	68	0.252	58	0.367
3	56	0.551	62	0.178
4	50	0.432	60	0.311
5	56	0.480	52	0.277
6	55	0.493	49	0.231
7	33	0.253	37	0.377
8	33	0.219	33	0.440
9	32	0.275	31	0.172

MAIN STUDY

One hundred and nine 7th and 8th grade students (6 schools) were randomly assigned to intervention on the school level: N_{exp}= 57; $N_{control}$= 52.

Tab. 3. Basic characteristics of participants.

Group	Gender (*N*) M	F	Grade CLS Average / median	Grade HS Average / median	SN
Experimental	26	31	2.304 / 2	2.143 / 2	N = 2
Control	30	22	3.37 / 3	3.326 / 3	N = 0

Note: M = male; F = Female; CLs = Czech Language Subject; Hs = History Subject; SN = Special Needs.

Research question and hypothesis

Does the created intervention battery have an impact on students' reading comprehension and metacognitive monitoring (bias index)? For the difference between the results in reading comprehension and metacognitive monitoring, a paired t-test was used to compare the groups (experimental/control) in pretest/posttest and an unpaired t-test when comparing groups (experimental/control) with each other. The effect size value is Cohen's d (1) 0.2–0.5 = small effect; (2) 0.5–0.8 = medium effect; (3) 0.8 and more = large effect. The following hypotheses were tested: H1: The students in the experimental group will have a higher level of reading comprehension and metacognitive monitoring after the end of the intervention than the students in the control group.

Tab. 4 Average level of reading comprehension and metacognitive monitoring before and after the intervention with division into experimental and control groups and Comparison of pretest and posttest results in experimental and control group – inductive analysis

	Reading			**Bias**		
	Before		**After**	**Before**		**After**
Experimental	4.441		4.687	0.021		-0.037
Control	3.562		3.674	0.053		0.093
	Reading			Bias		
Comparison pretest / posttest	T	p	d	T	P	D
Experimental group	-1.31	0.198	0.234	1.265	0.213	0.195
Control group	-0.36	0.719	0. 062	-0.86	0.396	0.167

Given the *p* – level and *d*, it is not possible to state that there was a statistically significant improvement in some groups/areas. The difference between the experimental and control groups was further calculated. H2: The students in the experimental/control group will show different levels of reading comprehension/AP, Bias, discrimination. This hypothesis was verified for both pretest and posttest.

Tab. 5. Comparison of experimental and control group for pretest and posttest – inductive analysis

Experimental / control group		**Reading**			**Bias**		
	N1/N2	***t***	***P***	***d***	***t***	***P***	***d***
Pretest	49/46	1.85	0.067	0.381	-1.21	0.228	-0.25
Posttest	51/46	2.51	0.013	0.510	-2.63	0.009	-0.54

Given the level of *p* – level and d at the selected level of significance (0.05) it is possible to state that there were significant differences between the experimental and control group proven in the case of reading comprehension (posttest) and bias index (posttest).

Given the level of *p* – level and d at the selected level of significance (0.05) it is possible to state that there were significant differences between the experimental and control group proven in the case of reading comprehension (posttest) and bias index (posttest).

RESULTS AND DISCUSSION

Research in the field of intentional intervention proves that this specific ability can be developed through systematic training (Schleifer, 2009). The results of the intervention study did not confirm the assumption that metacognitively designed teaching in work with didactic primary sources in history teaching has a significant impact on the development of understanding of reading comprehension and metacognitive monitoring indicated by the bias index. This finding contrasts with similar studies aimed at developing reading comprehension through the use of metacognitive strategies (Baker, 2002). Due to the fact that the study did not bring any significant conclusions, the obtained data are interpreted in the context of the limits of the study.

LIMITATIONS AND FUTURE DIRECTIONS

Regarding the development of metacognitive strategies, research has so far found that learning tasks must be adequately demanding and stimulating at the same time so that the student used metacognitive thinking (Prins et al., 2006). Less demanding tasks can be solved effectively through the already existing structure of previous knowledge. Therefore, a high level of prior knowledge can lead to a reduction in the subjectively perceived difficulty of the task and thus reduce the need to implement metacognitive approaches. On the other hand, solving too demanding tasks (despite the involvement of strategies) should lead to realistic self-reflection and completion of work. It is possible that the presented activities of the intervention battery were too demanding for the student to be able to engage and develop metacognitive strategies. Also, the activities may not have sufficient potential to develop metacognitive monitoring and reading comprehension. It is proposed to increase the potential of individual intervention activities. Also, attention is drawn to the small size of the sample ($\pi = 0.37$) and the fact that the given comparisons were 4.441 versus 3.562 in the pretest and 4.687 versus 3.674 in posttest. The student's CJ are also strongly influenced by (un)conscious heuristics (e.g. familiarity, fluency, font – Finn & Tauber, 2015) used when working with teaching material. Bias index, as an indicator of the level of metacognitive monitoring, can therefore be skewed. In the case that the text and test items were read to students fluently and without processing difficulties, a positive bias can be expected and vice versa (fluency effect – Carpenter et al., 2013). The feeling of fluency in material processing is at the same time associated with "shallower, less elaborate encoding" (Finn & Tauber, 2015, p. 571). Another factor influencing CJ is the familiarity of the topic (Metcalfe & Finn, 2008). Students influenced by familiarity increases the positive bias value. This raises the question of whether, in the case of experimental surveys designed in this way and similarly, CJ are a suitable methodological approach indicating the level of metacognitive monitoring. In the context of further research, it is recommended to relate the learning activities for students to the theoretical basis of historical thinking, as the general characteristic of metacognition and metacognitive strategies were used while preparing the teaching tasks for the intervention battery. The results of this study suggest that this may not be the appropriate approach. Therefore, it is recommended to focus on a domain-specific approach rather than a general domain one, which can be a impulse for similar research in other domains (e.g. science education, chemistry education) because self-regulated learning and metacognition are an accented topic even in domains built on exact research (Pamuk et al., 2017).

CONCLUSION

Although a significant effect of the intervention battery was not proven, it is believed the conclusions were significantly influenced by the shortcomings in it (potentially weak activity potency; general domain rather than domain-specific baseline), measurement tools, and research sample size. Nevertheless, it is also believed that metacognitively designed teaching in working with didacticized primary sources for the development of reading comprehension and metacognitive strategies has a place in the history lessons. Last but not least, it is a response to the file-drawer problem where “some studies, particularly those with statistically nonsignificant results, [are] never published” (Greene et al., 2018, p. 1094).

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Lapbook as a tool for collecting and hierarchizing content

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Abstract

Constructivist learning theory assumes the importance of a student's activity and independence in acquiring knowledge. In this case, gaining knowledge is a process that takes place in constant interaction with the environment and confrontation with oneself, in order to ultimately lead to the reconstruction of the image of one's own world. One of the tools for organizing self-acquired knowledge is the lapbook. It is something like a thematic folder in which the student collects information on a selected topic. The article describes the research on high school students who made their own lapbook. A pedagogical experiment (ones group technique) in which 53 students participated was used in the research. The influence of creating a lapbook on students' school achievements was described.

Key words

Constructivism; activating methods; lapbook

INTRODUCTION

The constructivist learning theory views knowledge as a form of mental representation, that is, as a construction of the human mind. This concept emphasizes the student's activity and independence, as a result of which they build the structures of their knowledge and not only record the information provided by the teacher (Shapiro, 1994; Lunenburg, 1998). According to the constructivist theory of learning, acquiring knowledge is a process that takes place in constant interaction with the environment, to ultimately lead to the reconstruction of knowledge about the world. The constructivist approach corresponds to activating and creative methods (Chlebounová, & Šmejkal, 2019; Schwartz, 2020). According to constructivism, the teacher should inspire and accept the autonomy of students and their initiatives in learning. Such behaviour is conducive to developing responsibility for one's own learning.

One of the tools to help students organize new messages and construct knowledge is the lapbook. It is a kind of thematic folder in which the student collects information on a selected topic. There is room for information, drawings, stories, charts, words, deadlines and photos. All this is placed in pockets, books of various shapes and on sticky notes. A lapbook is therefore something like an interactive folder resembling a paper theatre that fits on your lap, hence its name. The lapbook is defined as a learning tool that allows students to have fun, be creative and learn through hands-on experience (Fileccia, 2017; pp. 38-39). When creating a lapbook, the student uses raw data, basic sources together with other physical and interactive materials. This allows the student to build their own understanding of the research issues and formulate generalizations to be able to confront them with other opinions. Independent work engages students in experiences that may conflict with their assumptions. It nurtures students' natural curiosity as the most valuable motive for independent learning (Klus-Stańska, 2010).

LITERATURE REVIEW

Lapbook are widely described on Internet pages, e.g. on the website www.handsofachild.com (What is a Lapbook? 2018) and on The Old Schoolhouse Journal on the website www.thehomeschoolscientist.com. Goodwin (2016) mentioned the advantages of the lapbook for classes in science and found suitable ones for students with a wide variety of learning styles and levels of education. However, not much information is found about them in scientific research and literature. The only available diploma thesis in the Czech Republic (Mokrý, 2020) has the wrong methodology (the teacher gave students ready-made lapbook with tasks to be solved).

Despite the extensive use of lapbook in education, there is little research on this issue. Rukmiatun (2016) found that the lapbook was effective in teaching students reading comprehension. Fileccia (2017) recognized that the most important advantage of the lapbook is that children learn by doing, and Cañas and Medina Melcón (2017) found that their use also increases student involvement and interest (Rickard, 2017; pp. 15-17). Fileccia (2017) indicated that creating the lapbook improves remembering the information obtained by students. Andriievska (2018) studied the development of information skills in younger students. Peycheva and Lazarova (2018, pp. 959-960) discussed the use of lapbook in early childhood education. In recent years, research has been carried out on how lapbook can be used in the learning process (Canbulat & Hamurcu, 2021).

METHODS

Hypotheses and research goal

The independent creation of a lapbook by students, consisting of the independent construction and hierarchization of knowledge by students, corresponds to the constructivist concept of teaching. Constructivist teaching is based on the belief that learning occurs as learners are actively involved in a process of meaning and knowledge construction as opposed to passively receiving information.

It was decided to investigate whether the constructive teaching concept would work for students in the 1st grade of secondary school. The topic “Viruses” was selected as the scope of the material.

Students are not very interested in this topic (Rajsiglová & Poneszová, 2020). Therefore, teachers (Blahnová & Pavlasová, 2020) use various methods and techniques to get students interested in this topic. The main hypothesis was that creating the lapbook about the topic “Viruses” on their own would positively influence the level of students' knowledge and increase their motivation to learn detailed hypotheses describe the relationship between the content of the lapbook and the final level of the student's knowledge:

• the amount of information collected by the student in the lapbook have an impact on the level of the student's knowledge (the more information in the lapbook, the more information the student has);

• a number of different elements in the lapbook (appropriate grouping - hierarchy) have an impact on the level of the student's knowledge (the more different types of elements in the lapbook and the greater their hierarchy, the wider the student's knowledge);

• careful execution of the lapbook impacts the level of students' knowledge.

The main aim of the research was to check whether the production of the lapbook would affect the interest and motivation of students as well as the level of their knowledge. Further research goals were to check:

- Can the student's knowledge be assessed on the basis of the lapbook they made?
- Is the final grade from the post-test and ranged test correlated with the grade of the lapbook?

Research description

53 students of the first grades of secondary school from two parallel classes took part in the study. In order to find out what information about viruses they have after leaving primary school, the pre-test was performed. The test consisted of 10 closed questions about viruses. Then the students independently acquired their knowledge and created a lapbook. Students used the information contained in their textbook (Vojíř & Rusek, 2018) to create the lapbook. They could also use any other source they wanted. After making the lapbook, the students wrote the post-test. After 3 months, the durability of students' knowledge was tested. For this, the students wrote the same test again (it was a knowledge persistence test). In total, only 36 students completed all activities: completed the pre-test, made a notebook and completed the post-test, and wrote a persistence test and self-reflection.

RESEARCH

Students scored higher in the ranged test and post-test than in the pre-test. The average for the pre-test is 4.7 points out of 10 possible points, and for the post-test 9.2, in ranged test 8.9. The difference in the number of points obtained in the pre-test, post-test and persistence test is shown in Figure 1.

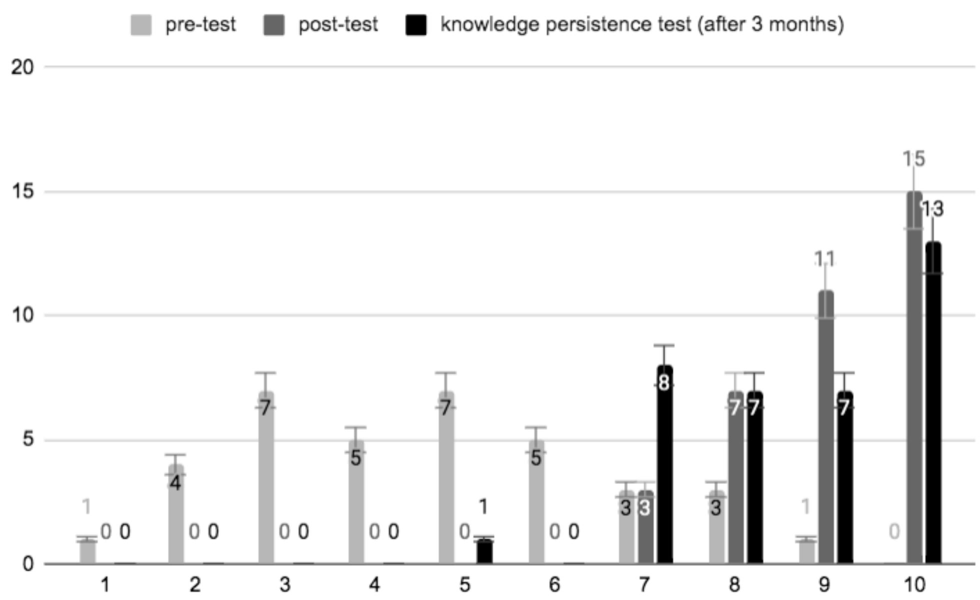

Fig. 1 The difference in the number of points obtained in the pre-test, post-test and persistence test.

In addition, for each question, the results from the post-test were higher than those from the pre-test (see Table 1).

Tab. 1 Percentage of correct answers to particular questions in the pre-test, post-test and persistence test.

QUESTION AND POSSIBLE ANSWERS	PRE	POST	PERSISTENCE
1. Viruses are made up of: only proteins; only nucleic acid; only sugars; proteins and sugars; proteins and nucleic acids.	73	100	92
2. Viruses: are organisms; they are not organisms.	46	92	92
3. In scientific language, we call a complete virus particle: virus; virion; complete virus; whole virus.	17	98	89
4. The virus genome is: complete genetic information of the virus; half of the virus genes; genes encoding ribonucleic acid; genes encoding deoxyribonucleic acid.	50	88	86
5. The nucleic acid that occurs in viruses consists of: DNA only; RNA only; DNA and RNA; no nucleic acids.	41	89	94
6. The morphological forms of viruses are: all viruses are the same, we do not distinguish between forms; various-shape capsids; helical, solid, spherical, solid-spiral.	75	98	100
7. How does viral infection proceed? Always the same: it infects and destroys an infected cell; there is a lytic and a lysogenic cycle; there is only a lytic cycle; there is only a lysogenic cycle.	54	96	89
8. The infectious cycle of a virus attacking animals containing DNA acid is as follows: adsorption, penetration, DNA replication, transcription, translation, assembly, release; DNA adsorption, replication, penetration, transcription, translation, assembly, release; DNA adsorption, replication, penetration, translation, transcription, assembly, release.	25	84	64

QUESTION AND POSSIBLE ANSWERS	PRE	POST	PERSISTENCE
9. Retroviruses are characterized by: carrying out the process of reverse transcription, i.e. DNA synthesis on an RNA template; carrying out the process of reverse transcription, i.e. RNA synthesis on the DNA template; carrying out the reverse translation process, i.e. RNA synthesis on the DNA template; carrying out the reverse translation process, i.e. DNA synthesis on the RNA template.	15	65	69
10. Viral diseases include: flu, mumps, rubella, measles; tetanus, lyme disease, syphilis, gonorrhea; flu, gonorrhea, syphilis, mumps; mumps, rubella, lyme disease, tetanus.	71	94	86

As we can see in the table above, the percentage of correct answers after making the lapbook increased significantly (comparison of the results from pre-tests for post-tests). The p value (one-tail test is 0.068053) calculated in the statistical program (https://www.naukowiec.org/program-statystyczny.html) is greater than the alpha value of 0.05, so it can be assumed that the main hypothesis is true. The students' knowledge thus gained also proved to be sustainable over time. The results from the unannounced test that the students took after 3 months are very good. The percentage of correct answers to particular questions in the test after 3 months ranged from 64% to 100% (average 86%).

However, we were interested in the relationship between the lapbook grade and the increase in knowledge. When assessing the lapbook, the teacher assessed:

- substantive correctness:
    - amount of information;
    - proper structure (grouping of information);
- additional information (outside the textbook);
- form of content presentation (diversity);
- the aesthetics of the lapbook.

The grades obtained by the students are shown in Table 2.

Tab. 2 Student grades (In Poland, the highest grade is 6 and the lowest is 1).

GRADE FOR THE LAPBOOK	3	3.5	4	4.5	5	5.5	6
NUMBER OF STUDENTS	1	0	8	8	16	0	3

It can be said that the students did their best and the lapbook they prepared was very good. Although the results of students in the post-test are clearly higher than in the pre-test, the attempt to find a correlation between the grade from the lapbook and the increase in students' knowledge was not confirmed. Spearman's correlation coefficient is -0.04. This means a very weak correlation - practically no relationship between the studied variables. So, our detailed hypotheses were not confirmed.

Increase in motivation

In conversations with the teacher, they talked about their commitment, they stated that such learning was pleasant for them, and they expressed a desire to perform this type of task more often. At the same time as the final test, the students wrote a self-evaluation. They answered 4 questions:

1. Finish this sentence: I made my Lapbook because ...
2. Finish this sentence: I believe that this method of learning is ... Explain your answer.
3. What methods of content organization and learning do you use?
4. Finish the sentence using the names of the emotions that accompanied you: Making such a Lapbook by myself gave me …

Students' answers to question 1 can be divided into 4 categories. 16 people wrote that they completed the lapbook because it was a mandatory task and / or they wanted to get a good grade. 12 students performed this task out of curiosity - they had never encountered this form of work before. 5 people did not answer this question and 2 said such activities were helpful in learning.

It is interesting to compare the answers to this question with the grade for the lapbook and the results of the post-test and final test, as well as with the teachers' opinion about the students.

Students who wrote that their motivation to make a lapbook was interest in the topic obtained higher grades in the lapbook and better results in the post- and ranged tests than students who mentioned "grade" in the lapbook as the motive for their activities. The group of students for whom the motivation was to obtain "good grade" is not very diverse. They are goal-oriented people who also get "good" grades in other school activities. On the other hand, the group of students who were guided by their interest is more diverse. It consists of both highly gifted students (having best school grades and participating in Olympiads) and non-gifted students (having low school grades). According to the students' teacher, they are often students who are not very hardworking and not engaging in learning.

Responses to question 2 were more personal and therefore more varied. Among the answers to the second question, the most numerous answer was: It is an effective and useful method, one remembers a lot. 13 students gave this answer. Four students also pointed out the time-consuming nature of this method. They also paid attention to individual preferences.

Four students also pointed out the time-consuming nature of this method. They also paid attention to individual preferences. For example, student A wrote: "A method different than all, because for one person this method of learning is better than, for example, mind maps or learning from a textbook", while student B wrote: "At first I thought it was pointless, but I remembered a lot of it." Student C's answer was: "It's very fun but time-consuming, and I personally like to work better with other methods."

When answering question 3, almost all students (27) listed mind maps as other methods of organizing content and learning.

Almost half of the students (17) felt joy and a sense of satisfaction, creativity, and pride in the work they performed. 9 people noted their scientific achievements and commitment. So, it can be concluded that creating a lapbook motivated them to learn.

CONCLUSION

The research confirmed the usefulness of the lapbook in science education at the secondary school level. After creating the lapbook, the students' knowledge level almost doubled, on average from 47% to 90%. The knowledge of the students was also stable, after three months on average 86% of the students' answers in the test were correct. The use of the lapbook increased students' motivation to learn. Comparing the students' answers regarding the evaluation of work with the lapbook with their achievements allows us to conclude that the increase in motivation to learn increased especially among students who were not previously interested in learning.

Rickard (2017), Andrijewska (2018), Peycheva and Lazarova (2018) and Canbulat and Hamurcu (2021) obtained similar results in different areas and groups of students. Because this research did not concern natural sciences and concerned students much younger (primary school), it is difficult to directly compare the obtained results.

The lapbook is often used in education, but there is no research on its effectiveness. The aforementioned work (Mokrý, 2020) has the wrong methodology. Therefore, it seems that our research can be considered a starting point for similar research that will be conducted in the field of natural sciences and among secondary school students.

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Project-Based Education Research Course Supports Exchange-students' Research Minded Teacher Identity

Leena Mattila, Heli Huovinen, Jan Lundell

Abstract

Project-based education (PBE) gives possibilities for students to work together and feeling of belonging in a community even during distance learning. At the Department of Chemistry, University of Jyväskylä (JYU), a group of exchange students participated in a PBE chemistry teacher education research course online. The goal of the course was to enforce the connection between research on science teaching and acting sustainable in society. This study is based on semi-structured online group interview of the students after this PBE course. The main focus of this investigation was how positive feelings and attitude affect learning.

Key words

Project-Based Education; professional development; sustainable development goals; positive attitude effects

INTRODUCTION

During academic year 2020-2021 only few students could travel to other countries since the Covid-19 pandemic made normal, on-site student exchange impossible. Almost all teaching in Higher Education globally were transferred online. Simultaneously, virtual exchange possibilities became real. Exchange opportunities abroad is still much more than just studies. It is about experiencing the foreign country and student life. "New Covid normal" was something different. Students were looking for different kind of support to handle their loneliness and other emerging personal problems besides being challenged with new forms of education. Planning studies and organizing teaching to support students´ engagement and motivation become more important than ever before. Moreover, teaching students needed new ways and perspectives also from teachers in the void of other educational-related social connections.

Student-activation strategies such as inquiry-based (science) education (IBSE) or project-based education (PBE) give more possibilities for students to work together and the feeling to be part of a community. Also, there is a significant body of research continuously proving their effectiveness (see, for example, Furtak et al., 2012; Rusek, 2021). Here, a case study to address students' views of a virtual research-focused course on sustainability is presented. The focus is on students' feelings and experiences after completing the online course as part of their exchange period. Our focus is to show how pedagogically engaging and meaningful online studies could help students to develop professionally, as well as to support the students to handle social loneliness.

THEORETICAL BACKGROUND

Emotions have been established as a significant factor affecting learning and attitudes for learning. Especially, emotions are both experienced in the school setting and instrumental for academic achievement and personal growth (Pekrun et al., 2018). Some studies have been made on how emotions affect learning at workplace. For example, Hökkä et al. (2019) have indicated that emotional dimensions have been mostly neglected in work-related research but also in research concerning education at Higher Education institutes. In addition, they have discussed how emotions have been described in resent publications highlighting especially the role of feelings in decision-making, attitude to studying for working life, and development of professional identity. At same time, agency and professional development have been in focus in Higher Education research (Vähäsantanen et al., 2019) giving two different perspectives on the research presented here: Firstly, how students feel when they study and make practical work on this example course, and secondly how the teacher of the course work in organizing and teaching the learning experience and its path during the course. Both sides are work-related but with different subjects of focus. However, in research it is challenging to separate work and practical work-related learning. As Arvaja (2018) have showed, tension between these two aspects as well as the tension between Higher Education institution leaders and teaching staff can be seen as a lack of interest of developing research-based and student-oriented teaching.

Emotions affect learning and professional growth. According to Hökkä et al. (2019) both negative and positive emotions are meaningful for learners. In general, more negative notions to learning are seen based on studies published. As Vähäsantanen et al. (2021) indicate, development of agency can be seen as active participation, for example, to take actions to develop students' work. Agency is also seen as a driving force to teachers to assess their own learning besides teaching. Moreover, agency can be seen as development of professional identity. Tews et al. (2017) have found that "fun supports learning" when they were looking at informal learning. In addition, they have emphasised that all "fun" is not equal and that should be remembered and accounted for when teaching or workplace are developed.

What students learn during their exchange study periods have been studied and described in more detailed in the last few years. Especially, Roy et al. (2019) have listed skills that students learn during short term study exchange periods. There are three areas highlighted: Cultural (outcomes, awareness/

global mindedness, intelligence, sensitivity and empathy, adaptability, intercultural competence), personal (awareness of moral and ethical issues, academic performance, self-efficacy, confidence) and career outcomes (professional development, career prospects, networking, soft skills, interest of career develop). In addition, there are also findings in research that learning appears in a spiral fashion and needs to be repeated several times in order to deepen the knowledge (Aarto-Pesonen et al., 2017). This gives especially a mindset for virtual educational efforts for which teaching and learning methods adopted should be repeatedly used and exploited. This is important in teacher education where the experiences and educational models used become familiar enough to the students to be exploited later in their teaching profession.

Research Questions

- How to use Project-based education (PBE) to support Student teachers' research attitude development?
- How do emotions effect student's professional development and learning?

RESEARCH COURSE ON PBE FOR STUDENT TEACHERS

University of Jyväskylä (JYU) organized a research course (5 ECTS) for student teachers during their study exchange period in Jyväskylä. They were studying in Jyväskylä only one term and during extreme Covid-19 pandemic times teaching was organized fully online. These exchange students were credit-base mobility students, and the students are expected to accumulate credit points from the University visited. According to the Erasmus Charter, all these credits should be recognised by the student's home university (European Commission, 2021). Some of the students were not able to arrive in Finland and they studied remotely from their own country. The research course was organized for the first time fully online, and it focused on Project-based education in the context of UN Sustainable Development Goals (UN, 2015).

Course started at the beginning of February and there were online meetings once a week, on Friday afternoons. At the beginning of the course students got open-ended description of the course outcomes and working methods. They were asked to trust in the process in order to mimic a research project and act accordingly. This was based on the pedagogical target to engage the students in the studies, to enhance their research-skills, and to increase their own agency and responsibility in the project outcomes and their own learning process. Shortly, the course was conducted in a way where the students changed their role from participating learners in the beginning to co-operational researchers in the end. The final product of the research project – and the outcome of the course - was a common pedagogical model that was co-created and collaborative owned (Aksela, 2019). The actual realisation of the course itself is presented elsewhere (Lundell et al., unpublished), and here we focus only on the outcomes from the interview with the students after the course.

Data Collection

After the PBE Sustainable course the students were asked to participate in an online interview. They were explained that they could decide themself do they want to participate and that results will be used for research, and that results will also be published. Students could trust on that information of the results will be handled confidentially, and they will not be recognised from the study. All students who participated the course and managed to pass it, were willing to participate in the online interview.

Data were collected using semi-structured interview performed via Zoom. All students were asked to join in video conference by Zoom for the group interview. The interview was recorded, and afterwards automatic texting was used to provide a preliminary transcript of the interview. The researcher interviewing the students was not familiar nor interacting with the students during the course the students had taken. Because students were not using headsets at the interview, texting had a lot of errors, with some parts needed to be corrected manually. This was made by an additional researcher not familiar with the course nor the students. Language of the interview was English.

The interview transcripts were analysed thematically by one author and transcripts were also read by the other authors of this study. In addition, facial impressions could be seen, and these were accounted for by adding explanations of them in the transcripts. Cultural differences were also discussed in the interview. However, it was impossible to minimise cultural effects on the results.

RESULTS

One out of three students could include credits of the course into current study degree at their home institution. Because of the Pandemic, only two out of three of the students could arrive to Finland but had to study remotely, because JYU was closed. The third student had to participate in the course from the student's home. Students were both in Master and Bachelor level, EQF level 6 and 7. European Ministers three levels education cycles, agreed on 2005 at Bergen during Bologna process, means same as 1st and 2nd cycle students. (Europass, 2021). The course that the students participated at was a master level teacher education specialisation course on research methods especially designed for exchange students. The course was delivered in English, since all students participating were exchange students from abroad. Two out of three of course students had studied in English before. Two out of three students had also done educational research during their studies at their home university earlier.

Students described the teacher of the course during the interview. They did not use the word "teacher". From the recording we can find that students had a pause before they found the word they wanted to use. It seemed they did not think "teacher" was the word they want to use. None of them had English as their mother tongue and finding a proper word to describe the relationship between the teacher of the course and students made them feel uncomfortable. They used many words to describe teacher, for instance, instructor, he, professor, supervisor, or they used the first name of the teacher or the full name of the teacher. Instructor was the most used word to describe the leader or teacher of the course. The most interesting finding was that they would not like to use word teacher, even that was the way it was described everywhere (Study system in JYU, information given to students etc). This could reflect the situation where the teacher was actually more a peer within the group as could be expected when a research group is collaborating and co-creating (Aksela, 2019)

When students were asked to describe their learning outcomes, they expressed views on research skills and writing report skills. When they were asked what they could add to their CV or application letter from this course if they were applying positions, they could not describe specific skills or competences. One of the students mentioned being acquainted with Finnish education system and experiencing it first-hand. The student thought it would be beneficial to mention studying in Finland when applying positions because that could strengthen their application for a teacher position in their home country. They could not describe other skills or competencies they had learned. This is quite a normal finding. If students were not oriented to skills and competencies, they are not able to describe them as outlined in the Erasmus Skills project (2020). From our transcript we can see that students mentioned many skills that has also described on short term exchange (Roy et al., 2019). They understood multicultural group skills, language skills, reporting skills and many cultural aspects, and described personal skills. This finding is in line with Roy et al. (2019). This course did not put focus on teaching skills or highlighted skills that could be learned besides research skills involved in science education to understand where learning takes place and how it can be made visible.

Many ways to describe emotions is observed from the interview transcript. Students describe their feelings in several ways, but always expressing them in a positive way. When asked why everything they say is positive, they started to think it more carefully. Different evaluation manners in different Higher Education institutions were highlighted, and it is one of the most remarkable findings in our study. Here is how the student described the difference:

"We have only like the zero-one, something is wrong, or something is right. Can you imagine, I didn't do like the teacher wanted me to do, but it was okay!"(S1).

The interview of the students was organized as a group interview. There were exchange students and virtual exchange students in the group interviewed. From the data we are not able to separate results whether the students were located on-site or whether they were distant, virtual students. There are several reasons for this: The group was small, and students heard each other's answers. The interview was conducted in a dialogic manner. In the future, it would be interesting to investigate if professional development and skills learned during exchange could be different for virtual exchange students compared to traditional exchange students. Moreover, in the post-pandemic era also hybrid teaching opportunities have merged, which could be employed to modify the possibilities to include local, exchange and virtual exchange students simultaneously on a lesson. In the long run being able to discuss your own research, validate it, employ it in another context and experience it first-hand are professional development skills that will affect the upcoming teaching career of any teacher student.

Students described their positive approach to this PBE-course by comparing it to their other courses both during the exchange period as well as their home institutions. They mentioned that normally they do not like study on Fridays and especially on Friday afternoons. They rather want to spend time with their friends. The PBE-course was organized on Friday afternoons, and still students anticipated to attend these course online sessions. By the transcript it is hard to find reason for this. Normal life was different during the Pandemic and spending time with friends was restricted for all students. However, this does not explain the positive attitudes the students had for studying educational research methods in the context of sustainability on Friday afternoons.

In the interview transcript it is seen that students indicate they always opened cameras for the teaching sessions. However, they did not do that in other study situations. They explained that in this course teacher always opened his camera as was done also in other courses. When asked why they choose to open camera, the students started to express reasons why they do not like to open camera. They found many reasons for this and at same time they could not find a particular reason why they wanted to open camera in this course. In addition, one of the students described that only once the student´s computer was broken, and the student had to participate via mobile phone. Expressing this the student appeared sad that it was not possible to open camera like everyone else were doing. This clearly state a feeling of belonging and mutual respect between the course participants, as well as deep engagement for the course and studying in this context. The engagement can be witnessed by changing their behavior during a learning situation. (Fredericks et al., 2004)

DISCUSSION

This research, in line with some others (e.g. Dolenc et al., 2022), showed that the PBE-course supported student's agency and self-efficacy. The project focused upon during the course was planned to be open ended in a sense of a real research project, and students felt they had a lot of decision-making power on their own project. This enabled the growth of students´ professional development, confidence in their own making, and their self-efficacy. In addition, we could also observe that by getting power on decision-making students felt satisfaction in their own doing and achieved outcomes. They were feeling positive and optimistic for learning and participating in the project, even Pandemic situation could have given them many reasons for negative feelings. On the other hand, they felt they learned, and in addition their self-competent level rose. It is seen that their professional skills and competencies as well as agency developed without them actually realising it themselves before this interview.

Positive atmosphere of the course obviously came from the group incorporating both the teacher and the students. All the students liked to work together, and they liked to learn the way course was organized. Will this work with another group is impossible to predict, but similar open-ended courses have been conducted after this research was performed, and all the courses seem to point to a similar direction. Based on the interview we are not able to describe what makes the course so successful. One important point was teacher´s attitude and working methods as highlighted by the students. This made the students feel that they are supported, cared for, and their skills appreciated. This also hides an authoritative teacher role and makes the teacher more a person who support learning and foster students' development. Based on the comments and attitudes expressed by the students during the interview, the students obviously felt this course teacher role different from the courses they had encountered previously. It would be interesting to make more research on this topic, but it means we should be able to follow also the teaching sessions or lectures besides conducting after-course interviews. This, however, could bring out data evidencing the actual activating components of teaching reaching for enhancing students' engagement and increased self-efficacy – and leading to meaningful and interesting learning experiencing supported by positive feelings.

It would be interesting to interview the teacher for more detailed insights on how teachers are prepared and supported for activating teaching methods. Moreover, how common it is to organize courses this way in JYU, as this example course was organized? What kind of support is offered to teachers in JYU and how such real-life approaches are cherished and nurtured? Usually, in academic context teaching is not valued as high as research activities. This makes also teaching development less valuable compared to research. The tension between research and teaching can be seen on lack of interest toward teaching. How did this course teacher get support and how this tension is seen or felt in JYU – or have we just stumbled upon a rare example of activating teaching methods in action? In addition, the teachers own feelings would be interested to hear and learn from. Did the teacher feel as positive in this course as the students did? How did the teacher feel working at the course as "instructor"? Did teacher understand and see teacher´s role same way as the students did? Was the teacher feeling motivated and professionally compatible? In future research on these topics would be interesting to make in order to triangulate the success of activating teaching and learning methods from the student and teacher perspectives. Our data from the student interviews point out a rare example of teacher jumping in the deep end of the pool with the students, and truly engage into a research project with unknown destination. The data shows very positive feedback of this challenging but rewarding approach by the students.

The way this PBE-course was organized to enable students´ research skills and competencies development. The important skill for student teachers was the confidence to use research in their future work. Teachers can develop their work by with a research-based attitude. Studying teacher´s own work (curricula, teaching material, students' learning and evaluating study outcomes) is the key to develop schools and teaching. The attitude towards research during academic studies is irreplaceable. Employing project-based education and right teacher attitude it seems to be possible to manage and support meaningful learning (Shuell, 1990).

Positive feelings and fun seem to make working easier, as mentioned by Tews (2017). In our research similar results are seen. Can we still say that positive feelings made learning easier or did learning create positive feelings? This is impossible to find out based on the data here. But does it matter which comes first? More important is to find out that positive feelings create positive outcomes. During hard pandemic time this PBE-course managed to create some positive outcomes. Exchange students described their self-efficacy growing, they felt themselves confident and their agency developed. They could describe many skills and competencies they learned. PBE-research course managed to fulfil their needs and gave them an idea how to do teacher work employing research to scrutinise learning and teaching. The students were motivated to learn, and they found their interest towards research. It was interesting to find out that as Aarto-Pesonen (2017) describe spiral of professional development, attitude can also change on repeating learning. This was seen among students who described they have done research studies before. On this course they still could learn new skills, found new positive attitudes and developed their professional skills as well as their attitude.

CONCLUSION

PBE proved a useful method for the research course. By this method, it is possible to motivate students to learn and to support their professional development. As seen in the virtual course and in the international context, PBE can offer possibilities to make learning fun and positive. It can also minimize hierarchy between students and teachers. International students could work together and adapt to multicultural group during the collaborative and co-creative PBE-course. Positive atmosphere helped students' self-efficacy development and initiated a creative atmosphere at same time they learned to make research during their exchange in foreign country. Besides skills and competences acquired, they expressed a positive and grateful attitude for the experience and the opportunity to attend the PBE-course.

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Promoting modelling competence in an IBSE-based project in a 5th grade biology lesson

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Abstract

Due to the importance of models in everyday life, students shall learn to use them not only as a method for transmitting information but as an instrument for scientific inquiry. Therefore, in this inquiry-based science education (IBSE) project 5th grade biology students researched the human backbone (vertebral column) and build a model in teams of two. Afterwards they presented, evaluated and reworked their models. Data were collected through a questionnaire with forced-choice items developed by Krell & Krüger (2010), based on the framework of modelling competence by Krüger & Upmeier zu Belzen (2010). The goal of this project is to measure and improve the level of student's modelling competence.

Key words

Inquiry-based science education (IBSE); models; modelling competence; human backbone; biology education

INTRODUCTION

Models have been part of our life for a long time, be it in school, science or everyday life. For example, children play with dollhouses or model trains, teachers demonstrate respiration using a model of lungs and young families dream of their own home by working together on an architectural house-model. The potential uses of models are therefore extremely diverse, including the field of natural sciences. Consequently, the competence to think in models and to deal with them in a reflective manner plays an important role in natural sciences (Grünkorn, 2014).

Due to the growing importance of models, especially in the context of school, the focus lies on describing the different aspects of models and their formation. Based on empirical studies (Crawford & Cullin, 2005; Grosslight et al., 1991; Justi & Gilbert, 2003) and scientific literature, Krüger and Upmeier zu Belzen (2010) developed a framework of competence, which forms the theoretical basis of our research project.

The research project was carried out on 16 July 2021 in a fifth class with 25 students at the Hans-Dietrich-Genscher-Gymnasium in Halle (Saale). The course of the project unit was planned and designed on the basis of the idea of "research", which is why we based our project on the idea of inquiry-based science education (IBSE).

THEORETICAL BACKGROUND

The need to investigate the role of models in the context of school has increased in recent years. For example Krüger and Upmeier zu Belzen (2010) cite several studies in which the opinions of students and student teachers on models were surveyed and tested. The descriptive aspect of models as mediums of perception for school education play a dominant role, while the function of models as research instruments for scientific knowledge acquisition plays a subordinate role (Krüger & Upmeier zu Belzen, 2010).

As a result of the change of perspective in the German education system, from input to output-oriented thinking, the focus of teaching and learning has been shifted to imparting competences (Grünkorn, 2014). Due to the development of science education standards, a focus on models and the modelling process has also been anchored in them, whereby students are to build and apply models in class and reflect on their meaningfulness (Grünkorn, 2014). The concept of competence, which was developed in the early 1970s in the field of psychology, focuses on the abilities of individuals to cope with problems and tasks in specific situations. It is important to mention that competences are not directly observable and therefore have to be theoretically modeled and operationalized with tasks in order to be able to be recorded (Grünkorn, 2014).

This project report is based on the theory-driven framework of modelling competence by Krüger & Upmeier zu Belzen (2010) (see Tab. 1). According to them, modelling competence includes the abilities “to be able to gain purpose-oriented insights with models and to be able to judge models in relation to their purpose, the ability to reflect on the process of gaining knowledge through models and modelling, and the willingness to apply these abilities in problematic situations” (Krüger & Upmeier zu Belzen 2010, p. 49). Krüger & Upmeier zu Belzen (2010) divide modelling competence into two dimensions: (1) Knowledge about models and (2) Modelling. The dimension of knowledge about models is based on the understanding of science and “expresses itself in epistemological and ontological positions on models”, while the dimension of modelling describes the “dealing with models within the modelling process in relation to scientific thinking” (Krüger & Upmeier zu Belzen, 2010, p. 50). More generally, dimension (1) includes conceptual knowledge and dimension (2) procedural knowledge.

Furthermore, their framework of modelling competence differentiates five sub-competences: Nature of Models, Multiple Models, Purpose of Models, Testing Models and Changing Models, which extend over three levels of complexity (Grünkorn, 2014). At level I, learners understand models as simple copies of reality, which can be attributed to the naive-realistic understanding of science. Students of level II have a relativistic understanding of science and therefore understand that models are not exact duplicates of the originals but are idealized representations of them. Finally, at level III, learners have a constructivist view of models that are understood as “models for something”, with which ideas can be tested, insights gained, and which can be understood as a method (Grünkorn, 2014). The framework of modelling competence developed by Krüger and Upmeier zu Belzen (2010) refers to the field of biology, with a particular focus on the dimension of cognition and the promotion of cognitive structures. The latter play a fundamental role in successfully solving problems in different situations, which is needed for the IBSE-based task that the students are confronted with in our project.

Recent literature highlights the effectiveness of project based education (PBE). “Reported values of PBE’s effectiveness reaching up to 97% suggest that when implemented carefully PBE outperforms the traditional teaching approach” (Rusek 2020). The reason might be that the method of IBSE in a project based setting aims at the independent action and activity of the students, to develop their own strategies for problem solving in order to gain an understanding of the topic (Klein 2013). According to the results of a Botanical Case Study by Renata Ryplová (2020) the student’s knowledge, engagement and attitude towards the topic showed a greater improvement in an inquiry and project based approach than in a conventional setting. Due to the described efficiency of IBSE and PBE, we designed our project accordingly. The project topic was the human backbone, which can be located in the subject curriculum for biology for 5th grade in Germany.

Tab. 1: Framework of modelling competence by Krüger & Upmeier zu Belzen (2010).

Sub-competences	Level I	Level II	Level III
Nature of Models	Replication of the phenomenon	Idealized representation of the phenomenon	Theoretical reconstruction of the phenomenon
Multiple Models	Different model objects	Different foci on the phenomenon	Different hypotheses about the phenomenon
Purpose of Models	Describing the phenomenon	Explaining the phenomenon	Predicting something about the phenomenon
Sub-competences	Level I	Level II	Level III
Testing Models	Testing the model object	Comparing the model and the phenomenon	Testing hypotheses about the phenomenon
Changing Models	Correcting defects in the model object	Revising due to new insights	Revising due to the falsification of hypotheses about the phenomenon

RESEARCH GOALS

According to Rusek and Dlabola (2013) project-based education helps to develop competencies better than any other way. Therefore, the aim of our IBSE-based project is to promote the modelling competence of the participating students and to evaluate possible developments and trends.

Consequentially our research question is, to what extent the modelling competence of 5th grade students can be promoted by building their own model during a 90 minute-long IBSE-based project.

METHODOLOGY

The framework of modelling competence by Krüger and Upmeier zu Belzen (2010) has already been evaluated and validated in the context of several dissertations and studies (Krell & Krüger 2010). In order to evaluate modelling competence different formats and tasks were developed. Grünkorn et al. (2009) established open task formats while Terzer et al. (2009) developed multiple-choice tasks.

Krell and Krüger (2010) dealt with the compilation of forced-choice tasks, for which they deductively developed items from the framework of modelling competence and then analysed them statistically. Their study was deductive and quantitative, which is why the chosen items were selected on the basis of statistical considerations (Krell & Krüger, 2010). As a result of the research conducted by Krell & Krüger (2010), three equivalent items emerged for each area of the competence model, which were integrated into the development of a forced-choice questionnaire (for an example see Tab. 2).

Out of the three items we chose one representative item per sub-competence in order to shorten the questionnaire to fit our purpose and timeframe. In general, forced-choice items are closed tasks that allow the subjects, in our case the learners, to choose only one answer which will then be evaluated (Krell & Krüger, 2011). The task type therefore generates relative data that “avoid any problems that may arise, for example, when using classic multiple-choice or rating scale tasks” (Krell & Krüger 2010, p. 35). In open task formats students can agree to different items and thus different levels of the modelling competence and therefore produce results that are difficult to interpret. Forced-choice tasks require students to select and indicate exactly one answer (Krell & Krüger, 2010). In order to ensure the comparability of the results evaluation of our research approach, this quantitative research method with a closed answer format was chosen to compare possible developments in the modelling competence among learners by means of a pre- and post-survey.

From the sample for our research, a forced-choice questionnaire was collected one week before and immediately after the project, on July 9, 2021 and July 16, 2021 in a fifth class with 25 students (11 female and 14 male) at the Hans-Dietrich-Genscher-Gymnasium in Halle (Saale). The quantitatively collected data were then analyzed statistically and visualized in diagrams.

Tab. 2: Forced-choice item for sub-competence Changing Models by Krell & Krüger (2010).

A model is modified to ...

A	verify further assumptions about the original. (level III)[1]	
B	fix what is damaged on the model. (level I)	
C	incorporate new knowledge about the original into the model. (level II)	

[1] The respective levels in brackets are only added for easier understanding and are not depicted in the actual questionnaire.

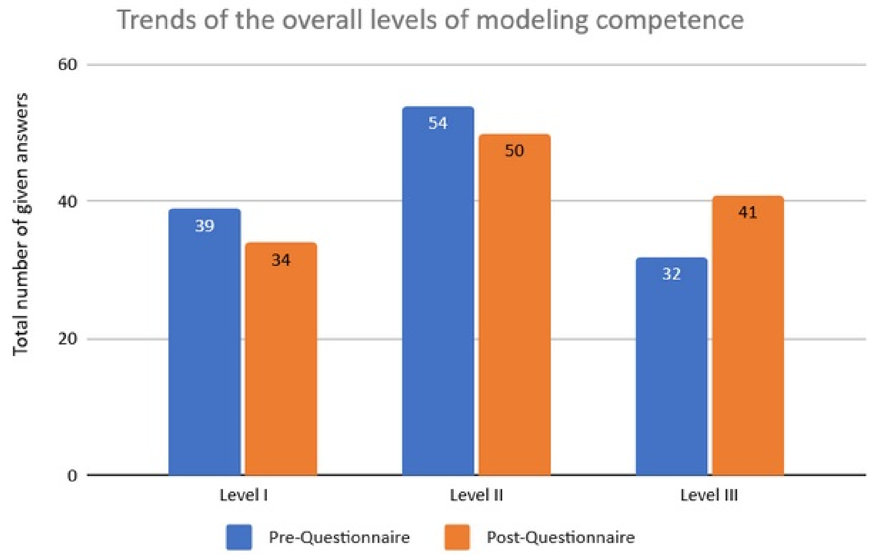
Project design

At first it is important to note that this project was first designed for a whole day. However, due to the pandemic a lot of classes had been cut short which is why the project got reduced to a 90 min lesson. Since it is an IBSE-based project, the project implemented the idea of students being scientists. As scientists they got to know the main parts of scientific research. During the free working phase the students worked independently on the topic in research groups of two. They researched the topic through different sources that were prepared on a 'research desk'. On this desk there were sources like images, videos, radio sequences, scientific texts etc. Based on their inquiries, they built their model with materials from the 'materials desk' where they could find sponges, wires, tape, modelling clay, balloons etc. After the research groups finished their models the assessment phase started, where they appraised each other's work through a short assessment table. To evaluate the process during the evaluation phase, the students exchanged their findings in class and concluded what materials and sources were most useful and what parts of the human backbone had to be depicted and differentiated. Next, the research groups entered the revision phase, in which they had time to rework and adapt their models based on the newly exchanged and evaluated knowledge. Most of the students seemed motivated to work independently and creatively on the topic.

RESEARCH RESULTS

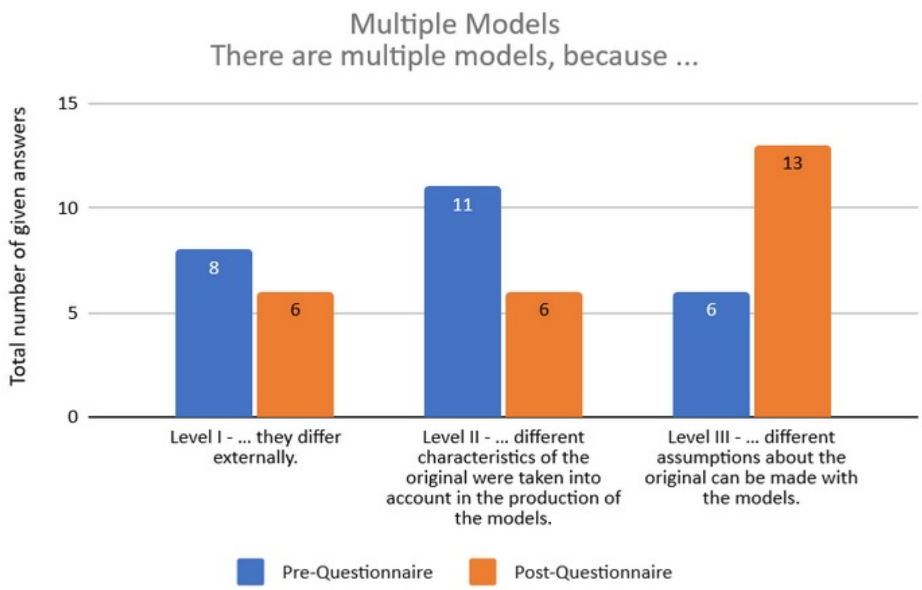
Overall, there is an upgoing trend of the levels of the modelling competence. In the post-questionnaire, there were more students who gave answers on level III and less on level I compared to the results of the pre-questionnaire. But in general the dominant level of the modelling competence stays at level II (see Fig. 1). It is important to mention that the figure shows the total number of given answers for each level. Looking at the results of the five sub-competences more closely, there are no significant improvements in the sub-competences Nature, Purpose and Testing of Models. However, there is a rising trend from level II to level III in the sub-competences Multiple Models and Changing Models.

Regarding the sub-competence Multiple Models, the total number of given answers changes from 11 on level II and 6 on level III in the Pre-questionnaire to 6 on level II and 13 on level III in the Post-questionnaire (see Fig. 2). There is a similar trend found for the sub-competence Changing Models. Here the total number of given answers changes from 12 on level II and 7 on level III prior to the project to 9 on level II and 13 on level III after the project (see Fig. 3). However, those improvements aren't significant and have little to medium effect.



mean pre:	1.94
mean post:	2.05
t-test/Cohen's d_z=	0.22
significance p =	.283

Fig. 1: Research results of the trends of the overall levels of modelling competence.



mean pre:	1.92
mean post:	2.28
t-test/Cohen's d_z=	0.30
significance p =	.142

Fig. 2: Research results of the sub-competence Multiple Models.

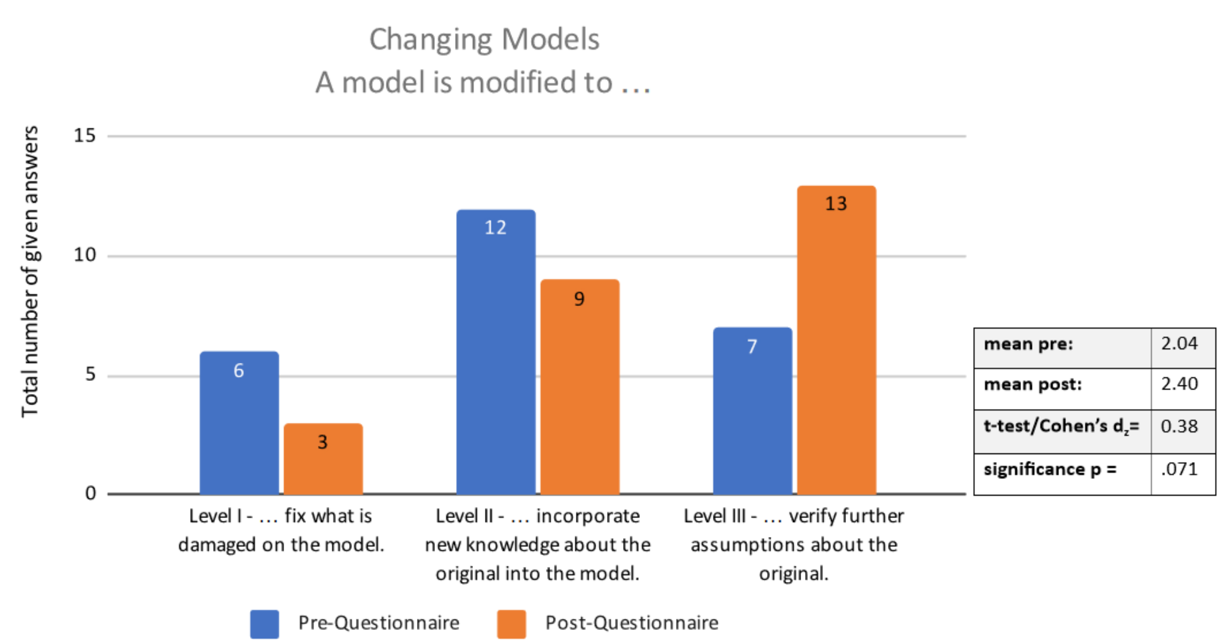


Fig. 3: Research results of the sub-competence Changing Models.

DISCUSSION

Although the results were not significant and showed little to medium effect, the improvements in the aspects of Multiple Models and Changing Models can be traced back to the assessment phase and the revision phase of our project plan. Through the assessment phase the students could see multiple models with different foci and with different parts of the original. In the revision phase the students got a better understanding that models do not have to be final and can be adapted to new acquired knowledge. The improvement of the overall level of modelling competence proves that by learning *with* and *through* models can help to reach a relativistic (level 2) or even constructivist (level 3) view on models.

However, there are several reasons that could have affected the results which are not significant and had little effect. The forced-choice items are not constructed for 5th graders which leads to the assumption that their reading competence was not advanced enough to understand the items fully. The effort to shorten the questionnaire to fit the purpose seems to not have taken effect. Additionally, the students had to take this poll in the last 5 minutes of the lesson. This might result in them lacking concentration and not having enough time to think their answers through. Furthermore, in order to promote competences properly a lot of time and effort are required, which means that a 90-minute-long project would not be sufficient. However, our project or similar activities can provide first steps in order to promote a students' (modelling) competences.

CONCLUSION

To draw a conclusion, models offer various functions and uses which can be implemented in educational contexts. This is the reason why improving the modelling competence is essential. The general positive trend found in the level of modelling competence in the presented data is promising. Since our project design is adaptable, it has great potential for further studies. Additional research could explore the effect of structured, guided or open inquiry based education on the modelling competence. Another interesting insight would be to look into possible differences in modelling competence based on gender, age or type of school. Multiple implementations of the project would provide more data from a larger sample, so that significant and unambiguous research results can be obtained. The improvements the students made through one intervention should serve as an inspiration and motivation for teacher students to implement IBSE into their work more frequently.

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Students' misinformation hunt: A case study

David Fatka, Svatava Janoušková

Abstract

This is a case study of open assignment in secondary education, targeted at misinformation related to chemistry. In the assignment, the students were to find the misinformation by themselves using the web with little direction. Therefore, the case study was targeting both the difficulty of the very open approach to assignments and the recognition and critical assessment of misinformation in the students.

The case study discovered that the ability of surveyed students to deal with very open assignment was not on the desirable level and nearly half of them failed. Once the students overcame this initial difficulty, the argument quality of the students was generally on point, showing understanding of the chosen topic. However, the most common scientifically accurate arguments were based on popularization science articles or outlets of fact-checking organizations that each themselves declared their sources, not on the scientific papers.

Key words

Misinformation; open assignment; case study; source declaration

INTRODUCTION

Chemistry, when taught, tends to be a rather marginal subject for less generalistic secondary education facilities, such as in this case Economic Lyceum. There, however, is a potential to shift the students' interest in it, according to the current research (Rusek, 2014). The desired shift in interest requires not only the usage of methods that can spark such interest in the students, but also issues they can make use of outside the classroom setting and push them towards stronger interest as well (Janoušková et al., 2010). Especially when the students' motivation is low, it becomes increasingly hard to satisfy such conditions.

The possibilities the Internet brings to the teaching of natural sciences have been described scientifically for several decades (Hargis, 2001; Tsai & Tsai, 2003; Childs et al. 2011). At the same time, the internet-based information about science was widely discussed because of the quality of the science information and increasing presence of science misinformation (e.g. Howell, 2013, Keller et al., 2014). As several authors pointed out, it is important for science learners to cultivate a critical stance towards scientific information provided by public web pages (e.g. Tseng, 2018), even more so when false information spreads throughout social media faster and wider than true (e.g. Tseng, 2018, Vosoughi et al., 2018). We strongly agree with this view, because Eurobarometer survey shows trust in information coming from webpages to be higher than in those coming from TV, radio broadcasts or printed newspapers. However, there are differences by age. Younger people more likely trust online sources – online newspapers and news magazines (from 60% among those aged 15 to 24 falling to 34% among those aged 55 or over) and video hosting websites and podcasts (46% among those aged 15 to 24 down to 16% of those aged 55 or over) (EC, 2018).

Multiple studies connect the ability to work with internet sources effectively and their critical evaluation with the development of scientific literacy. Some studies (Janoušková et al., 2020) indicate that the students accept the information without further assessment, only remembering them and keeping them at personal conduct knowledge level. Thus, they understand a class of subjects simply and easily grasped that lend themselves to changes in personal conduct, but that do not require detailed comprehension (Coyle, 2005). Other studies show that only some students are able to ask the right questions on the topic directly after reading the text or blogpost at hand, while others can do so only after they are lead to do so and some have trouble formulating such questions even then. This skill is connected not only to the developments of the students' scientific literacy, but also to the complexity of the topic and text at hand (Tseng, 2018). When dealing with misinformation, there is also the additional risk of confirmation bias, where people find it easier to believe the information falling well into the current mental framework and preconcepts of the topic at hand regardless of its truthfulness (Sharon & Baram-Tsarabi, 2020). Therefore, the development of scientific literacy and the teaching of natural sciences has to include the development of open-mindedness, intellectual diligence and intellectual courage in order to discern the misinformation from the valid information (Sharon & Baram-Tsarabi, 2020).

This case study targets the student´s use of the Internet when encountering a chemistry-based issues. We present the information about how the students tackled a very open assignment of finding and subsequently debunking any chemistry-related misinformation they encounter on the web, which issues they found, types of the web pages they worked with and how they worked with the information uncovered in terms of quality of the arguments they provided to refute the chosen misconception. This approach enabled the students to choose the issue (misconception) in the chemistry field they are interested in, which could enhance their motivation to solve the task and how they used different sources to find arguments against it.

METHODOLOGY

Assignment specifics

The student body this case study was conducted upon were 60 Economic Lyceum students finishing their first grade, i.e. secondary education students aged 16 to 17. They worked on the task as a part of their chemistry course, taught by the main author for the whole term.

The task was assigned in a very open manner: "Use web to find some chemistry-themed information that attempts to convince you of some untrue statement. Use more credible sources to debunk and refute the false information. Declare sources of both the misinformation and your analysis (refutation)." Time to turn the assignment in was set to two weeks to alleviate possible time constraints. A non-graded part of the assignment also wanted students to think about how and why such misinformation spread, but as that part provided no measurable output, it was ignored in the further analysis.

Both the task itself and the subsequent case study were, thus, aimed at the students' ability to detect the misinformation, evaluate the reliability of given sources and declare the sources as a key element of academic honesty, and put forward the arguments that would refute the selected misinformation, all framed in the complexity of the very open assignment.

Data collection and processing

The students' assignments were assessed with marks (1 – the best; 5-the worst), which is a common way of the students' evaluation in the lessons. Specific feedback was given to students as a part of their course and the attractiveness and difficulty of the task in terms of obstacles in its solution was discussed. In the second pass, we categorized students' work by success in fulfilling the task and by the category of the misinformation they worked with, source of misinformation and the quality of arguments (see table 1). For further processing, only these anonymized records were used in order to reduce the effect of unconscious biases as well as to protect their personal data. These records were subsequently subjected to semi-quantitative descriptive analysis, enabling us to form case study results and direct us for possible further exploration of the topic.

We analyzed those students' responses where the assignment was understood correctly. All the correctly processed tasks were sorted by broader category of misconception debunked (e.g. health, vaccination), the source of misinformation was recorded (texts or videos), and the quality of arguments was assessed according to four predetermined categories (1) Successful refutation – scientifically accurate arguments, (2) Unconvincing refutation – mix of scientifically accurate arguments and partially/not fully correct or incorrect opinions/arguments (own, coming from non-expert person or unknown origin) where the scientifically accurate arguments prevail, (3) Unsuccessful refutation – mix of scientifically accurate arguments and partially/not fully correct or incorrect opinions/arguments (own, coming from non-expert person or unknown origin) where the subjective opinions prevail and (4) Inconclusive stance – a category of seemingly correct arguments which do not correctly refute the misinformation.

RESULTS

The analysis shows next results. 20% of all students didn't turn the assignment in and as such, couldn't be assessed further. Among the assignments turned in, 17 (28.3% total students) went off topic, showing some misunderstanding of the assignment. Often, the reason was the inability to pick an actual misinformation, often (but not exclusively) just referring to some fact-checking website instead of using it as a source for debunking. The remaining 31 students solved the task according to the guidelines. Among those, 23 (38.3%) solved the task individually and the rest cooperated in two naturally-formed groups of four after having this approach acknowledged by the teacher, who allowed for this, given that they asked long enough prior the deadline on their own initiative.

This leaves us with 25 assignments showing the understanding of the assignment at hand. Those were subjected to subsequent analysis of issues and sources chosen and refutation success. The refutation success was mostly dependent on coherent reasoning and the argument quality (see the Method section). Using actual academic papers as sources was very rare but would also not be expected from the students in their age. Most common scientifically accurate arguments were based on popularization science articles or outlets of fact-checking organizations that each themselves declared their sources. The success of the debunking is summarized in Tab. 1. The "unconvincing refutation" category, where 4 assignments lie, does generally mean weak argumentation with a lot of incorrect non-expert arguments or arguments of unknown origin, the single inconclusive stance comes from the sources that show the analysed information may have some merit. Despite that being a case of commendable academic honesty not trying to shoehorn the sources into the expected outcome, the sources are also weak in this case and if they supported the refutation with the same quality, would leave the assignment as another unconvincing one.

Tab. 1 Refutation success of on-topic assignments.

ASSIGNMENTS AMOUNT	SUCCESS LEVEL
18	Successful refutation
4	Unconvincing refutation
2	Unsuccessful refutation
1	Inconclusive stance

The thematic analysis shows that the most common misinformation to debunk were the "kitchen-based" ones, i.e. those that misinform the reader about their nutrition – promising weight loss using unscientific means, promoting fad diets (i.e. alkaline diet) or warning about some assumedly dangerous food component, with 11 cases. Other topics point to the connection between currently spreading (and, thus, possible to find easily) misinformation and contemporary events with 4 misinformation articles concerning SARS-CoV-2 vaccines and three more barely on topic ones on the dangers of technology – microwave ovens or 5G emitters. In the case of the microwave ovens, it should be noted that the students were Czech and a high-profile Czech politician has spread this misinformation prior the assignment, making it easy to remember for the students. Finally, most sources where the misconception was debunked were written articles (84%). 16% of students used TikTok and YouTube videos as the misconception source.

DISCUSSION

First and foremost, it should be noted that as a case study, this study is inherently limited in scope and as such should not be taken as a proof for any findings, more as a prompt for further research. Another study limitation is that the author was in the time of work a teacher of the students and as such might show unconscious biases. This second limitation was attempted to be mitigated by time delay (2 months) between data collection and grading and subsequent analysis of the anonymized dataset.

That said, the study shows that in this case, the very open assignment was hard for the students compared to very specific and detailed assignment given to the students which students are used to. Only about half was able to deal with the assignment's intentional vagueness and off topic assignments were common. In the class discussion more than half of the students which failed assessed the task as difficult. However, they find it interesting after they understood the assignment and saw the completed task of their classmates. 20% of student which did not complete the task did not take part on the discussion. The majority of them did not finish the first school year and left the school.

However, once dealt with this initial difficulty, the argument quality of the students was generally on point, showing understanding of the chosen topic. The sources the students declared were generally not of very high quality with some of them not declaring their own sources (unknown source) or presenting the own not fully correct opinions/arguments or not fully correct arguments coming from non-experts. The students, however, generally avoided the expected pitfall of the sources not supporting their claims and kept their sources relevant to the topic at hand.

The topics chosen point to the two main types of misinformation being easy to find upon first inspection, those being the current affairs (such as the SARS-CoV-2 pandemic and vaccination campaigns) and the nutritional health. However, by the discussion the students stated their interest in these particular issues.

CONCLUSION

The case study was performed on the body of 60 students aged 16 to 17, finding the very open assignment hard for students, but showing their ability to discern internet-based misinformation on a satisfactory level once dealt with the difficulty of the task at hand. Most common misinformation found were either related to nutritional health or dependent on the current affairs. It seems, such approach can be used more often in order to cultivate a critical stance towards scientific information provided by public web pages.

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Students' conceptions about the sense of smell

Julia Dreyer, Elisabeth Hofer

Abstract

Topics addressing everyday phenomena, such as sensory perception, are particularly conducive for the development of students' conceptions. Whilst some studies have investigated students' conceptions about the senses of sight and hearing, research regarding students' conceptions about the sense of smell is still missing. Therefore, we conducted an explorative study in which we interviewed six secondary science students. By applying qualitative content analysis, we found that students had a basic understanding of the sense of smell and its functions. However, we identified the inappropriate conception that smell would be forwarded directly from nose to brain without any further processing.

Key words

Students' conceptions; sense of smell; model of educational reconstruction

INTRODUCTION

From the perspective of constructivism, learning is always a process of re-learning, which is based on the things we already know (Taber, 2006). Students develop knowledge and beliefs from their experiences in daily life or previous teaching and bring them into the class (Schrenk et al., 2019). These conceptions (*students' conceptions*[1]) – regardless if they are appropriate or not – constitute the starting point for further learning and, consequently, need to be considered when planning lessons (Treagust & Duit, 2008). If teachers are not aware of students' conceptions or ignore them, they run the risk of designing learning environments that are incompatible with students' prerequisites, thus, impede the development of scientifically appropriate conceptions (Amin et al., 2014). According to the *Model of Educational Reconstruction* (Duit et al., 2012) the structure of subject matter cannot be adapted directly from science, but needs to be transformed for instruction. For this purpose, subject matter needs to be explored from both the perspective of science and the perspective of students. Exploring subject matter from both perspectives and contrasting them allows teachers to design

[1] We are aware of the diverse terminology in this field of research (e.g., alternative conceptions, preconceptions; cf. Krumphals et al., 2022). However, as we do not focus on differences between these terms, we use *students' conceptions* as umbrella term for conceptions that differ from the scientific perspective, regardless of their origin.

learning environments that address common learning difficulties and provide fruitful learning opportunities (Duit et al., 2012; see Fig. 1).

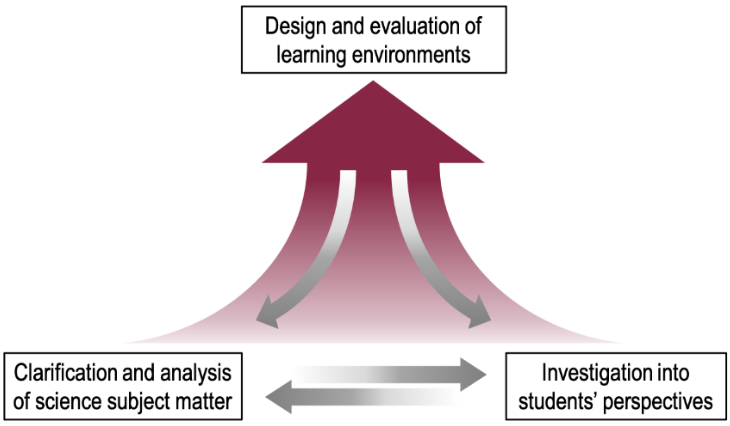

Fig. 1 The Model of Educational Reconstruction with its three components (Duit et al., 2012).

On the one hand, topics that address everyday phenomena and allow students to rely on personal experience are ideal for creating engaging learning environments (cf. Lindner, 2014). On the other hand, these topics are particularly conducive for the development of students' conceptions, increasing the importance of investigating into them. It is these topics which carry the "projectivity" potential (cf. Rusek & Becker, 2011) and can attract students' interest, therefore pull them in a flow of independent learning. This is also the case with the topic of human senses and sensory perception. It has the potential to introduce practical work in quite a natural way and thus to repair one of the reoccurring absences of science instruction (see Hofstein & Lunetta, 2004, p. 48; Rusek et al., 2020). With the closeness to students' life experiences and considerably safe procedures, there is a potential of using this topic to foster students' inquiry skills in a more open form (see Banchi & Bell, 2008) which have been targeted quite seldom (Kohutiarová & Kotuľáková, 2022; Rusek & Gabriel, 2013). However, contrary to the senses of sight and hearing, the sense of smell has rather been neglected in both everyday consciousness and science education (Heller et al., 2009). The same applies to research regarding students' conceptions in this field. Some studies have been conducted regarding the senses of sight and hearing (e.g., Böschl et al., 2018; Dannemann & Gropengießer, 2017; Hammann & Asshoff, 2017), however, research regarding students' conceptions about the sense of smell is missing so far.

Thus, the aim of this exploratory study is to gain a first insight into students' conceptions about the sense of smell, contrasting the findings with the scientific perspective and formulating implications for the design of learning environments. For this purpose, we firstly examine the scientific perspective of the sense of smell. Subsequently, we describe the design and method of the study before presenting an overview of the identified students' conceptions. Finally, we discuss these conceptions with regard to the scientific perspective and derive implications for teaching about the sense of smell and sense perception in general, respectively.

THE SENSE OF SMELL

The sense of smell, also known as *olfaction*, serves the perception and evaluation of smells and fulfils various functions, e.g., warning of danger (smoke, dangerous gases, toxic food), regulation of body functions (metabolism, digestion), basis for non-verbal communication between individuals of species (pheromones), or eliciting emotions and memory (Hillis et al., 2020). Beyond that, the sense of smell significantly influences the aroma perception of taste (Berg et al., 2019).

In general, there are two types of human odour perception: (1) the ortho-nasal perception, where odour molecules enter the nasal cavity by inhaling air, and (2) the retro-nasal perception, which is caused by the scents included in our food and drink. When chewing or drinking, these odour molecules partially pass into the gas phase, thus can pass the throat to the nasal cavity (Landis et al., 2005). Irrespective of the type of odour perception, the effective smelling process starts inside the nasal cavity, more specifically, in the olfactory region. This part of the nasal mucous membrane (olfactory epithelium) contains olfactory receptor neurons (also: olfactory sensor neurons) that have dendrites with specific extensions (olfactory cilia) protruding into the nasal cavity (Hillis et al., 2020). On the cilias' membrane, specific chemoreceptors (odour receptors) are located. When odour molecules enter the olfactory region, they dissolve in the mucus at the surface of the epithelium and bind to these receptors (Berg et al., 2019). There, the sensory signal is converted to an electrical signal (transduction), which is then forwarded via axons to the olfactory bulb in the brain (transmission) (Hillis et al., 2020). All axons of olfactory sensor neurons with the same type of chemoreceptors converge on a specific glomerulus in the olfactory bulb. From there, the electric signal is transferred to specific mitral cells, which send the information to other areas of the brain (Smith, 2009). As the receptors of olfactory neurons can be activated by different types of odour molecules, all the electric signals have to be evaluated simultaneously. The smells we perceive in everyday life are not single sensory signals, but combinations of different odour molecules, which activate complex and specific patterns in our brains (Smith, 2009).

DESIGN AND METHOD

As stated above, the aim of this study was to gain a first insight into students' conceptions about the sense of smell. For this purpose, we conducted guided interviews with secondary science students. The question to answer was the following: What students' conceptions do secondary science students have about the sense of smell?

Sample

In total, N = 6 students (three female, three male) of the sixth grade (about 12 years old) of a secondary school were interviewed. Grade 6 was selected as the human senses and sensory perception are emphasised in science lessons in grade 8 in the selected type of school (NKM, 2015). Moreover, primary science education primarily deals with the senses of sight and hearing (Böschl et al., 2018). Hence, we expected that it is possible to gain knowledge particularly about students' pre-instructional conceptions in this way. All students participated voluntarily in the interviews after their parents had agreed with that. Thus, the sample can be seen as convenience sample (Cohen et al., 2011).

Methods of data collection

For the purpose of data collection, we conducted guided interviews (Cohen et al., 2011). By introducing guiding questions and stimulating material (e.g., Concept Cartoon, drawings, anatomical model, candy for chewing), we aimed at eliciting students' conceptions. To create an open, child-friendly interview atmosphere, the students had to guess several fragrances (orange, vanilla, peppermint etc.) and were invited to formulate their associations spontaneously at the beginning of the interviews. Afterwards, the interview proceeded addressing the following topics: (1) subjectivity of olfactory perception, (2) evolutive functions of the sense of smell, (3) function and structure of the nose, (4) other human senses, (5) the smelling process, and (6) the influence of smelling on the sense of taste.

The guiding questions and stimulating materials were developed based on the scientific perspective explored. To address the specific prerequisites when interviewing children (Cohen et al., 2011), the interview was arranged in an action-oriented manner as it has already proven successful when investigating students' conceptions about the sense of sight (Dannemann & Gropengießer, 2017). Instead of just asking questions, the students had to fulfil tasks, such as to argue about a Concept Cartoon, to draw sensory organs or to illustrate the smelling process in a given figure and explain it. The interviews took about 10-15 minutes each, were audiotaped and fully transcribed subsequently.

Methods of data analysis

The collected data were analysed applying the method of qualitative content analysis (Kuckartz, 2014). For the first coding process, we followed a deductive, concept-driven approach. Before examining the data, the main categories were established based on the six topics of the interview guideline (see above). For the second coding process, an inductive, data-driven approach was used. Subcategories were formed based on the data material for three of the main categories (see Tab. 1).

Tab. 1 Overview of the main categories and subcategories for data analysis.

MAIN CATEGORY (Subcategories)
SUBJECTIVITY OF OLFACTORY PERCEPTION
EVOLUTIVE FUNCTIONS OF THE SENSE OF SMELL (Identification of substances; Support of the sense of taste; Protection from spoiled or toxic food; Relation between smell and emotions; Functions of the senses of animals)
FUNCTION AND STRUCTURE OF THE NOSE
OTHER HUMAN SENSES
SMELLING PROCESS (Constitution of smell; Brain as place of perception and processing; Memory of smell; Neural pathways; Function of nasal hair)
INFLUENCE OF SMELLING ON THE SENSE OF TASTE (Relevance of sense of smell for aroma perception; Retro- AND ortho-nasal aroma perception; Retro-nasal aroma perception; Anatomical connection between nose and mouth; Influence of a cold)

RESULTS

The majority of students described (in some cases only after several inquiries) the fact, that the interpretation of smell is subjective and, therefore, people may have different “opinions” about smell. Four of six students described the warning and protective function of the sense of smell. Whereas all of these four students mentioned the protection against spoiled or toxic food, none of them stated the perception of smoke (in case of fire) or toxic gases. It is also remarkable that three out of six students thought rather about animals than about humans when they stated the function and relevance of the sense of smell. With the “animal” sense of smell they associated functions, such as recognizing enemies, finding food or fending off enemies by using self-smell.

In the course of the interviews, it became apparent that the students in this study had a rather low prior knowledge about the anatomy of the nose. Most of them referred exclusively to external parts (e.g., nostrils, bridge and side of the nose, bones, cartilage, skin). Four out of six students also named the nose hairs and described their function. Two of them were aware that the nose hairs are involved in the smelling process and one student even mentioned the olfactory centre and the olfactory sensor neurons. Moreover, three of the students described breathing as an important function of the nose, however they did not make an explicit connection between breathing and smelling.

All of the interviewed students described that the brain is essential for the sense of smell. In five out of six illustrations the students drew a direct connection between the nose and the brain (see Fig. 2) that was described as a “tube” by one student. Not surprisingly, the students did not mention the process of smelling by relating to recognition and transduction. However, one of them already indicated the transmission of electrical stimuli through the nerves by using the analogy of electrical wires. This student was already able to name the nerves of the various sense organs.

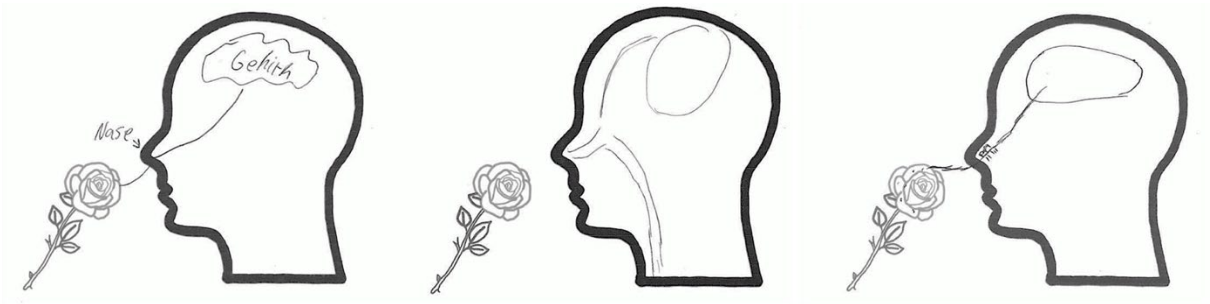

Fig. 2 Three of the drawings the students created to illustrate what happens when they smell at a rose.

In the course of the starting phase of the interview, only three of six students considered the relevance of the sense of smell for the perception of taste. At the end of the interview, all of the students described any kind of relation between these two senses. Asking the question, why they could taste “less” while holding their nose closed, resulted in various hypotheses: three students referred to the limited ortho-nasal aroma perception as cause for the weakened taste perception, one to the limited retro-nasal aroma perception and two students assumed the combination of limited ortho-nasal and retro-nasal aroma perception to be causal for this effect.

DISCUSSION

The results of this study show that the interviewed students had a rather little knowledge about the anatomy of the nasopharyngeal space. Böschl et al. (2018), who investigated students’ conceptions about the sense of hearing, made similar observations regarding the structure and function of human ears. For this reason, it seems to be advisable to introduce the relevant anatomical aspects (e.g., structure of nose and pharyngal, basic structure of the brain) before discussing the respective processes of sensory perception.

It turned out that some of the students were already aware of the individuality and subjectivity of olfactory perception and mentioned that people can have different “opinions” about specific fragrances or odours. This awareness can be used to make clear that this subjectivity is not unique for the sense of smell but applies to all senses. Moreover, it can serve as basis for discussing that sensory perception is always the result of input (from sensory organs) processed in the brain with the consequence of different sensory experiences. In particular for the sense of sight, many students struggle to acknowledge that what they see is never the representation of reality, but a construction of their brains (Dannemann & Gropengießer, 2017). To support students in developing appropriate conceptions regarding sensory perception, teachers can refer to illustrations of the stimulus-response scheme (stimulus → sensors → transduction + transmission → brain areas → sensory impression → constructed perception) as suggested by Heller et al. (2009).

As previously mentioned, all students were able to describe the relation between the sense of smell and the sense of taste at the end of the interview. However, it remains unclear if the students have already developed a deeper understanding of this relation, e.g., that the sense of smell does not only influence the intensity of taste but its absence would also limit the “tastes” we perceive to only five distinct sensations (sweet, salty, sour, bitter, umami). To explore this connection, teachers can introduce material (e.g., air up® bottles) that allows students to experience the retro-nasal and ortho-nasal aroma perception by their own.

Overall, both the number of interviews and sample of students do not allow to formulate generalised statements about students' conceptions about the sense of smell. However, the results show several similarities to findings from studies dealing with the senses of sight and hearing, e.g., that a stimulus that reaches a sensory organ is passed on directly – without processing – to the brain, where it is detected as such. Moreover, the interview procedure that was adapted from Dannemann and Gropengießer (2017) proved to be successful for collecting data regarding lower secondary students' conceptions about sensory perception. To extend and/or validate the findings of this study, additional data need to be collected in the form of questionnaires or further interviews.

CONCLUSION

In this study, we investigated students' conceptions about the sense of smell. For this purpose, we conducted guided interviews with N = 6 secondary science students. Applying the method of qualitative content analysis, we found that the interviewed students had rather little knowledge about the anatomical structures of the nose and the general patterns of sensory perception. Even though they were aware about the brain's “involvement” in the olfactory process, they were of the opinion that smell is inhaled with air and then forwarded without further processing directly to the brain. This conception – that sensory perception reflects reality – confirms findings from former studies regarding the sense of sight. Beyond that, students were able to name basic functions of the sense of smell and recognised the relation between the senses of smell and taste. Moreover, they considered “smelling” to be subjective what can serve as basis for discussing general patterns of sensory perception.

Acknowledgement

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Teachers and Implementation of IBSE: Research Review

Viktória Kohutiarová, Katarína Kotuľáková

Abstract

Teachers play a key role in implementation of IBSE. It is crucial to conclude the lately discussed factors supporting and hindering their implementation of the approach into science lessons. The present paper reviews articles on factors influencing teachers' use of IBSE mainly from databases WOS and ERIC from 2011 to 2021. It also aims to identify their implications and open questions for the next research. We aim to gather researched factors influencing implementation of IBSE and to identify the methods of their analysis for further research. Implications and open questions for further research propose the next steps in order to add to the topic of our interest. Implications suggest necessity to study factors in different teacher contexts, address the relationship of individual factors and the types or components of implemented IBSE. Next research should focus on factors only subjectively reported by teachers to improve their IBSE implementation.

Key words

IBSE; laboratory work; review

INTRODUCTION

During the past decades there has been efforts worldwide to implement IBSE (e.g., NRC, 2000; ŠPÚ, 2015), as the previously used transmissive approach seems to be insufficient in meeting new goals of science education, such as practices and nature of science (Rocard, 2007). Despite the attempts to reform science teaching, studies revealed that many teachers as potential implementors of IBSE still prefer and use more transmissive approach to teaching (e.g., Koballa et al., 2000; Capps & Crawford, 2013; Kotuľáková, 2020). Teachers' enactment of IBSE has become a focus of numerous studies aiming to understand what hinders and what supports teachers' use of the approach with intention to catalyse the implementation of IBSE. Similar trends appeared among topics presented at the PBE conference (Čiháková, 2018; Janštová & Pavlasová, 2018; Janštová et al., 2013; Pavlasová et al., 2017; Vojíř et al., 2018). Those factors interact with personal teachers' beliefs about teaching and science (Crawford, 2007) and affect the teaching process and its outcomes. Identified and analysed factors can be addressed and focused on in teachers' preparational programs intentionally, systematically and for sufficiently long time as indicated also by Hofer et al. (2020).

Since there is no research review generalising the latest findings and implications for next research in this area, we decided to conduct the investigation.

The present article reviews the research from 2011-2021 on a range of factors that influence teachers' implementation of IBSE with aim to answer following research questions:

1. What factors are influencing implementation of IBSE into science teaching were identified in research conducted between 2011 and 2021?
2. How are the factors influencing IBSE implementation investigated?
3. What are the implications and open questions of included articles for future research?

METHOD

Data collection

Systematic approach was used during the selection of articles for the research review (Zawacki-Richter et al. 2019). The articles were searched for in databases Web of Science (WOS) and Educational Resources Information Centre (ERIC). As parameters in search for articles following key words were used: "implementation of inquiry", "inquiry", "IBSE", "science teachers", "factors", "barriers", "IBSE barriers", "enactment". In case of both databases the inclusion criteria were set to include only articles published between 2011 and 2021 in journals assessed with Q1 or Q2 quartiles and 2 dissertations from ERIC related to the topic of research review. Other inclusion criteria were common school setting (excluding articles aimed at special education, remote or online education) and research article (excluding conference articles or research review articles). The articles that were not full-text available were also excluded from the study. The search conditioned by mentioned inclusion criteria resulted in inclusion of 70 research articles.

Data analysis

To answer the first research questions the articles were coded using MAXQDA Analytics Pro 2020 Programme. We coded the articles for:

- Publishing information (year, journal)
- Type of research (type of methodology, research question, data collection method)
- Sample teachers' characteristics (subject, educational level, teachers' level)
- Other research information (country, factors influencing teachers' implementation of IBSE)

With aim to respond the question about used methods the discussion, conclusion and / or implication part was examined and questions for future research were extracted, whether they were mentioned directly or indirectly. The methods relation to individual factors was examined.

RESULTS

Characteristics of included research articles

The included research articles were published in 24 different journals. Some of the most prolific journals in publishing research articles related to teachers' implementation of IBSE were International Journal of Science Education (n = 14), Research in Science Education (n = 11) and Journal of Science Teacher Education (n = 9). Other journals each published 4 or less related articles in the past decade (see Tab. 1).

Tab. 1 Distribution of related research articles in journals

NUMBER OF ARTICLES	JOURNAL
14	International Journal of Science Education
11	Research in Science Education
9	Journal of Science Teacher Education
4	International Journal of Science and Mathematical Education
3	Journal of Science Education and Technology
	Eurasia Journal of Mathematics, Science and Technology Education
	Science Education
2	Chemistry Education Research and Practice
	International Journal of Primary, Elementary and Early Years Education
	Research in Science and Technological Education
	Journal of Baltic Science Education
1	Chemistry-Didactics-Ecology-Metrology
	School Science and Mathematics
	Teaching and Teacher Education
	Journal of Turkish Science Education
	Educational Research: Theory and Practice
	Frontiers in Psychology
	Teachers and Teaching: Theory and Practice
	Cultural Studies of Science Education
	Educación XX1
	South African Journal of Education
	Early Childhood Education Journal
	Teacher Development
	ZDM Mathematics Education

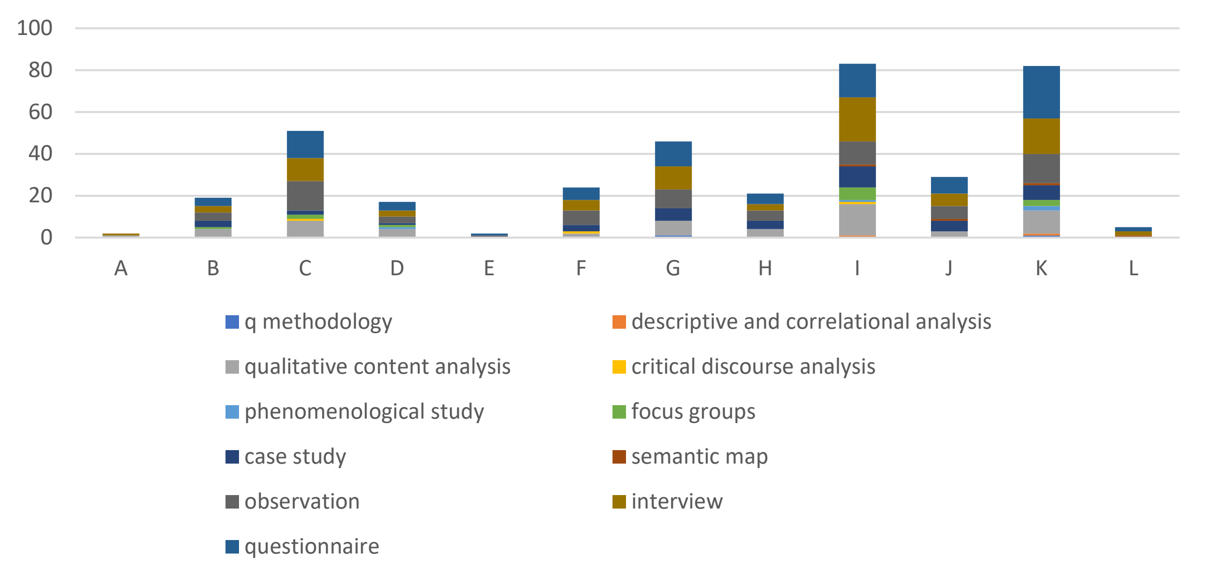

Fig. 1 Methodology in relation to factors

Factors listed in Fig. 1: A-subject; B- personal or characteristic features; C-continual professional development; D-other beliefs; E-scientific experience; F-community or coaching; G-beliefs about IBSE; H-field experience; I-external; J-teacher preparation programme; K-self efficacy beliefs; L-prior experience as student

Most of the studies was conducted on teachers from United States (n = 32) and Europe (n = 27). However, countries almost intact by research in this field locate in South America (n = 1) and Africa (n = 3). The overall number of included nationalities is higher than number of research articles, since 4 research papers focused on more than one nationality.

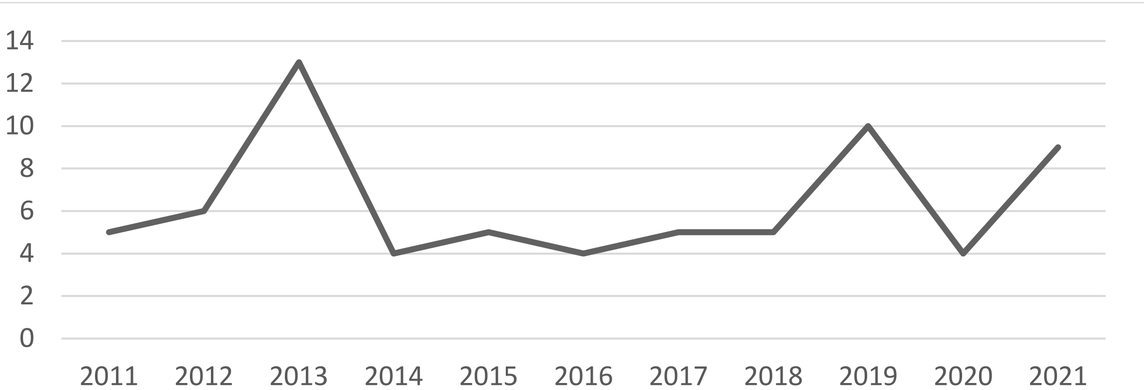

Fig. 2 Frequency of related articles in years 2011-2021

The frequency of publishing related research articles in each year (see Fig. 2) shows a peak of interest in 2013 (n = 13). After 2013 the number of articles related to the topic decreased, but starting in 2019 (n = 10), it seems that the interest in the topic has been renewed, as the number of articles published by October 2021 moves towards 10.

While the characteristics of teachers included in the studies are discussed, some of the studies were not specific on their sample characteristics in terms of some marks followed in this study. In-service teachers were a focus of study in 38 cases, quite frequently also beginning teachers (n = 27). Pre-service teachers were less common centre of study (n = 14). Majority of the investigated teachers taught at secondary educational level (n = 59), specifically lower (n = 28), upper (n = 21) and unspecified (n=10). Some of the studies combined in their samples teachers of more than one educational level, which resulted in including also primary teachers (n = 20). Teachers of level lower than primary were the subject of study in 4 cases and only a single study focused on teachers of tertiary education. Teachers' specialisation was quite evenly distributed in chemistry (n = 39), biology (n = 32) and physics (n = 32), while geography teachers were half less frequent (n = 14) and in 24 cases it was not specified.

Methodology used for investigations of IBSE implementation

The articles varied in use of methodology; however, mixed-method approach was dominant (n = 39), with purely qualitative (n = 22) and quantitative approach (n = 9) were less frequent. Some of the studies claimed to use qualitative approach or method, but this code was revaluated, as they later quantified their results or otherwise mixed qualitative approach with quantitative.

Research questions formulated in relation to qualitative parts of methodology were descriptive (n=19), also causal (n = 15) and relational (n = 13), while in qualitative parts exploratory research questions (n = 46) were central in comparison with interpretive (n = 8) or predictive (n = 3) research questions.

Analysing methodology more specifically, methods used for data collection included following: questionnaire (n = 39), interview (n = 37), observation (n = 33), focus groups (n=7), q-methodology (n = 2). Following methods for data analysis were mentioned: qualitative content analysis (30), case study (n = 15), phenomenological study (n = 2), descriptive and correlational analysis (n = 1), critical discourse analysis (n = 1) and semantic map (n = 1). While some of the studies did not combine the methods, other studies used a set of methods to respond the research questions.

Factors influencing teachers' implementation of IBSE

The variety of factors that were either a subject or a result of studies was based on data categorized according to their nature into 2 categories: teacher-centred and teacher-perceived factors (see Tab 2). The names of categories were derived inductively. The difference between the categories lays in the subjectivity in case of teacher-perceived factors, while teacher-centred factors objectively characterise the teacher. This division can be seen in case of 'pedagogical content knowledge' in teacher-centred factors in relation to 'pedagogical content related self-efficacy beliefs' in teacher-perceived factors. The lack of pedagogical content knowledge was observed by researchers in former category, in latter it was reported by teachers as their opinion.

Tab. 2 Factors categorisation

<table>
<tr><th>TEACHER-CENTERED FACTORS</th><th colspan="2">TEACHER-PERCEIVED FACTORS</th></tr>
<tr><td rowspan="2">Professional development (22)</td><td rowspan="2">Self-efficacy beliefs (6)</td><td>Pedagogical content related (15)</td></tr>
<tr><td>Science content related (18)</td></tr>
<tr><td>Teacher preparation programmes (12)</td><td colspan="2">Teachers’ beliefs about and attitudes to IBSE (19)</td></tr>
<tr><td>Pedagogical content knowledge (11)</td><td colspan="2">Other beliefs (8)</td></tr>
<tr><td>Community or coaching (10)</td><td colspan="2">EXTERNAL TEACHER-PERCEIVED FACTORS</td></tr>
<tr><td>Personal and characteristic features (7)</td><td colspan="2">Time (23)</td></tr>
<tr><td>Field experience (7)</td><td colspan="2">Curriculum and system (19)</td></tr>
<tr><td>Prior experiences as students (3)</td><td colspan="2">Physical resources (14)</td></tr>
<tr><td>Scientific experience (1)</td><td colspan="2">Students (14)</td></tr>
<tr><td>Subject taught (1)</td><td colspan="2">School administrator and management (11)</td></tr>
<tr><td></td><td colspan="2">Teaching/learning materials (2)</td></tr>
</table>

Discussion

Results show renewed interest in factors influencing IBSE implementation. It may point at the fact that previous research from about 2013 has not been effective enough to identify all the keys to teachers’ implementation of IBSE. It seems that these earlier studies have focused predominantly on the influence of professional development on implementation of IBSE as such, while the later studies started to address the influence of wider range of factors, as well as to attention to components of IBSE (e.g., argumentation) and types of IBSE (open, guided, structured). However, other characteristics has not significantly changed. Another explanation for the renewed interest may be Capp and Crawford’s warning dealing with ambiguity of term ‘inquiry’: “The word inquiry is used in a variety of contexts. Without adequate support, these meanings can become easily lost or misunderstood. If these issues are not addressed, we fear we will find ourselves in a similar place 10 years from now, where even the best teachers are not engaging their students in scientific practices or teaching about NOS” (Capps & Crawford, 2013).

Most of the studies recognised the science subjects the participating teachers taught, however, some of the articles don’t specify teachers approbation. These cases may point to the fact that these teachers teach science as integrated subject (see Rusek et al. 2022) which is a standard in some western countries and in early and primary education.

The fact that we identified majority of research focused on teachers of secondary level of education can be interpreted likely by the fact that in most of the countries science education happens mostly during secondary education and is mostly compulsory. Less scientific content is taught during earlier studies and upper secondary education can be differentiated, therefore most of the articles aimed at the highest concentration of teachers that might implement IBSE into their science lessons.

From the findings regarding to research questions, most of the studies aimed to identify the factors influencing teachers' implementation of IBSE rather than evaluate the already discovered factors and their relationship to teachers' implementation.

While factors subcategories like "professional development" seem to be clearly understandable, we would like to comment on some that may be ambiguous, such as "personal and characteristic features" and "other beliefs". "Personal and characteristic features" comprised influences such as communication skill, self-confidence, family background of the teacher (e.g., scientist in their family), but also such attributes as race or sex, as in Gaylor's research (2017) male and African-American teachers were more probable to implement IBSE. "Other beliefs" include beliefs about role of the teacher (source of information, authority, the controller) that were not usually compatible with IBSE approach, as well as beliefs about students (their capability or interest to do inquiry).

The methodology analysis showed that methods usually used for data collection were questionnaire, interview or observation, while qualitative content analysis emerged as the most used data processing method. However, common use of these methods to evaluate among others such factors as professional development or external factors may question the objectivity of results, as while teachers may complain on lack of materials in an interview or questionnaire, their problem with implementation of IBSE may origin in their beliefs about IBSE or lack of professional development.

Implications

Some of the studies that we focused on offered implications for teachers' preparation programmes, teachers' professional development and curriculum as well as for the next research. These seem to be the remedy to improve the so far rather traditionalistic teachers' teaching conception (see Rajsiglová & Poneszová, 2022) and introduce some improvement. Future studies in this field may be of longitudinal character to track the sustainability of IBSE approach in teachers' practice; they can focus on discovering new factors as well as investigating the factors already identified and relationships between them. For identified factors' deeper understanding, they should be studied individually in relation to IBSE implementation, i.e. IBSE as such or specific kinds or IBSE aspects. It would be necessary to focus on subject-specific sample of teachers, as teachers of different subjects seem to experience different obstacles and opportunities in IBSE implementation (Breslyn, 2012). Individual attention should be paid to factors such as professional development that were only subjectively reported by teachers to improve their IBSE implementation, as the causality should be proved more objectively.

CONCLUSION

This article investigated studies on teachers' implementation of IBSE in science. 70 studies from WOS and ERIC published between 2011-2021 were reviewed, which showed renewed interest in the topic in past years. Wide range of factors from studies was divided into 2 categories: teacher-centred and teacher-perceived factors. Implications from studies and review suggest changes in teachers' preparation and professional development and curriculum. In future research correct methodology and objectivity should be emphasised, as most of the studies relied on teachers' subjective reports of implementing IBSE without validating their claims. Factors should be studied in context of teachers of different subjects and studies should investigate relationships between factors themselves, as well between factors and specific kinds or aspects of IBSE.

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Teaching methods and activation strategies from the lower-secondary school students' perspective

Ina Rajsiglová, Viktorie Poneszová

Abstract

The effect of teaching methods and activation strategies on Czech and Finnish students' interest in biology classes was examined. The research tool was a questionnaire with 5-point Likert scale. Ninth graders from Czechia, Prague (n = 195) and Finland, Oulu (n = 178) attended in the research. Nonparametric statistical tests were used to evaluate the data. The research revealed the only significant difference, namely in excursions. Czech students require them distinctly more than Finnish. Educational implications in relation to international cooperation have been proposed, teachers can draw inspiration from the same materials or work on joint projects to encourage interest in biology classes.

Key words

Teaching methods; biology; ninth grade students; questionnaire survey

INTRODUCTION

The academic success of students and motivation to learn largely depends on the teacher's ability to engage students. This is related to the choice of teaching methods and, among other things, the teacher's ability to guide students through the learning process. Successful application of teaching methods allows students to better master the subject (Porozovs et al., 2015; Rajsiglová, 2018).

Janoušková and Maršák (2008) state that the ways in which science is taught in schools are considered to be one of the main reasons for the declining interest of young people in studying science.

Teaching methods, activities or strategies that enable the teacher to support students in achieving quality performance and at the same time offer a certain flexibility to the actors of the teaching process, i.e. both teachers and students, are optimal for achieving teaching goals in the lesson. Teaching methods, which also allow for teacher-pupil interaction, support the internalisation of the objectives set by the teacher for the lesson as well as the objectives of the curriculum. (cf. Hidi & Renninger, 2006; Porozovs et al., 2015; Rajsiglová, 2018).

In our paper, we focus on teaching methods and strategies that are currently used in the teaching of natural sciences, while the subject of our interest is teaching in biology classes. In addition to Czech students, Finnish students are also involved in the survey; thanks to the Erasmus plus program, we also had the opportunity to look into Finnish school classes.

THEORETICAL BACKGROUND

From the international TIMSS (Mullis et al., 2020) and PISA (OECD, 2020) surveys, it is clear that the results of Finnish students are still at the forefront of the surveys, although their results have been deteriorating since 2006. In the part of science literacy, students from Estonia and Japan achieved the best results in 2018, and despite a large gradual decline of 41 points since 2006, students from Finland also achieved the best results. Compared to Czech students, Finnish students clearly achieve better results (497 vs. 522) in the areas of science literacy mapping (Blazek et al., 2019; OECD, 2020).

The contents of both Czech and Finnish curricular documents show that it is necessary to influence students in such a way that educational process: a) will be enable them to learn independently, in addition to knowledge, skills and habits; b) will be enable them to form such values and attitudes that will lead to judicious and cultured behavior and responsible decision-making (FEP EE, 2021; FNBE, 2016).

This is very general, but it is related, among other things, to the need to use such teaching methods and ways of cognition, by which students are adequately guided through the educational process. The methodological nature of the teacher's work is also related to the requirement to revise or innovate existing teaching methods and teaching strategies (FEP EE, 2021; FNBE, 2016).

With the change in educational approaches, teachers are encouraged to create a creative environment for the student's learning and to be a mentor offering guidance, a facilitator and a proofreader in one. Teachers should therefore seek to introduce methods and forms into the teaching that support the learner's learning, or to innovate or change them if they are no longer functional in relation to the creative atmosphere and classroom climate (Rajsiglová, 2018).

Students participating in the research of Porozovs et al. (2015) stated that their ability to focus attention during biology classes depends on the task assigned to them. Most of all, they prefer watching the teacher's presentations, listening to the teacher's storytelling about the actual topic, as well as performing laboratory and group work. Most students like to take part in discussions, less preferred is working on individual tasks, filling out worksheets or completing projects.

As for the excursion, as an organizational form, Uitto and Kärnä (2014) commented that the excursion was not preferred by Finnish students and the authors recommended this conclusion for closer examination. In contrast, Juuti et al. (2010) found that Finnish students are interested in excursions and acknowledge this interest by connecting students to the school curriculum with its real use in life, which the authors clearly consider beneficial. The excursion is, among other methods, see the next chapter, included in this survey.

We conclude the theoretical overview with the work of Rusek and Asunta (2011), who state that progress in any teaching technique depends not only on the creativity of teachers, but also on their inspiration. The authors discussed Czech and Finnish view on project-based learning (PBL), in which teacher students were involved. They reported on the cooperation of international workplaces and mutual inspiration, in relation to PBL and partial methods that accompany PBL.

In the contribution, Rusek and Asunta (2011) further note that they perceive a more visible influence of ICT in school practice. Many student teams used motivational videos and ICT support to keep in touch during group work while working on assigned tasks. Students also used ICT in communication with the teacher or in the final phase to present the results of the assigned work. Although they were university students, it is evident that the ICT challenges currently also apply to primary and secondary schools. The updated version of the FEP significantly included ICT in the revision of the FEP (FEP EE, 2021).

From the above, it is clear that it is useful for the teaching community to examine which methods used by teachers are attractive to students and how much these methods contribute to attracting attention to the subject and its educational content. We therefore determine the following research questions:

1. Which teaching methods and activities are suitable for increasing interest in biology among the monitored students?
2. Are there differences in the preferences of teaching methods and activities between these Czech and Finnish students?
3. What educational implications could be derived from the research?

RESEARCH METHODOLOGY AND RESEARCH QUESTIONS

The quantitative research is presented in the paper. Ninth graders of lower secondary schools in Oulu, Finland (n = 178) and Prague, Czech Republic (n = 195) participated in this study. Research tool was a questionnaire with 5-point Likert scale items (from “strongly disagree” to “strongly agree”). The questionnaire investigated which of 15 examined teaching methods and activities (see Tab. 1) included in biology lessons would increase the interest in biology among observed students.

The items were designed so that 9-grade students could understand them. To test this intention, a pre-survey was conducted in 2018 with Czech students aged 13-16 years (n = 7). After adjustments based on the results from the pre-survey, the questionnaire was translated from Czech language to Finnish language. The translation was done by Mr. Mgr. Jan Dlask, Ph.D. and Mr. Lasse Suominen, M.A.

In autumn 2018, data collection took place in the Finnish city Oulu. Questionnaires were distributed by the author (V. P.), who also explained the assignment in English, she answered questions and was present throughout the data collection process. A Finnish teacher was also available to translate the information into Finnish if necessary. In spring 2019, data collection was carried out in the Czech Republic in Prague.

Cronbach's alpha coefficient (α = .75 for Czech questionnaire, α = .79 for Finnish questionnaire) was used to measure the reliability of the questionnaire. For the further procedure of statistical data analysis, the evaluation was performed at a significance level of α = .05. Since this was an item-by-item evaluation on an ordinal scale, the Mann and Whitney U-test was used to determine the results. The *p*-value and effect size (coefficient *r*) were also calculated. Reference values of effects (Cohen, 1988) are mentioned under the Tab.2. Statistical tests were made in R 3.6.2., package Ltm. Pairwise deletion was used to handle missing values.

RESULTS

For answering the first research question, mean and standard deviation were measured for each of questionnaire item, separately for Czech and Finnish students. The mean and standard deviation were calculated from 5-point Likert scale answers. Therefore, mean ranges from 1 (strongly disagree) to 5 (strongly agree). Often, the value of mean is around 3, which was the neutral point of this Likert scale.

Results show that Czech students welcome the inclusion of science films or videos in biology lessons (*M* = 4,24, *SD* = 1,01). Furthermore, Czech students would like to work more often with mobile phones, tablets or computers (*M* = 3,94, *SD* = 1,27). Results also indicates that Czech students would be more interested in biology if teachers told their own experiences more often (*M* = 3,87, *SD* = 1,35) and organised science excursions for students (*M* = 3,87, *SD* = 1,34), see Tab 1.

Finnish students would appreciate more science films or videos in biology lessons (*M* = 3,89, *SD* = 1,24), the teacher's lecturing in an engaging way (*M* = 3,88, *SD* = 1,13) or if the teacher focuses on topics suggested by the students (*M* = 3,81, *SD* = 1,03), see Tab 1.

The second research question focuses on differences in the preference for teaching activities between Czech and Finnish students. Mann and Whitney's U-test was used to determine whether there is a difference between the answers of Czech and Finnish students. Based on the results of this statistical test and its *p*-values, it was found that for 8 teaching activities out of 15 there is a statistically significant difference between the preferences of Czech and Finnish students, see Tab. 2.

Tab. 1 Methods and activation strategies in order of mean of Czech and Finnish students' preferences

CZECH STUDENTS	***M***	***SD***	**FINNISH STUDENTS**	***M***	***SD***
WATCHING VIDEO AND DOCUMENTARY	4,24	1,01	WATCHING VIDEO AND DOCUMENTARY	3,89	1,24
WORKING WITH PC, TABLETS, PHONES	3,94	1,27	ENGAGING LECTURING	3,88	1,13
TEACHER'S STORYTELLING	3,87	1,35	TOPICS THAT STUDENTS SUGGESTED	3,81	1,03
EXCURSION	3,87	1,34	TEACHER'S STORYTELLING	3,67	1,16
LAB WORK	3,84	1,29	ACTIVITIES THAT STUDENTS SUGGESTED	3,60	1,09
ACTIVITIES THAT STUDENTS SUGGESTED	3,83	1,31	LAB WORK	3,51	1,23
ENGAGING LECTURING	3,82	1,27	WORKING WITH PRODUCTS OF NATURE	3,50	1,17
TOPICS THAT STUDENTS SUGGESTED	3,75	1,35	STUDENTS' STORYTELLING	3,45	1,18
GROUP WORK	3,70	1,29	EDUCATIONAL GAME	3,41	1,32
WORKING WITH PRODUCTS OF NATURE	3,62	1,26	WORKING WITH PC, TABLETS, PHONES	3,40	1,24
STUDENTS' STORYTELLING	3,55	1,28	GROUP WORK	3,28	1,28
EDUCATIONAL GAME	3,42	1,39	DISCUSSION	3,24	1,27
DISCUSSION	3,29	1,38	EXCURSION	3,11	1,45
MODELS AND DRAWINGS	2,97	1,43	WORKSHEETS	2,98	1,33
WORKSHEETS	2,44	1,31	MODELS AND DRAWINGS	2,95	1,15

M = mean, *SD* = standard deviation

Tab. 2 shows that Czech students statistically significantly request a change for 7 of the activities studied, which could be used by the teacher to attract their attention. Finnish students ask for fewer changes in the inclusion of observed activities in biology lessons. Only work with worksheets contributes to Finnish students enjoying science more compared to Czech students. However, if we compare worksheets with other teaching activities, it turns out to be one of the least preferred teaching activities (see Tab. 1).

However, according to the effect size of measured differences, there is no considerable difference between Czech and Finnish students' opinion on teaching activities in biology lessons. Measured effect sizes turned out to be small. The only exception is excursion for which medium effect size was measured (U = 12030, p = 2.562E-07, r = .3). In summary, the results show that only excursion is the learning activity for which we notice a significant difference.

Tab. 2 Methods and activation strategies from the point of view of Czech and Finnish students in order of effect size

TEACHING ACTIVITIES[1)]	MEDIAN		MODUS		$U^{2)}$	$r^{3)}$
	CZ	FIN	CZ	FIN		
(3) EXCURSION	4	3	5	5	12030**	0,30[A/B]
(10) WORKING WITH PC, TABLETS, PHONES	4	3,5	5	3	12603**	0,27[A]
(5) GROUP WORK	4	3	5	4	13938**	0,20[A]
(6) LAB WORK	4	4	5	4	14368**	0,17[A]
(15) ACTIVITIES THAT PUPILS SUGGESTED	4	4	5	3	14417**	0,17[A]
(1) WATCHING DOCUMENTARY OR VIDEO	5	4	5	5	14680**	0,15[A]
(12) TEACHER´S STORYTELLING	4	4	5	5	15037*	0,13[A]
(8) WORKSHEETS	2	3	1	3	21329**	-0,23[A]
(2) WORKING WITH PRODUCTS OF NATURE	4	4	5	3	16089	-
(4) DISCUSSION	3	3	3	3	16401	-
(7) EDUCATIONAL GAME	4	4	5	5	16883	-
(9) MODELS AND DRAWINGS	3	3	3	3	17018	-
(11) ENGAGING LECTURING	4	4	5	5	17383	-
(13) PUPILS´ STORYTELLING	4	3	5	3	16030	-
(14) TOPICS THAT PUPILS SUGGESTED	4	4	5	4	16732	-

1) Numbers in brackets are item numbers from questionnaire
2) U = U-test results, p-values: $^{\text{no mark}}p > 0{,}05$, $^{*}p < 0{,}05$, $^{**}p < 0{,}01$
3) r = effect size, [A]small effect (0,1 to 0,3), [B]medium effect (0,3 to 0,5), [C]large effect (0,5 and higher), Cohen (1988)

DISCUSSION AND EDUCATIONAL IMPLICATIONS

The results of this study show that the observed students do not require significant changes in relation to teaching methods or strategies, while the statement is more pronounced in favor of Finnish students. Juuti et al. (2010) also concluded that students do not wish for extensive changes in their teachers' teaching. Given the results of this work, it seems that the interest in the current concept of teaching among Finnish students still persists. After all, traditional teaching has long been respected in Finland and Finns (including students) have confidence in it (Simola, 2005). This is also later on reflected in the way teachers implement innovation (see Kohutiarová & Kotuľáková, 2022).

Uitto and Kärnä (2014) concluded that Finnish students often work in science classes under the guidance of Finnish teachers and that this way of working contributes to their positive attitude towards science. Our results also show that Finnish students welcome the presentation of the curriculum content by the teacher herself/himself. However, to only right an engaging lecturing of the topics that students are currently interested in will increase their interest.

Both groups of students, Czech and Finns, require watching videos and documentaries to increase interest in biology. To support their interest, Czech students demand the teacher's storytelling and working with IT tools. Knowledge is today produced and distributed with the generous help of information and communication technologies, and the result is the involvement of information and communication technologies in the educational process (Maněnová, 2012). In summary, these are conservative approaches that students welcome in class; those for Czech students are further linked to aspects of the modern age, where ICT tools belong.

If we look at the results of the research from another point of view, then right the excursion encourages further discussion. Excursion is considered an activating form of teaching, which happens, however, only with proper preparation and guidance using activating teaching methods. This is aptly expressed by Petty (1996), according to which excursions allow the real world to enter into learning and teaching. Compared to other teaching methods, students remember more thanks to excursions and these are very useful for the teacher-student relationship. But it also has its limits, which at first glance may provide arguments why not organize excursions. Many studies confirm that traditional teaching appears to be better than non-traditional in terms of the level of achieved results (Pavlasová et al., 2015).

The antagonistic views of the excursion are given by two Finnish publications, and at the same time the results of our research also indicate a certain degree of contrast. Uitto and Kärnä (2014) commented the fact that the excursions were not preferred by Finnish students and the authors recommended this conclusion for closer examination. The results of this research show that excursions are unlikely to contribute to higher enjoyment of biology lessons among Finnish students (13th of 15 items, see tab. 1). In contrast, Juuti et al. (2010) found that Finnish students are interested in excursions. The Czech students' results copy Juuti's et al. (2010) conclusion, as the excursions would probably contribute to the higher enjoyment of biology lessons of the monitored Czech students.

Despite of the fact that the effect size of the monitored methods and activities, with the exception of excursions, is low, it encourages us to derive suggests in relation to educational implications.

This can be reflected, for example, in the preparation of teaching materials. The preparation and selection of worksheets is an important part of the teacher's work. But students perceive working with worksheets as a neutral or less favour activity in teaching, which is evident from the results of our work and the results of Porovoze et al. (2015). It is therefore necessary to offer students worksheets with a variety of tasks that will help students practice and make the topics of lessons more attractive. Last but not least, it is also desirable to explain to students the function of worksheets and the purpose of their using in teaching.

Next implication follows relation to ICT. Czech students will welcome working with IT tools more often in science lessons. The ICT topic was accentuated by the revised version of the FEP EE, in which the so-called digital competence is newly added (FEP EE, 2021). Due to the IT competition, which is also included in the Finnish curriculum (FNBE, 2016), Finnish teachers are also called upon to implement IT tools in teaching (not only) science and to support students in developing this competence. The educational implications can be seen in the online connection of pupils and/or their teachers and working on joint projects or sharing learning materials, which is also discussed in Rusek and Asunta (2011). An indisputable bonus of the educational implication is practicing English.

CONCLUSION

The results of this work bring findings that are related to the teaching methods and activation strategies in biology classes from the perspective of ninth graders from Czechia, Prague, and Finland, Oulu. Czech students require teachers to include more work with IT tools (mobile phones, tablets or computers) and excursions. Finnish students will welcome engaging lecturing, the teacher's storytelling and work on topics proposed by themselves. The interest in biology in both groups of students can be encouraged if teachers include science documentaries or videos and work with them. The survey revealed that Finnish students demand fewer changes from their teachers, in relation to the monitored assets and methods in teaching biology, compared to their Czech peers.

With respect to the low effect size values, educational implications were derived: 1) it is possible to collaborate on joint projects, create and share teaching materials; 2) ICT competence can be supported by online connection of students and their teachers, while 3) the bonus of international cooperation will be the strengthening of communicative competencies and training of English language at the peer level.

Due to the fact that the survey took place at the local level, Prague for the Czech Republic, Oulu for Finland, we are aware of the limit of our research. The results cannot be considered for the whole territory or their other parts. Nevertheless, we believe that it is useful to refine and expand similar surveys, especially in order to find ways to make teaching more attractive and how to reflect it from the students' point of view on an international level.

In conclusion, a qualitative survey, e.g. on the basis of an interview with pupils, would further enlighten their view of the teaching methods and activation strategies included by teachers into biology lessons. Further research in this area is therefore required.

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The Identification of Girls' Attitudes to STEM via Science Camp "Lab Technology and Everyday Life Consumption"

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Abstract

The "Lab Technology and Everyday Life Consumption" a two-day science camp is one of the national activities of the European project Empower Girls to Embrace their Digital and Entrepreneurial Potential (GEM), which aims to promote the interest of girls aged 12 to 16 in STEM and the related field of ICT in the Czech Republic. In this paper, we focus on the description of preparation, implementation, and evaluation of the camp, as well as on the results of the evaluation of girls' attitudes identified in questionnaire surveys conducted in two runs, which took place at the Department of Chemistry and Chemistry Education, Faculty of Education, Charles University at the end of August and October.

Key words

Project GEM; STEM; science camp; girls' attitudes to STEM

INTRODUCTION

Digital innovations and technologies (e.g., robotics, industrial automation, artificial intelligence, blockchain, virtual realities) play an essential role for Europe's prosperity. An immense challenge about digitalization is that it transforms our labour markets with rapid pace (COM, 2018). People need to be prepared to adapt to changes and possess a range of transversal skills and competences to reach Europe's full innovation potential. But "40% of European employers have difficulty finding people with the skills they need to grow and innovate" (COM, 2016). People need STEM and mainly digital skills for almost every job (in one way or the other), but "43% of European citizens do not have basic skills in this area." (European Commission, 2022) and "for every 1000 women, only 24 graduate in ICT-related fields" (European Commission, 2018). Also, to secure its technological leadership, Europe's labour markets need skilled employers in all STEM related sectors, on all professional levels and with a diverse range of technological knowledge are necessary (EU STEM Coalition, 2016). But a large majority of EU28 countries have recently experienced recruitment difficulties due to a substantial lack of suitable candidates (STEM Alliance, 2017) and only 15% of tech sector workers in the EU are women. Participation at senior management and board level is even lower (European Commission, 2020). Encouraging women into STEM and ICT fields and building a gender balanced tech sector will play an important role in order to boost innovation and bring economic benefits to the European Economy

(European Commission, 2018). But “the lack of interest among girls to pursue studies in ICT and STEM remains a clear problem. This leads to lost social and economic opportunities and risks reinforcing gender inequality” (COM, 2018). It is obvious, that, although gender gaps and skills gaps in STEM/ICT sectors have been acknowledged and counteractions have been triggered, the effort cannot be slackened but have to be intensified further. We cannot allow for existing gaps to widen. Education and training clearly are recognized as the way to achieve this as e.g., tackled by the New Skills Agenda, the Women in Digital Strategy and the Digital Education Plan (e.g., Chapman & Vivian, 2016; Microsoft, 2017; Milgram, 2011; Sammet & Kekelis 2016; Wang et al., 2015).

The project European project Empower Girls to Embrace their Digital and Entrepreneurial Potential (*GEM project*, © 2018) specifically answers to the call: *Training in digital and entrepreneurial skills for girls - Addressing the gender gap in digital and entrepreneurship sectors.* The concentration to an inspiring science summer schools (camps) with STEM topics is what the International Centre for STEM Education as project leading institution and all higher education partners are renowned for and what can be important contribution for improvement in this area with main focus to girls and their challenges and chances on the labour market (European Commission, 2019).

In this paper, we focus on the description of preparation, implementation, and evaluation of the camp prepared in line with the objectives of the GEM project, as well as on the results of the evaluation of girls' attitudes identified in questionnaire surveys.

DESCRIPTION OF THE GEM PROJECT

The project GEM aims to promote the interest of girls aged 12 to 18 years in STEM and the related field of ICT to inspire them to choose careers and become entrepreneurs in these fields (Bilek, 2018; Dimitriadi, 2013; Milgram, 2011). The GEM is a European Union co-funded pilot project established for this objective the project consortium, which organizes exciting and cost-free summer camps for girls in all 11 participating countries. The focus of the project is also to establish a wide-reaching network of schools, higher education institutions, companies, and policy makers who support girls in pursuing these careers. The GEM consortium consists of 11 higher education institutions from 11 countries (Germany, Cyprus, Czechia, Spain, Greece, Lithuania, Malta, The Netherlands, Norway, Sweden, and Slovakia). They are in collaboration with partners from business, policy, and education providers at a national level. This means that the GEM community is drawing from an unbeatable mixture of STEM education expertise, STEM/ICT subject knowledge, and transnational project experience (*GEM project*, © 2018).

GEM in the context of Czech educational system

Education in Czechia is compulsory from six to fifteen years (The Ministry of Education, Youth and Sports, © 2013 – 2022). This compulsory education covers five years of primary education followed by four years of lower secondary education. Education is free in all state schools; children can be educated by parent's decision also in private schools. The Czech school system is organized by a two-level system: Framework Educational Program (FEP) as guidelines for School Educational Programs (SEP) as its own school product. In FEP are listed only the so-called educational areas and their educational fields, which can be applied as school subjects. In the area of STEM, the educational areas are Maths and its applications, Man and Nature (Physics, Chemistry, Biology and Geography), Man and Health, Man and His World, Man and World of the Work and Informatics. During the primary level, learners' study integrated science and ICT, and during the lower secondary level, separated subjects are usually applied, e.g., physics, biology, and geography in all four grades, chemistry usually in the last two grades (Šorgo et al., 2017).

GEM SUMMER CAMP “LAB TECHNOLOGY AND EVERYDAY LIFE CONSUMPTION”

The GEM approach in Czechia is applied by the Department of Chemistry and Chemistry Education, Faculty of Education, Charles University in Prague.

The plan for the Czech GEM Summer Camp was to organize two events for around 30 girls aged 12 to 16 years. It was decided that the main topic should be related to the professional and research orientation of the organisers; this means chemistry and related disciplines. It was supposed to focus on the consumption of everyday life and its consequences with STEM, mainly with laboratory activities. The topic was chosen accordingly with the general learning outcomes of the GEM project projected at all national GEM summer camps. Then each activity had a series of learning outcomes derived from the general learning outcomes. The general learning outcomes were formulated:

- Girls will have increased their interest in STEM / digital disciplines.
- Girls will become aware of their own potential.
- Girls will be enabled to perform successfully in STEM / digital disciplines.
- Girls will be encouraged to study or pursue careers in STEM / digital sectors.
- Girls will have confidence to consider leadership positions in STEM / digital sectors.
- Girls will have an enhanced employability with regards to STEM / digital labour markets.
- Girls will want to know more about STEM.
- Girls will want to be involved in STEM.

The projection of the goals mentioned was implemented in the case of Czechia at the Summer Camp with the title "Lab Technology and Everyday Life Consumption". Its concretization was prepared on the content oriented to learners and their interest and knowledge level.

The first run of the two-day science camp of the GEM project took place at the end of the summer holidays, i.e., 30 - 31 August 2021. Twenty-one girls aged 12 to 16, who were interested in science and technology, completed a diverse program every day from 9:00 to 17:00. The program consisted of:

- lectures on Natural Sciences, Technology and Other Related Areas in Our Lives and Chemistry and Art,
- workshops with these topics: Computer in the Chemical Laboratory and Natural Science Principles in Simple Experiments with Substances of Daily Consumption,
- laboratory work with these topics: How Substances around us are separated in a Chemical Laboratory, We Measure with a Computer in a Chemical Laboratory, and Colours in a Chemical Laboratory.

The second run of the two-day science camp of the GEM project took place during the autumn holidays, i.e., 27 - 28 October 2021. Twenty-nine girls and two boys aged 12 to 16, who were interested in science and technology, completed a diverse program every day from 9:00 to 17:00. The program was the same as the previous one, although it included a new topic of Chemistry for Health and Beauty.

The professional part of the programs was supplemented by discussions with women-lecturers who were experiencing their working careers in the world of science and university education, about their lives and careers. It means that mentor and lecturers for summer schools were recruited from the academic staff of organisers and their co-workers from other academic institutions. Mostly women (5 women and 1 man). With lecturers and a mentor, individual meetings were organized and oriented around the content of their sessions. The sessions were about the GEM project, about the learning plan, and about how one is supposed to lead groups during the GEM summer camps and communicate with participants and their parents.

The learners worked during lectures in a whole group and for workshops and laboratories, they were divided into two groups based on their own decision. The plan was to have a series of activities related to various STEM areas. The programme included not only lectures, workshops and laboratories, but also ice-breaker activities, games, and refreshing breaks. Parents brought their children to the faculty every morning and picked them up again after the activities.

Learners were led by a female mentor who accompanied them throughout the summer camp. She will be their contact person all the time. Among other things, the mentor made sure that the group worked safely, respecting social distancing rules, sanitizing tables, and any equipment used. The mentor was also in close contact with all lecturers (Bednarova et al., 2019).

IDENTIFICATION OF GIRL'S ATTITUDES TO STEM AND THEIR EVALUATION CONNECTED WITH GEM SUMMER CAMP

Objective and setting of the environment

The main objective of realised GEM Summer Camp was to support girls' positive attitudes to STEM through their activities in the university environment. The recruitments were organized mainly through the Facebook group (Učitelé přírodovědných předmětů [Teachers of Science Subjects], © 2022) and through workshops with teachers and future teachers connected to the organizer's department. As there was a capacity limitation in the laboratories, it was decided that the event would be held in two summer schools during the holidays of secondary learners. The first one in August and the second one in October of year 2021. The organizers discussed the content of the summer camp with the National GEM Team (NGT) and the advisory group consisting of teachers, policy makers, and other stakeholders.

The organizers created information posters for each summer school, which were consequently published on the Facebook group and distributed in print form to schools in Prague and its surroundings. The project was introduced here, and the learners were invited to register online (using a QR code) together with the confirmation of their parents. This recruitment campaign was successful, as for the first event, 21 girls applied and for the second event, 29 girls and 2 boys applied to join the summer camp. After the initial registration, parents were informed of the conditions (incl. Covid-19 requirements) and asked to fill in and sign the consent forms for data collection, photography, etc. On the official website of the Faculty of Education of Charles University, a summer camp support page was created that included information about the project and the summer camp.

Data collection

The identification of girl's attitudes to STEM was planned through the pre- and post-learner questionnaires, and also was added a questionnaire for the mentors and educators developed in the project Work Package led by a consortium partner from Malta. The questionnaires were translated into the Czech language.

All learners and parents were informed that their participation is voluntary and that when filling out the questionnaire, learners will be asked not to write their names on it and may choose not to complete it. Furthermore, the questionnaires will be encrypted, so that even the identity of the school will be anonymised. All raw data will be securely stored, and the data obtained will be used solely for the compilation of this research.

The pre-questionnaire was given to the learners as their first activity of the summer camp, while the post-questionnaire was their last activity. Mentors and lecturers were also asked to complete a questionnaire giving their views and feedback after the summer camp.

Data analysis

For descriptive analysis, median and mode were used with respect to the use of Likert scale in questionnaires (McLeod, 2019). To determine the effect of science camp on learners' attitudes, we first subjected the data to Kolmogorov-Smirnov and Shapiro-Wilk normality tests, both of which indicated a non-normal distribution of the data. Since we were able to identify individual participants' tests through the code, we then chose the Wilcoxon Signed Ranks Test. The Wilcoxon Signed Ranks Test and effect size *r* was used to compare changes in attitudes after summer school. Effect size *r* was calculated as positive *Z* divided by square root of the sample size *N*, i.e., $r = \frac{Z}{\sqrt{N}}$, and it is interpreted as small effect for *r* from .1, medium effect from .3 and large effect from .5 according to Cohen (1988).

RESULTS

A total of 50 female and 2 male learners participated in GEM Summer Camps 2021 and all completed the pre- and post- questionnaire in Czech language. The sample consisted of 12-year-olds (12), 13-year-olds (13), 14-year-olds (13), 15-year-olds (10) and 16-year-olds (4). All the learners were studying or had studied Mathematics, Physics, Biology, and ICT, and more than half of them also studied Chemistry.

Their perception of scientific disciplines was relatively high. On the scale that identifies a position from 1 (to me “subject” means nothing, or “subject” is boring) to 7 (to me “subject” means a lot or “subject” is interesting), medians and modes were 6 and higher in all items with exception the meaning of the subject science (see Tab. 1).

Tab. 1 Perception of scientific disciplines by learners who participated in GEM camps (N = 52)

TO ME	**…MEANS NOTHING / …MEANS A LOT**		**…IS BORING / …IS INTERESTING**	
	Median	***Mode***	***Median***	***Mode***
SCIENCE	5	5	6	7
MATHEMATICS	6	6	6	7
BIOLOGY	6	7	7	7
CHEMISTRY	6	7	7	7
PHYSICS	6	6	6	7
FURTHER STUDIES IN STEM	6	6	6	6

Their feelings about school STEM subjects and studying STEM subjects were expressed at the beginning of the summer school on a 5-point scale (strongly disagree – 1, disagree –2, neither agree nor disagree – 3, agree – 4, strongly agree – 5). This was the only item measured in both questionnaires (see Tab. 2). "Before" summer school learners had a neutral opinion only on the item "STEM is easy for me" (median and mode 3). In all other statements, they agreed and presented their positive opinion about STEM and STEM education. In most items, it showed increasing in the positive learner's attitudes with small or medium effect, but it was not statistically significant with exception of statement "I generally have fun when I am learning STEM topics," where was also the greatest effect size .38. Another exception is for statement "What I learn in my STEM subject(s) is worthwhile for me because I need this for what I want to study later on," where the results suggests that there was instead a slight decrease in positive attitude but is not statistically significant and without any effect.

Tab. 2 The attitudes of the learners who participated in GEM camps about school STEM subjects (N = 52)

STATEMENTS	**BEFORE**		**AFTER**		**WILCOXON SIGNED RANKS TEST**		***EFFECT SIZE***
	Median	***Mode***	***Median***	***Mode***	***Z (after-before)***	***Asymp. Sig. (2-tailed)***	***R***
I am interested in learning about STEM.	4	4	4	5	-1.648^{b}	.099	.239
I generally have fun when I am learning STEM topics.	4	4	5	5	-2.742^{b}	**.006**	**.380**
Making an effort in my STEM subject(s) is worth it because this will help me in the work I want to do later on.	4	4	4	4^{a}	$-.787^{b}$	.431	.109
What I learn in my STEM subject(s) is worthwhile for me because I need this for what I want to study later on.	4	4	4	4	$-.021^{c}$	.984	.003
STEM is useful in helping to solve the problems of everyday life.	4	4	4	4	-2.301^{b}	.021	**.319**
STEM is easy for me.	3	3	3	3	-1.624^{b}	.104	.225
STEM is helpful in understanding today's world.	4	4	4	4	$-.899^{b}$	.368	.125
It is important to know STEM in order to get a good job.	4	4	4	5	-1.829^{b}	.067	.254

Note: a – multiple modes exist, the smallest value is shown; b – based on negative ranks; c – based on positive ranks.

After the summer school, the learners also used a 5-point scale (strongly disagree – 1, disagree –2, neither agree nor disagree – 3, agree – 4, strongly agree – 5) to show how much they agree or disagree with statements regarding their approaches to science and ICT, and how this summer school has contributed to it. The results (see Tab. 3) show the most positive agreement with the statements “I can imagine myself working in a science-related job” (median = 4, mode = 5) and neutral attitude towards working with ICT-related job (median = 3, mode = 3), which relates with the content of summer school.

Tab. 3 The (dis)agreement of the GEM participants with the statements related to science and ICT (N = 52)

FOLLOWING THE SUMMER CAMP:	***MEDIAN***	***MODE***
I can mention ICT-related uses and applications.	4	4
I am aware of gender stereotypes.	4	4
I am aware of the relevance of digital technologies in my life.	4	4
I am ready to engage in science.	4	4
I am ready to engage in ICT.	3	3
I can imagine myself working in a science-related job.	4	5
I can imagine myself working in an ICT-related job.	3	3

The learners had the possibility to identify which summer camp activity was their favourite and which was their least favourite. It was no surprise that the most favourite activities were laboratories, experiments, and active work. As the least favourite, they wrote most often “nothing” and in few instances they mentioned “listening” or “theory”.

Overall, they answered the questions “Did you enjoy the summer camp programme?” and “Did you feel comfortable during the summer camp?” in 80% “yes” and “almost always” and in the next 20% “most times”. Their average position in response to the question “Do you think differently about science since attending the summer camp?” was between “a little” and “quite a lot”.

Finally, we have to say that we observed groups of girls with high motivation for STEM. It means that we worked with a very specific kind of learners and not with a sample representative of all girls within this specific age. Below are selected examples of their motivation for participation in the activity:

- *“I don't like to sit and do anything!”*
- *“It strengthened my desire to become a respected person in a given field where there are mostly men!”*
- *“I would like a slightly longer term. Maybe a week of camp would be great!”*
- *“Spend more time working in laboratories and working with hazardous chemicals that we wouldn't try at school!”*
- *“I can brag in the chemistry class after my participation in this camp!”*
- *“Those breaks are unnecessarily long. We lose time to explore something else.”*

DISCUSSION

The relationship to STEM and its individual components and connections to everyday life found in girls was very high. The reason for it must be the recruitment of participants highly interested in the GEM camp program. But probably not only that. We noticed an increase in their interest and motivation for laboratory activities, as well as for future connection with STEM during camp activities prepared especially for girls. It is in consent with Murphy (2019), which one states that girls' school graduates have higher levels of self-confidence in their science-related skills compared to female graduates of co-ed schools. Specifically, girls' school alumnae, when compared to female graduates of co-ed schools, report greater confidence in their ability to: use technical science skills such as tools, instruments, and techniques, understand scientific concepts, generate a research question, explain the results of a study; and determine how to collect appropriate data.

The female lecturers also confirmed their surprising experience of leading girls in their topics. They appreciated the most that "girls will have an increased interest in STEM / digital disciplines" and "they will want to know more about STEM" (cf. Master et al. 2014; Solanki & Xu, 2018). The lecturers also highly appreciated the participation of the girls who really enjoyed the work in the laboratory and worked hard and followed the instructions. They observed the statements "I become like a real scientist" very often (cf. Barron & Kattan, 2022).

CONCLUSION

In this paper, we present a description of the preparation, implementation and evaluation of the two-day science camp which is part of the activities of a GEM project aimed at encouraging girls to pursue STEM and ICT fields to increase the number of women in STEM-related and ICT-related jobs. Questionnaires were used to evaluate the camp and assess the girls' attitudes towards STEM and ICT before and after the camp. The results show that the participating girls already came with a positive attitude towards STEM and there was no statistically significant change after the camp with exception of statement "I generally have fun when I am learning STEM topics". According to the post-camp questionnaires, girls can also imagine themselves working in a STEM-related job, but unfortunately, they have a neutral attitude towards their involvement in ICT-related jobs, which is related to the content of the camp activities. More focus on ICT will be needed when organising the next camp.

In the end, we can express the motivation for continuing the GEM activities and for the dissemination of GEM ideas in the future by the statement of one of female lecturers in the evaluation questionnaire: "*I tried to motivate them, in general, to think so that they would not be afraid to get involved in things that someone thinks are more for boys (I did not say this, I did not want to polarize that we are girls and guys may be more inclined to do something in science and technology, but to just take it as normal, that we work in a lab with devices and it's fine). I didn't talk about gender stereotypes, so I gave less value. On the contrary, I assigned the highest value to realizing my own potential - in the discussion,* *I tried to reassure the girls that everyone has a different style of work, someone more theoretical or creative, another likes systematic work, and all this is fine, everything is needed. And let them try to find out what they are good at and just use it and develop it.*"

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Comparison of the Results of Didactic Tests of Fifth Graders on the Basis of Gender and the Proclaimed Curriculum at Primary School

Vlastimil Chytrý, Lucie Bílkovská

Abstract

The presented study deals with the issue of comparing achievement in didactic tests in mathematics between boys and girls in the context of preferred teaching management strategies. The research sample consisted of a total of 1133 respondents (Montessori - 73; Hejný - 332, ordinary primary school - 510; Dalton - 218). It turns out that statistically significant differences between boys and girls are only in an ordinary primary school and at a one percent level of significance ($p < .01$; $d = .297$). Examining the differences across these areas, especially for boys and girls, shows that both boys ($p = .030$) and girls ($p = .053$) may differ in achievement depending on the type of school they attend.

Key words

Achievement in a didactic test; proclaimed curriculum; gender

INTRODUCTION

The issue of didactic testing is still relevant not only in the Czech environment (usually ČŠI - Czech School Inspectorate, Kalibro or CERMAT - Centre for Learning Outcomes), but also in international researches, such as TIMSS (Trends in International Mathematics and Science Study) coordinated through the Association IEA (The International Association for the Evaluation of Educational Achievement), or PISA (Programme for International Student Assessment). The latter is considered to be the largest and most important international research on the measurement of educational achievements currently taking place in the world. PISA researches fall under the activities of the OECD (Organization for Economic Cooperation and Development). On the one hand, we encounter a number of national or international testing as mentioned above, but on the other hand, these tools are not used to compare different approaches to education in terms of preferred teaching management strategies (Montessori schools, Dalton schools, etc.). The tools these didactic tests represent are usually domain-specific with a focus on a specific area. The presented study is focused on mapping the differences in achievement in a didactic test in mathematics between boys and girls in relation to the preferred teaching management strategies, as defined by the authors Chytrý et al. (2020). During the research, the distinction will be made between pupils attending Montessori primary schools, pupils taught according to the Hejný method, pupils from ordinary schools, and pupils from primary schools based on the Dalton Plan.

MAIN CONCEPTIONS OF LEARNING

The trend of mechanical learning in schools continues to prevail despite the fact that routine repetition of procedures leads, for example, to a reduced interest (Schiefele & Schreyer, 1994) and to the fact that pupils do not understand how to use their knowledge, or how to modify it in a given context (Pressley et al. 1992). Halpern (2014) states that pupils are over-trained in a mechanical application of certain formulas and are not taught to stop and think about the way of the answer they should expect or how to proceed in solving a problem. Within this approach, we come to the question of the constructivist conception of teaching which is contrasted with the transmissive approach based on knowledge transfer and work with an algorithm. Behaviourism, constructivism and social constructivism can be included among the main modern concepts of learning, the basic features of which can be summarized in several points. While cognitivist theories are more interested in mental processes, behaviourism is an approach in psychology based on the assumption that behaviour can be scientifically studied without knowledge of the internal mental states of the organism. An important finding associated with behaviourism is the principle of conditioning and strengthening positive motivation to learn through ongoing rewards. Study materials based on this psychological direction are always waiting for the student's response (Hunt, 2000). The constructivist conception is often perceived as an ideal tool or starting point for lifelong teaching (Bertrand, 1998). Within this approach, educators should first consider their students' knowledge and only then link that knowledge to practice (Mvududu & Thiel-Burgess, 2012). In contrast, social constructivism emphasizes the irreplaceable role of social interaction in the construction of knowledge (Kalhous & Obst, 2002). According to Molnár et al. (2007), the differences between these approaches can be presented as shown in Tab. 1.

Table 1 Educational approaches' overview

	BEHAVIORISM	**COGNITIVISM**	**COGNITIVE CONSTRUCTIVISM**	**SOCIAL CONSTRUCTIVISM**
DEFINITION OF LEARNING	Behaviour change attitudes	Acquisition of new ways of information processing	Personal finding of meaning	Penetrating the culture of certain communities
THE COURSE OF LEARNING	Creating connections between stimuli and reactions, distinguishing between stimuli, generalization of reactions	Transfer of information from short-term to long-term memory, coding in the form of various representations	Problem solving, assimilation, accommodation of knowledge structures, reflection on experience	Dialogue with experts and peers, confrontation of opinions, opinions

PREFERRED TEACHING MANAGEMENT STRATEGIES

Within the Czech educational system, the term alternative school is often used where alternative teaching styles are associated with the term constructivism or constructivist conception of teaching. Pupils construct their knowledge and become partakers in the teaching process. According to Pecina and Zormanová (2009), constructivism aims to elevate the independent process of creating pupils' own knowledge. Teaching itself is determined by the pupil's current skills, findings, knowledge and the very approach to learning (Kalhoust & Obst, 2009). At this point, it should be noted that when we talk about an ordinary primary school, it is not possible to say that it is a school working primarily in a transmissive way because the sets of given strategies have a non-empty intersection. In a simplified form, it is possible to distinguish them in the following way using a table 1:

Tab. 1: Comparison of the significant aspects of different conceptions (Chytrý et al., 2020)

Aspect	Montessori	Hejný	Dalton	Ordinary School
Role of Teacher	guide	guide and facilitator	facilitator	Source of information
Learning Theory	individual constructivism	social constructivism	social constructivism	Transmissive approach with elements of constructivism
Way of Work	individual	individual/group	group	Frontal
Age Groups	heterogeneous	homogeneous	heterogeneous	homogeneous
Main Idea	help me do it myself	joy of learing	Freedom for cooperation and assignments	Not stated

Content knowledge or algorithms knowledge are not sufficient for the 21st century. "Pupils need to know how to read, understand and think critically…" (Ronzano, 2010, p. 4). Teaching is becoming dynamic and pupils are becoming increasingly active participants in their own educational process (Kasper & Kasperová, 2008). The exact conception of teaching in Dalton schools is challenging because the content of the Dalton plan is understood differently by teachers. The principle of deferred attention is applied in Dalton school teaching (Röhner & Wenke, 2003), especially because the teacher does not have the opportunity to pay attention to all pupils at once. The Montessori approach occupies an important place in the field of alternative education worldwide (Lopata et al. 2005). This is an approach that was primarily focused on children with special educational needs. The Hejný method is a schema-oriented education method in which pupils try to discover and understand mathematics themselves through an independent creation of these schemata.

MATERIALS AND METHODS

Research Sample

The research sample with preferred Montessori approach numbered 73 respondents (36 boys, 36 girls, 1 pupil did not state gender), the Hejný method involved 332 respondents (boys 182, girls 149, 1 pupil did not state gender), ordinary teaching at primary schools involved 510 respondents (251 boys, 259 girls) and the number of pupils with the Dalton approach was 218 (102 boys, 116 girls). As part of the research, we worked only with respondents who attended the same year and it was therefore an age-homogeneous group.

Tool for Assessing Mathematical Problem-Solving Skills

A combination of released mathematical tasks from CERMAT was used to determine the mathematical skills of 5th graders. From these tasks, a final test was compiled in which the tasks were slightly modified on the basis of pilot testing and interviews with didactics experts. The final form of the assignment contained 10 tasks, some of which contained one or more sub-questions. In terms of time, the test of mathematical skills was designed for one lesson (i.e. 45 minutes). The reliability of the tool was examined, due to dichotomous items, by the Kudera-Richardson formulas and the value was 0.807.

Research goals, problems and hypotheses

The main goal was to compare the success rate of pupils in the didactic test in mathematics depending on the proclaimed curriculum and gender. There are two research questions associated with this:

RP_1: What is the achievement of pupils in the didactic test in mathematics with respect to the preferred teaching management strategies?

RP_2: What is the influence of the preferred teaching management strategies on the pupil's achievement in the didactic test in mathematics with respect to gender?

Both research problems can be further refined through hypotheses, where we work primarily with null hypotheses:

$H_{1\text{-}0}$: The average values corresponding to the achievement in didactic tests do not differ between boys and girls due to the preferred teaching management strategies.

$H_{2\text{-}0}$: The average values corresponding to the achievement of boys in didactic tests do not differ due to the preferred teaching management strategies.

$H_{3\text{-}0}$: The average values corresponding to the achievement of girls in didactic tests do not differ due to the preferred teaching management strategies.

Results

Individual differences / dependencies will be evaluated on the basis of both descriptive and inductive analysis. Table 2, in which we limited ourselves to the average and median for capacity reasons, shows the difference in achievement in the didactic test in mathematics between boys and girls with respect to the preferred teaching management strategies.

Tab. 2: Achievement of boys and girls in the didactic test with respect to the proclaimed curriculum

PROCLAIMED CURRICULUM	BOYS – AVERAGE / SD	GIRLS – AVERAGE / SD
MONTESSORI APPROACH	14.42 / 4.15	14.80 / 4.26
HEJNÝ METHOD	13.03 / 4.36	13.53 / 4.23
ORDINARY PRIMARY SCHOOL	13.55 / 5.80	11.02 / 5.70
DALTON PLAN	11.56 / 4.82	11.87 / 5.09

At first glance, it is clear from the table that girls are more successful on average than boys in all cases except in an ordinary primary school. The biggest difference in performance/achievement can be noticed in pupils attending an ordinary primary school. This conclusion will be supported by further calculations in the inductive analysis. Overall, the boys from the Dalton plan and the girls at ordinary primary schools became the least successful. In the case of the hypothesis $H_{1\text{-}0}$, we always compare two sets (boys and girls) for each preferred teaching management strategy separately. The detected p-level values, including the test criterion, are listed in the following table.

Table 3: Comparison for individual preferred teaching management strategies (inductive analyzes)

PROCLAIMED CURRICULUM	*T*	*P*	COHEN´S D
MONTESSORI APPROACH	-.281	.78	.066
HEJNÝ METHOD	-.643	.521	.071
ORDINARY PRIMARY SCHOOL	3.351	.001	.297
DALTON PLAN	-.377	.706	.051

Note: Cohen's d (d = 0.20 small effect, d = 0.50 medium effect, d = 0.80 large effect)

Table 3 reads that statistically significant differences between boys and girls are only in an ordinary primary school and at a one percent level of significance (p <0.01). It is also clear from the values of Cohen's d that these are usually only small differences. In the case of the hypotheses $H_{2\text{-}0}$ and $H_{3\text{-}0}$, we always compare more variables and thus use ANOVA. The values are shown in the following table. Due to the fact that in this case we are working with multiple variables, the values of post-hoc analysis will be added directly to the table for capacity reasons.

Table 4: Basic ANOVA values for comparing individual preferred teaching management strategies with sex differentiation

	F	*p*	Eta^2
BOYS	2.797	.041	.030
Post hoc analysis: M – D**, H – D*, B – D**			
GIRLS	4.965	.002	.053
Post hoc analysis: M – O**, M – D*, H – O**, H – D*			

As for boys and girls, there were significant differences in achievement in the didactic test in mathematics between Montessori - Dalton. In addition, however, differences have emerged between other approaches to education (see post hoc analysis - table 4). While for boys the differences are significant at the five percent level of significance, for girls it is one percent level of significance; this is also evident on the basis of substantive significance. After multiplying by 100, we get the % explained by the given factor.

DISCUSSION AND CONCLUSION

Research by Ingacio et al. (2006), as well as research in our country (primarily in ordinary primary schools) has shown that boys are on average more successful in solving mathematical problems than girls. A significant difference was found only between boys and girls in an ordinary primary school. Due to the fact that there were no significant differences in most areas, we consider it appropriate to pay more attention to the constructivist approaches that have the most promising results in terms of long-term knowledge acquisition (De Jong et al., 2012). For example, in the case of Montessori pedagogy, children work with designed materials, so on the basis of direct manipulation with objects they can discover new knowledge that leads to the discovery of new problems (Fyfe et al., 2014). In these types of schools, the manipulation of subjects is important, where this manipulation then directly leads to the fact that students practically solve problems with immediate control of possible errors (Laski et al., 2015). Similar to Montessori pupils, pupils from those schools where teaching took place according to the Start Together program were also highly rated in comparison with the regular primary school. We consider it appropriate to mention that the borderline in terms of division into productive and reproductive methods according to Lerner (1986 in Chytrý et al., 2014) is also a method of problem interpretation, because it not only acquires knowledge already done, but also new. In conclusion, we would like to point out that in primary schools, a transmissive teaching method based on a frontal organizational form is still preferred (Korbel and Paulus, 2017), which leads to formalism as the most serious didactic problem (Hejný & Stehlíková, 1999). Article by Říčan and Chytrý (2020) describing the differences between the types of schools in terms of metacognitive monitoring. In this case, these differences turned out to be significant between (a) general elementary schools, (b) Dalton education elementary schools, (c) RWCT program elementary schools.

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The Qualities of Tasks in Inorganic Chemistry Based on the Analysis of Entrance Procedure at the Faculty of Science, Charles University

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Abstract

Although the purpose of the admission procedure is selecting the most suitable candidates, it can also show their level of knowledge. Therefore, we decided to analyse tasks in inorganic chemistry used in the admission procedure at the Faculty of Science, Charles University. The parameters of each task (success rate, ULI(1/2) coefficient, RIR coefficient, instruction analysis) were compared one to another resulting in: (i) recommendations for effective usage of the specific tasks, (ii) a list of troublesome topics for applicants (ideal gas law) and (iii) a list of tasks with a low item discrimination (preparation and manufacture of compounds, observation of chemical reaction, etc.).

Key words

Inorganic chemistry; admission procedure; item analysis

INTRODUCTION

The popularity of activation strategies and alternative teaching methods (such as inquire-based education and project teaching) has been increasing in last decades. Nevertheless, to use these methods effectively, it is also vital to identify current problems in studying and teaching natural sciences. Focusing on Chemistry, the troublesome tasks can be identified by the item analysis of Chemistry tests used in the process of university admission procedure. Based on its results, teachers can include activities focusing on topics which were marked as troublesome. Moreover, previous research (Adesope et al. 2017; Yang et al. 2019) shows that students improve their skills more effectively by completing similar tasks (as in the admission procedure) than by any other revising method. Therefore, practise tests consisting of such tasks lead to a more affective learning. Moreover, students and teachers receive feedback based on the practise test results. (Adesope et al. 2017; Yang et al. 2019).

Admission procedure plays a key role in tertiary education as it reveals the level of applicants' obtained knowledge as well as topics that can be considered as troublesome for them (Zwick, 2007). Based on the analysis of the results in the admission procedure, university teachers can adjust the content of their classes and help students to deal with misconceptions as well as missing pieces of knowledge in the context of the given field – for example chemistry. These adjustments are crucial in natural sciences as there is a higher portion of students who do not finish their studies and even change the field of study (Pikálková et al., 2014). This research focuses on chemistry which offers a range of study programmes as Biochemistry, Environmental Chemistry, Chemistry Oriented at Education to name, but just a few examples. All of them are offered at the Faculty of Science, Charles University where the research was held.

At first, an item analysis of each chemistry test used in the admission procedure was used for obtaining feedback regarding the level of applicants' chemistry knowledge, specifically inorganic chemistry as it contains topics which are taught in the first year of high schools/universities. The results of the analysis show tasks and topics which are either troublesome for the applicants or the items that do not select potentially good applicants from the others - items with low discrimination index which are not suitable for the purposes of the admission procedure. Based on the results, the list of recommendations for adjustments of the tasks in inorganic chemistry is presented in the paper for improving the selection of the applicants in the admission procedure.

THEORETICAL BACKGROUND

Knowledge test as a form of admission procedure

Knowledge tests is just one example of the admission procedure organization. As Žoudlík says (2009, p. 6), the most prevalent organization forms are: i) scholastic aptitude test; ii) knowledge test, eventually special talent exam and iii) interview. Furthermore, the admission procedure can also consist of more parts – a combination of exams listed above or the admission procedure can also be done without knowledge tests – for example, based on average high school marks. Each organization form poses advantages as well as disadvantages regarding prediction validity, finances and administration and organisation work (Žoudlík, 2009, p. 6 – 7). However, Bartáková et al. say (2018, p. 67) that high predictive validity of admission procedures should be required as a higher result is supposed to indicate a higher probability of academic success of the individual (Brown; 2003). However, there are many studies focusing on predictors of academic success – for example Berger (2012), Rubešová (2009) and Škaloudová (2003) to name examples. The studies conclude that the average of high school marks as well as knowledge tests are valid predictors of academic success. Moreover, Rubešová says (2009, p. 98) that 64% of the variability of academic success (average university mark) can be explained by obtained data from two knowledge tests (mathematics and geography) and the high school marks average. The knowledge test plays a significant role as using just a single predictor (high school marks average) explains only 47% of the given variability (Rubešová, 2009, p. 97 – 98).

Since the academic year 2017/2018, the admission procedure at the Faculty of Science consists of a knowledge test the content of which depends on the combination of applicants' fields of study. The knowledge test focuses only on one field (Chemistry, Biology, Mathematics) based on applicants' preferences. Our research follows the work of Martincová (2001), Jedličková (2007), Štefanová (2007) and Belháčová (2009) who analysed chemistry tests at Charles University, and therefore have similar background as our research. The conclusions of the research presented in this paper are compared with results of these studies as well as other foreign studies although none of them covers all topics presented in this paper.

Analysis of knowledge test in inorganic chemistry – results of previous studies

There have been several studies focusing on the analysis of knowledge tests in chemistry – Belháčová (2009), Jedličková (2007), Martincová (2001) and Štefanová (2007). All studies used item analysis as a tool for the interpretation of obtained results. However, none of these studies covers all topics in inorganic chemistry. There have also been foreign studies – Herridge (2016), Howe (1971) and others. Their conclusions in the field of inorganic chemistry are following. The success rate in tasks focusing on inorganic nomenclature depended on the specific tasks as the success rate varies greatly (Martincová, 2001) which complies with Herridge's findings (Herridge, 2016). However, Adesoji and Babatunde (2008) together with Howe (1971) point out that a part of students face problems when they are asked to solve tasks within this topic. Tasks containing a description of a chemical reaction show a low success rate (Martincová, 2001). Tilahun and Tirfu (2016) also mention students' lack of experience from laboratory sessions to decrease success rate in specific chemistry tasks. Comparing properties of elements based on trends in the periodic table is a topic with a low success rate (Štefanová, 2007) and also low item discrimination (Jedličková, 2007). Moreover, this topic has also been reported by Herridge (2016) and Rayisyan (2020) as troublesome for students. Tasks focusing on ideal gas law application in inorganic chemistry are troublesome for students (Herridge, 2016; Šrámek & Teplá, 2021). Tan (2002) also mentions reactions of complex salts, thermal decomposition tasks focusing on the solubility of inorganic compounds as troublesome for students. Nevertheless, Šrámek et al. (2021) mention thermal decomposition as a topic with a low item discrimination. As some of the presented results contraindicate one another and also the level of students' knowledge and skills vary in place and time, we can see great potential in investigating the qualities of tasks in inorganic chemistry.

Goals and methods

The main goal of this research was to find the most troublesome topics in inorganic chemistry as well as items with low item discrimination leading not only to an improvement in the admission procedure at the Faculty of Science, but also to adjustments of subject content in the study programme - Chemistry. Based on obtained data and conclusions of previous research, the following research questions were settled: Which topics in inorganic chemistry are troublesome for university applicants at the Faculty of Science? Which tasks in inorganic chemistry have low discrimination index?

METHODOLOGY

The research sample consists of 1 780 applicants in the study programme Chemistry. The research tool consists of 8 tests containing 240 tasks (30 tasks per test) between 7 and 9 of which focused on inorganic chemistry. Each test was taken by 223 applicants on average. All tests contained only multiple-choice questions with one correct answer out of four. Based on the analysis, firstly, we obtained the item success rate stating the percentage of applicants who succeeded in the task (Chráska, 1999, p. 47). Secondly, we obtained discrimination indexes, specifically ULI(1/2) and RIR coefficients, which provide us with information on how well the item selects suitable candidates from the others. Thirdly, a distractor analysis of each item was performed. Lastly, the content analysis of each item was made and compared with most common chemistry textbooks according to Huvarová (2010) as the contest of high school textbooks is essential for candidates' preparation for the admission procedure as the test should follow the subject matter which is taught (American Educational Research Association, 2014) as well as current curriculum (Driessen et al. 2007).

The construct validity of knowledge test is approved by an expert panel which consists of 3 authors of tasks and 1 or 2 employees of the Department of Teaching and Didactics of Chemistry which is an acceptable approach according to Taherdoost (2016).

Items with low success rate

To answer the first research question, item analysis of each knowledge test was done separately. As Chráska says (1999, p. 47) the item is considered troublesome when the success rate decreases under 20%. However, as the standards of discrimination index differ between items with a success rate between 30% and 70% and the others, we decided to mark all tasks with a success rate below 30% as troublesome since there is a 25% chance of guessing the correct answer in the item. According to Berk (2002), students often benefit common errors in test constructions allowing them to guess the correct answer more easily and thus the likelihood of "being lucky" can exceed 25%. Each of the marked tasks was compared to other tasks within the topic. If the average success rate within the topic is below

30%, it is referred to as a **troublesome topic.** If the average success rate within the topic is at least 30%, it is referred to as a **potentially-troublesome topic**. The topics which did not contain any marked question are considered to be suitable ones and thus can be considered as acceptable according to Šrámek (2021).

Items with low item dicrimination

To answer the second research question, the item discrimination was calculated for each task indicating whether the tasks distinguishes overall successful and unsuccessful applicants. Bílek and Jeřábek say (2010, p. 55) that suitable tasks fulfil one of the following conditions: i) the success rate is either between 20% and 30% or between 70% and 80% and ULI(1/2) reaches at least 0.15; ii) the success rate is between 20 and 80% and ULI(1/2) reaches at least 0.25. However, the discrimination index can be also evaluated based on RIR coefficient. The value of RIR coefficient is acceptable tasks exceeds 0.15, in suitable tasks even 0.25 (Varma, 2021, p. 7). In this research, only tasks with both discrimination indexes below the defined criteria are marked as items with low discrimination.

RESULTS AND DISCUSSION

Firstly, the research focuses on troublesome topics of inorganic chemistry and secondly on the tasks with low item discrimination. We found only one potentially-troublesome topic in inorganic chemistry – reaction of acids with metals. Secondly, the research aims at tasks with low discrimination indexes.

Potentially-troublesome topics

The topics of reaction of acids with metals covered 6 tasks. However, the success rate below 30% was observed only for one task. The task focuses on ideal gas law application as well as the reaction of sulphuric acid with iron. The success rate of this task was 25% and we suppose that the incorporation of ideal gas law application played a crucial role in this task as a similar item (not requiring ideal gas law) showed a success rate of 65%. We suppose that the calculation of the volume of obtained hydrogen at standard temperature and pressure might lead to an increase in the success rate in the troublesome task as ideals gas law is not included in “commonly used high school chemistry textbooks“ (Huvarová, 2010, p. 26). On the other hand, both of the mentioned tasks showed acceptable discrimination indexes between 0.18 and 0.36. The success rate in the last four tasks varied, specifically the tasks focusing on the reaction of sulphuric acid with metals showed a higher success rate (55% on average) than tasks focusing on the reaction of nitric acid (32% on average), albeit similar discrimination indexes (0.19 – 0.39). Martincová says (2001, p. 89) that the success rate depends on the choice of specific metal or acid. However, all analysed items can be considered acceptable or very suitable for the purposes of the admission procedure.

Topics with low discrimination indexes

The data analysis revealed four topics (preparation and manufacture of compounds, observation of chemical reaction, reaction of alkali metals with hydrogen/water, trends in the periodic table of elements) containing tasks with low discrimination indexes and their detailed analysis regarding discrimination indexes follows below.

The topic of preparation and manufacture of compounds includes four tasks. The first task focuses on the manufacturing process of sulphuric acid. As the formula of this compound is well-known, the success rate reached 87% leading to the limitation of item discrimination. The second item aims at the reaction of manganese dioxide with hydrochloric acid and the applicants are asked to answer which gas is produced in this reaction. The success rate of this item is 52%, the lowest one within this topic. We suppose that part of the applicant supposed that reaction of manganese dioxide with hydrochloric acid leads to the production of manganese(II) chloride, oxygen and water. Surprisingly, this answer was chosen predominantly by students who reached the overall test score above the average which lower the item discrimination indexes. Despite this drop, both discrimination indexes in these tasks reached sufficient levels (0.18 – 0.22). The other two tasks belonging to this topic focused on nitrate acid production and sodium sulphate preparation. Both of these tasks showed a suitable success rate (66%, 73%) and discrimination indexes (0.18 – 0.24).

The second topic focuses on the observation of chemical reactions described in a short text. There were 4 tasks belonging to this topic and the success rate varied from 35% to 65%. Based on the frequency of chosen alternatives in each task, we suppose that two out of four answers are easily crossed out and then part of the applicants guess the correct one which leads to a decrease in discrimination indexes. Moreover, the drop in discrimination indexes can be partly caused by the necessity of text analysis, not mainly chemistry as it is in other types of tasks. In this topic, there was only one item with suitable item discrimination (0.25 – 0.32). The task focuses on the reaction of a cupric compound with sodium iodide and the reaction of iodide with starch. Moreover, Belháčová says (2009; p. 24) that tasks focusing on using the knowledge of chemistry in practice show low success rate which is in compliance with conclusions of Martincová (2001, p. 94), but contradictory to our findings. Despite the variety of conclusions of the studies, we do not recommend similar tasks in the admission procedure as the studies consider this topic to be either troublesome or unsuitable.

The third topic consists of the reactions of alkali metals (with water or hydrogen) as there were only two items in this topic. As the success rate of the task focusing on the reaction of alkali metals with water reaches high levels – 87%, it leads to low item discrimination (0.13 – 0.22). On the other hand, the success rate of the item aiming at the reaction of alkali metals with hydrogen is lower (76%), albeit the discrimination indexes of the item are very high (0.41 – 0.52). Summing up the data, the reaction of alkali metals and water reach too high success rate which makes it unsuitable for the purposes of the admission procedure which is not the case of the reaction of hydrogen with alkali metals.

The fourth topic focuses on trends in the periodic table of elements. There were fifteen tasks aiming at a comparison of particles size, atomic mass, electron configuration, stability of compounds, electronegativity and also the position in the periodic table. Each task combines the knowledge of the properties listed above. The success rate of twelve out of fifteen questions varied between 60% and 80% and the item discrimination indexes were between 0.15 and 0.41, acceptable qualities of all items. The last three questions belonging to this topic showed a success rate between 33% and 47%. The task focusing on the properties of hydrofluoric acid reaches the lowest success rate as well as the lowest discrimination indexes (both of which are below the required levels). Based on the analysis of the frequency of the answers, we suppose the answer "Hydrofluoric acid is a strong acid." affects the attributes of the item as this false statement was chosen predominantly by students who reached the overall test score above the average which lower the item discrimination indexes. We suppose some of them might have been confused by the comparison of hydrochloric acid and hydrofluoric acid it was done in one of the alternatives in the task. Furthermore, we assume that the lower success rate in the other two tasks (44%, 47%) was caused by troublesome alternatives –"All halogens have the highest oxidation number of VII." and "All transition metals have the electron configuration of $ns^2(n\text{-}1)d^{1\text{-}10}$." Martincová says (2001, p. 102) that usage of words as "all, most of, none of … " is not recommended in tasks as it leads to applicants' confusion and misunderstanding. Furthermore, Martincová states that the success rate of the item strongly depends on the specific task which is in compliance with our findings. However, Štefanová (2007, p. 70), Herridge (2016, p. 31) and Rayisyan (2020, p. 939) say that these tasks show a low success rate which was not confirmed in our research. All in all, we can recommend most of the analysed tasks as suitable for the purposes of the admission procedure despite having found three items with problematic alternatives.

Lastly, there were other five topics in inorganic chemistry in which all items reached acceptable or suitable success rates as well as discrimination indexes. The topics are dissolution of substances in water, transition metals, oxidation numbers, the solubility of sulphur and the preparation of ethyne. Martincová says (2001, p. 96) that the topics of oxidation numbers and dissolution of substances in water depend on the specific task.

As the goal of this research was the analysis of knowledge tests in Chemistry used at the Faculty of Science, Charles University, the conclusions cannot be applied to other groups of high school students. Unfortunately, the comparison of our findings with previous studies is limited since none of the studies mentioned in the theoretical part covered all topics presented in this work. This paper is a part of a study focusing on item analysis of knowledge tests in Chemistry as one of the valid predictors of academic success and it is followed by publications focusing on other fields of chemistry (general, organic and biochemistry) as well as adjustment of subject content in Chemistry study programme at our faculty.

CONCLUSION

This study presents the analysis of chemistry tests, specifically inorganic chemistry tasks, used in the admission procedure between 2016 and 2019 at the Faculty of Science, Charles University. The analysis leads to the following recommendations. Tasks focusing on the reaction of metals and acids should not involve the application of ideal gas law as it is not paid attention to in high school chemistry books. Tasks aiming at the preparation and manufacture of compounds are not suitable if the formula of the product is well-known and therefore applicants can cross out the alternatives containing incorrect formulae. Tasks focusing on the reaction of alkali metals with water reach too high a success rate leading to very limited item discrimination, and therefore we do not recommend such tasks in tests. However, we recommend reactions of different alkali metals with hydrogen as the discrimination indexes reached high values. Tasks aiming at the observation of chemical reaction is not recommended as the discrimination indexes of most of the analysed items are low.

Additionally, the article presents suitable topics for the admission procedure such as dissolution of substances in water, transition metals, oxidation numbers, the solubility of sulphur and the preparation of ethyne. Moreover, the text points out troublesome tasks and offers suggestions of their adjustments so that the parameters of the tasks were more suitable for the admission procedure. Furthermore, this article provides feedback on high school students' obtained knowledge in inorganic chemistry. Additionally, university teachers can make changes in their lesson plans to focus on the troublesome parts of inorganic chemistry based on the outcomes of this research. However, as the paper presents the results of a case study, the findings cannot be generalized, therefore another research has to be performed to verify the statements for a different sample of applicants.

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The role of the interactive animations in Science education and their impact on the students' motivation and knowledge

David Šarboch, Milada Teplá

Abstract

The article summarizes the results of research dealing with the influence of interdisciplinary interactive animations on the academic achievements and intrinsic motivation of students in the teaching of chemistry and biology. The main goal was to find out whether the use of the dynamic visualization tools (concretely interactive animations) leads to better results and higher motivation of students who work with them (experimental group) in comparison with students using static educational tools only (control group). Two types of questionnaires (MSLQ and IMI) and knowledge tests were used in the survey. The collected data were statistically processed and subsequently evaluated. The results manifested that students working with animations showed significantly higher motivation in the subject matter and achieved statistically better results.

Key words

Science education; interactive animations; intrinsic motivation

INTRODUCTION

Students' motivation has been a very strongly discussed topic recently (Ikwuka et al., 2017). Today, many professionals report the necessary transition from traditional frontal education to a more attractive form for students and, as a result, for teachers as well (Čapek, 2015; Nodzyńska, 2012; Szarka et al., 2016). This transition is in great demand, especially in the natural sciences. According to many authors, it is possible to reverse this perception by using visualization tools that will simulate or at least animate complex phenomena (e. g. Barak & Ashkar, 2011; Nodzyńska, 2012; Schönborn & Anderson, 2006). One of the visualization tools that can be used for this purpose is educational animation.

This study deals with the use of educational interactive animations in chemistry and biology at lower and upper secondary schools in the Czech Republic. These animations were created by the authors of the paper or their students studying at the Department of Teaching and Didactics of Chemistry, Faculty of Science, Charles University. The animations introduced the topics of photosynthesis, cellular metabolism and digestion in the human body (Šarboch, 2018; Teplá & Klímová, 2014).

ANIMATION

Animations can be classified as dynamic visualization tools, which can include simulations and videos (Ainsworth & Labeke, 2004,). The animations used in this study are a type of 2D animation. When such a tool is created for use in teaching of any type and level, we are talking about educational animation.

It has been widely accepted that animation leads to more efficient teaching (e. g. Löwe, 2003; McElhaney et al., 2015; Zare, 2002). Animations have the potential to illuminate concepts that are otherwise very abstract and difficult to understand. This is also confirmed by the authors Barak & Ashkar (2011), who argue that animations are applied to support the transition from abstract to concrete thinking. In this way, they help to develop the student's comprehensive understanding a enhance its motivation. In an educational context, animation is particularly effective when it visualizes processes that cannot be observed or are difficult to explain (Ikwuka et al., 2017). Understanding such complex, abstract concepts results in better memorization, thus better academic achievement, and animation can also prevent misconceptions or possible preconceptions to the right level (Zare, 2002).

A meta-analysis by Berney and Bétrancourt (2016), which analyzed 140 pair-wise comparisons in 61 studies (a total of 7036 respondents) dealing with the comparison of the effects of static (images, texts, …) and dynamic models (animations) in teaching, pointed to a long-lasting discrepancy between different research outcomes. Of the 140 studies, 43 (30.7%) pointed to more positive effects of the use of animations compared to static models, while according to the results of 14 studies (10%) static objects are more effective than dynamic ones. A large number of surveys (a total of 83, i.e. 59.3%) did not find any significant difference between teaching using static and dynamic models. The authors' conclusions therefore speak of a positive effect of animations in comparison with static models. This statement is supported by the average value of Hedges *g*, equal to 0.23, that points out to the substantive significance of the conclusions. A similar result was achieved by the authors Kaushal and Panda (2019) dealing with the impact of dynamic visualizations on pupils with different degrees of spatial imagination. In their meta-analysis, they analyzed data from a total of 22 studies. The results of this analysis show that the use of dynamic animations compared to static visualizations has a positive impact on academic achievement for both students with higher spatial imagination ($g = 0.34$) and students with lower spatial imagination ($g = 0.58$). As a result, animations reduce cognitive overload of students.

Also other authors argue that animation can lead to increased motivation, increased academic achievement, reduced learning time, gaining student attention, and support for cognitive processes (Barak & Ashkar, 2011; Ikwuka et al., 2017; Rieber, 1991; Rosen, 2009; Stith, 2004; Szarka et al., 2016).

Among the negatives of educational animations we can include, for example, the transience of the presented information. Thus, animation does not offer permanent, but only temporary information. From this it is evident that the given information can remain in the working memory of the students for only a few seconds and subsequently other information can be displaced (Bétrancourt & Tversky, 2000). Another negative factor may be the so-called "split attention effect", or "fragmented attention effect", which in many animations may be caused by their excessive complexity. Some objects may move at the same time, and students are then forced to divide their attention, which can lead to imperfect capture of the required information (Lowe, 1999).

THE AIM OF THE STUDY

It is evident that the results of already published studies are not uniform and therefore further research and search for variables that affect the effectiveness of animations is needed (students' motivation, the role of teacher in educational process, students' academic achievements, gender, etc.) (Höffler & Leutner, 2007). The main goal of the study described here is to find out what effect the use of educational animation has on the motivation and academic achievements of students of the educational level corresponding to the lower and upper secondary schools.

In view of the above objectives, two research questions have been identified:

1. What effect does the inclusion of educational animations have on the student's intrinsic motivation?
2. What effect does the inclusion of educational animations have on the student's academic achievements?

THE METHODS AND STUDY DESIGN

In this study, quantitative oriented pedagogical research was chosen as the basic research method. Two types of research tools were used in the research carried out in this work - a knowledge test (in the form of pretests and posttests) and standardized motivation oriented Pre- and Post-Questionnaires. The research was anonymous.

Research sample

The study was carried at four Czech high schools in 2019-2020 in lessons of Biology and Chemistry. There were 149 students (5 classes) participating in this experiment (3rd grade of lower secondary school and 1st, 2nd and 4th grade of upper secondary school). Each class was divided in two groups – an experimental group (EG) and a control group (CG). Students in the CG were taught without the support of animations - the way students were used to, whereas the students in the EG were taught with the support of animations. Both groups of students were taught by the same teacher.

Research tools

In order to measure the influence on students' motivation, there were two of standardised questionnaires used in this study – before (Pre-Questionnaire) and after (Post-Questionnaire) the experiment. The **Pre-Questionnaire** was created by selecting sixteen statements from MSLQ (Motivated Strategies for Learning Questionnaire) (Pintrich et al., 1991) in a way that each of the selected statement belong to one of these scales: *intrinsic goal motivation*, *extrinsic goal motivation*, *self-efficacy for learning and performance* and *control beliefs*. This Pre-Questionnaire was used in the CG as well as in the EG at the beginning of the first lesson (before the incorporation of animations in lessons in the EG) to determine the general motivation strategies of students (Tab. 1).

Tab. 1 The time schedule for the use of individual tools during the research

Time span	Control group	Experimental group
1. lesson	*Teaching with static and dynamic visualization tools* At the beginning of the lesson, students completed the pretest	
2. lesson	*Teaching with static and dynamic visualization tools* At the beginning of the lesson, students completed the PreQuestionnaire	
3. lesson	*Teaching with static and dynamic visualization tools* At the end of the lesson, students completed the Post-Questionnaire B	
4. lesson (the beginning of the taught topic)	*Teaching with static visualization tools*	*Teaching with dynamic visualization tools*
Lessons needed to presenting the topic	At the end of the lesson(s), students completed the Post-Questionnaire B	At the end of the lesson(s), students completed the Post-Questionnaire A
Final lesson	At the beginning of the lesson, students completed the posttest	At the beginning of the lesson, students completed the posttest

The **Post-Questionnaire** was created by selecting twenty-five statements from IMI (Intrinsic Motivation Inventory) (McAuley et al., 1989; Ryan, 1982) in a way that each of the statements belongs to one of these scales: *interest/ enjoyment, effort/ importance, perceived competence* and *value/ usefulness*. All of these scales belong to the area of students' intrinsic motivation. The Post-Questionnaire was created in 2 modifications – one focusing on using the animations in education process - **Post-Questionnaire A** - and one focusing on traditional teaching methods (mainly static visualization tools) in education process - **Post-Questionnaire B**. The Post-Questionnaire B was completed twice: (i) after the first lesson held without any dynamic visualization tools in both groups (the EG and CG); (ii) after the second lesson held without any dynamic visualization tools only in CG. Then the Post-Questionnaire A was completed at the end of the second lesson only in the EG (after the lessons supported by educational animations). In all of these questionnaires, the 7-point scale was used so that students could show their level of agreement with each of the statements in the questionnaires (from "absolutely agree" to "absolutely disagree") (Pintrich et al., 1991; Ryan, 1982). The two Post-Questionnaires A (EG) and B (CG) were compared and assessed during the statistical processing. Both of the above research tools have been widely used in the past to determine the level of intrinsic motivation in science subjects (Kuncová & Rusek, 2019; Šmejkal et al., 2016; Tóthová et al., 2019; Vojíř et al., 2019).

In order to measure the level of students' academic achievements in the study, a test of knowledge was used twice – before the experiment (**pretest**) and after the experiment (**posttest**). There were from 6 to 8 tasks in these tests (according to the topic), all of the questions focused on the topic of the lesson. The tests contained open questions as well as cloze ones. Before the tests were given to students, they had been approved by an expert panel formed of 4 Biology-Chemistry didactics and teachers. The reliability of these tests measured by Cronbach's alpha was 0.68 in average.

During the work in experimental groups, one of the three interdisciplinary interactive animations describing photosynthesis, digestion in the human body or cellular metabolism was used. All of these animations were created in Adobe Flash CS6 animation software (and its later version). The research was preceded by a pilot survey, which was conducted in 2018 at a secondary school with 30 students participating (Šarboch et al., 2020). The time schedule of the tools use is summarized in Tab. 1.

Data processing

This chapter summarises the data processing of the study. The obtained data were statistically analysed by IBM SPSS Statistics 25 with the support of appropriate methods of statistics. Significance was assessed using non-parametric tests, setting the significance level at α = 0.05. Non-parametric tests (Mann-Whitney U test and Wilcoxon signed-rank test) were used because the data did not conclusively show a normal distribution. The effect size was calculated based on Cohen's *d*.

First, the reliability of the results for each scale was calculated for all entered questionnaires. Reliability was assessed using the Cronbach's alpha coefficient. The calculated reliability values for all types of questionnaires used (Pre-Questionnaire, α = 0.951; Post-Questionnaire A, α = 0.901; Post-Questionnaire B, α = 0.890) were at the required level, as the value of the coefficient exceeded the generally accepted minimum of 0.70 (Nunnally, 1978). The obtained data are therefore internally consistent and can be considered reliable.

Before finding the answer to the first research question, it was important to find out the initial state of CG and EG in relation to the perception of students' general motivation strategies (to eliminate the fact that such as EG would be more motivated before the animations are employed). For these purposes, data from both Pre-Questionnaires (in relation to the student's general motivational strategies used) and the Post-Questionnaires B entered in both groups after the first lesson (in relation to the student's intrinsic motivation) were compared between the control and experimental groups. We chose the Mann-Whitney U test as a suitable statistical method for both comparisons. Then, the same instrument (Mann-Whitney U test) was applied for compare the results of Post-Questionnaire B and Post-Questionnaire A.

In order to answer the second research question, we compared the results of the knowledge pretests and posttests. First, we used the pretest to find out the initial state of the monitored students in relation to their knowledge in the field of the topic, before starting the research survey. Then to determine the possible differences between CG and EG concerning pretests, the non-parametric Mann-Whitney U Test was used. Due to its results (the groups were balanced at the beginning of the research), a non-parametric Wilcoxon signed-rank test was applied to determine the shifts between the test and posttest results for CG and EG separately. In order to compare the results of posttests between CG and EG students, the Mann-Whitney U test was used again.

THE RESULTS OF THE STUDY

The influence of educational animations on students' motivation

According to the results of Mann-Whitney U test, there was no statistically significant difference between students of CG and EG at the beginning of the study (*p* value was greater than 0.05 for all scales). Given that the two groups were initially comparable, we were able to find an answer to the first research question. We compared the measured results from Post-Questionnaire B entered in CG (topic taught static visualization tools) and from Post-Questionnaire A entered in EG (identical topic taught with the support of educational animations). The results showed that the use of educational animations in science teaching has a great positive effect on the three components of students' intrinsic motivation (interest / enjoyment: $p = 0.001$; $d = 0.644$; perceived competence: $p = 0.001$; $d = 0.639$; value / usefulness: $p < 0.001$; $d = 0.715$;) and a low, not significant, albeit positive influence on effort / importance ($p = 0.102$; $d = 0.304$). In short, after the first experimental lesson the students' motivation significantly differed between the control and experimental lessons, with a large weighted mean effect size (d = 0.58).

The influence of educational animations on students' knowledge

According to the non-parametric Mann Whitney U test, no statistically significant difference in the results of the knowledge pretest was found between CG and EG students at the beginning of the survey (p = 0.39; d = 0.086). The results of the non-parametric Wilcoxon signed-rank test show that there was a significant difference between the two groups (CG: $p < 0.001$; d = 1.29; EG: $p < 0.001$; d = 1.45) concerning posttests. However, the comparison of the effect sizes showed that the improvement was more pronounced for EG students, whose teaching was supported by the use of educational animations. Comparing the results of posttests between CG and EG by the Mann-Whitney U test showed that the students of the experimental group achieved significantly better study results than the students of the control group (p = 0.032; d = 0.41).

CONCLUSION AND DISCUSSION

Through a pedagogical experiment, it was found that the use of educational animations in the teaching of science subjects (chemistry and biology) has a positive effect on the intrinsic motivation of students with a large weighted mean effect size d = 0.58. This manifested itself primarily in the expression of interest, perceived competence and also in the perception of the importance of the subject matter. This is probably related to the fact that appropriately used animations in teaching reduce the cognitive burden of the curriculum and the degree of abstraction (Berney & Bétrancourt, 2016; Chandler & Sweller, 1991). As a result, it leads to the maintenance or even growth of students' interest in the topic and the willingness to put more effort to better understand the curriculum. Furthermore, it was found that educational animations and their use in teaching has a positive effect on the student's academic achievements (d = 0.41).

Compared to the previous researches, the positive effect of using animations is higher than the results of meta-analyzes performed by Berney and Bétrancourt (2016) with a material value of 0.23 (Hedges *g*), but also higher than the results of meta-analyzes performed by Höffler and Leutner (2007) with a material value of 0.37 (Cohen's *d*). The above differences may be the result of the heterogeneity of the individual studies included in the meta-analyzes (e.g. Höffler and Leutner also included video-based studies in their work). According to the results of both Post-Questionnaires, students in EG were significantly more motivated than those from CG. This could seem evident as there appears a novelty effect of animations in EG that lights up the students' motivation.

In order to find out whether the animations really have a positive effect on students' motivation over a longer period of time, a longitudinal study would be needed.

Due to the positive results of this study, its authors recommend the use of educational animations in chemistry and biology classes. However, the frequency of their use, as well as the best methods of working with them, need to be further investigated.

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To integrate or not to integrate, that is the question: A Delphi study on teachers' opinions about integrated science education

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Abstract

The integrated conception of science disciplines' teaching under the name Science has been seen as one of the solutions how to motivate students towards learning science as well as how to contextualize subject matter of the particular sub-disciplines. However, there is a limited evidence about both teachers' willingness to change their approach as well as their preparedness to teach an integrated subject. In this study, Delphi method was used on a sample of 15 teachers from various school in order to gain their opinion about strengths, weaknesses, opportunities or threats of teaching integrated Science. The results then represent a first foot-hold for further discussions in this respect.

Key words

Integrated science teaching; science education; delphi study

INTRODUCTION

Over the last 30 years, researchers have been reporting neutral to negative attitudes towards science or its particular sub-disciplines. This phenomenon is seen in Czechia (Bílek, 2008; Janoušková et al., 2014; Švandová & Kubiatko, 2012) but also abroad (Jarvis & Pell, 2002; Salta & Tzougraki, 2004; Sjøberg & Schreiner, 2005). This is also reflected in students' results of the PISA (Programme of International Student Assessment) tests (OECD, 2016, 2019). In these tests focused on scientific literacy, Czech students' score has been decreasing steadily since 2006 (Blažek & Příhodová, 2016; Palečková, 2007) which, together with the attitudes, shows a negative trend which needs to be dealt with.

Moreover, a lower effect of science subjects education has been found by the Czech school inspectorate (ČŠI, 2017) or in other studies (Medková, 2013; Rusek et al., 2019; Rusek & Tóthová, 2021). Majority of studies in this area in unison suggest a remedy in the student-centred, constructivist approach and also in accordance with Stuckey et al. (2013) stress the need to present students with a relevant and meaningful content.

In this respect, integrating particular science disciplines offers connection of topics which are then shown in a more meaningful way. In addition, this enables teachers to employ more effective teaching strategies (Straková, 2002; Yager & Lutz, 1994). Integrated science teaching is therefore a widely focused topic (Åström, 2008; Bílek et al., 2008; Hejnová, 2011; Kim & Bolger, 2017). A comprehensive review by Linn et al. (2016) showed international tendencies, which are being strengthened worldwide within the integrated STEM (Science technology, engineering and mathematics) movements.

For integration to have any effect soon, first of all, teachers need to be motivated to make a change. However, there is a strong tradition in training teachers in two majors only. This either means combining teachers or revisiting the system of their education. One way or another, teachers' willingness to make a change is crucial.

For this purpose, qualitative information were needed. To get more relevant information, a larger group of participants was needed. Group interviews offer such an option, however, stronger participants overshadow less-assertive or more quite ones (Green, 2014). For this reason, the Delphi method which already used in several science education research seemed ideal. Since it has found use in science education research already (e.g. Osborne et al., 2003; Rundgren & Rundgren, 2017), it was used for this research too.

RESEARCH GOAL AND METHODOLOGY

The goal of this research was *to map possibilities of integrated science implementation in schools*. For this purpose, a three-round Delphi study was conducted among lower and upper-secondary school teachers of scientific discipline.

The study followed a traditional Delphi conception and was divided into three rounds (see Tab. 1).

Table 2 Delphi phases overview

STEP	NUMBER OF RESPONDENTS	TOPIC	VIA
PARTICIPANTS' SELECTION		Reason to teach Science integrated	Facebook group
FIRST ROUND	15	SWOT for integrated Science	E-mail
SECOND ROUND	11	Comments to the analysis before	Google form
THIRD ROUND	11	Comments to the improved statements	Google form

Participants' selection

This study participants were recruited from a Facebook group *Teachers of scientific subjects*. Researchers first asked a general question about the reason to teach Science instead of separate subjects. They responded to every comments with an attempt to get as many ideas from both points of view as possible. Based on these comments, 15 participants were chosen for the study. They were explained the goal of the study and were asked for their consent to be addressed in the first round. The following factors were taken into account: strong opinion, evidence-based argumentation, various opinions sides, level of education. The sample consisted of five teachers from lower-secondary, seven grammar school, one vocational school and two leisure time facility science instructors.

Research design and data treatment

The study was conducted in three rounds. An email was used for the first round in which the participants were asked to describe an ideal conception of science teaching and perform a SWOT analysis of integrated Science teaching.

All three authors together analysed the first two responses and created the main codes. The rest (the open description as well as the arguments in the SWOT analysis) were coded by one researcher. Randomly selected 10% statements were re-checked by a second researcher who confirmed the coding was correct. The categories were subsequently grouped and used for the second round.

For example, a participant's statement "*a subject where the aim is not to convey to pupils all the knowledge of natural sciences in the last 2000 years, but to let them experience great natural science discoveries, laws and ideas*" saturated the codes: IBSE and selected (integrated) topics. The complete transcript of the comments was published by Kolafová (2021) and for the extent's sake is not presented in this paper.

For the second and third rounds, Google forms were used. First, the participants were presented a list of statements to particular parts of SWOT. Their task was to assign relevance factors 1-5 (5 the highest) to each statement and eventually add a new one. Second, a coherent text as a compilation of the participants' free description was provided for their comments or completions.

By doing so, the overall statement got improved for the third round. Arguments the participants found the most fitting were identified. According to previous Delphi studies (e.g. Osborne et al., 2003), only statements which received a mean score higher than 3.0 were used for the third round. It was performed similarly to the second only with the improved text and filtered and ordered statements.

The participants were, again, free to add more comments or arguments. Evaluation of this round then produced the final results.

RESULTS AND DISCUSSION

1st round

The SWOT analysis results are shown in the separate categories:

Strengths

- Offers an interdisciplinary knowledge, prevents duplicities, prevents duplication of topics.
- Makes teaching more attractive for students and teachers. It motivates and activates them.
- Allows for a wider connection with practice (closer to real scientific activity).
- Offers the opportunity to include more topics or topics more relevant for students.
- Aims to develop higher-order thinking (Bloom) as well as critical thinking.
- Develops the student cooperation.
- Develops teamwork in a team of teachers.
- Has a support in education systems abroad.
- It strengthens the possibilities of implementing inquiry-based or project learning.

Weaknesses

- Lack of teacher readiness to teach all integrated disciplines (teachers are experts in two disciplines).
- Difficulty of inclusion in the school life (schedules of cooperating teachers, other lengths of teaching units, requirements for classrooms).
- Lack of supporting materials (textbooks, manuals).
- Risk of content reduction and lack of thematic breakdown (a way out of classic themes).
- Time consuming for the lesson preparation, thematic plans (revolutionization of the breakdown of traditional structures, demands for the preparation of the thematic plan).
- Unwillingness of school management and teachers to change.
- Resistance from students who prefer the traditional concept of teaching.
- Insufficient resources (problems with the integration of extracurricular activities, in which some students are unable to participate for financial reasons).

Opportunities

- Strengthening the students' interest in individual subjects and self-education.
- Presenting a comprehensive, more realistic, world view.
- Supporting and even provoking teamwork between students, teachers and students and teachers.
- Greater possibilities for developing competences for learning and problem solving
- Modernization of education.
- Possibility of involving practitioners.
- Possibility to find inspiration not only abroad, but also in some Czech schools where this system already works.

Threats

- Misunderstanding on the part of parents and the public (criticism of conservative-minded people).
- Refusal by teachers during the general introduction.
- Financial costs (experimentation aids, laboratory kits, etc.).
- Insufficient support from the Ministry of Education
- Education system's rigidity (Integrated Science would bring more bureaucracy than positives).

The grouped participants' coded statements are shown in Table 1.

Table 3 The participants' views of ideal Science teaching

Outcome	**Key words**	**Frequency**
IBSE	Inquiry, IBSE, motivation experiments, unknown outcome, inquiry-tasks	6
Project-based education	Project-based education, project	5
Selected (integrated) topics	Overlapping topics, the best from the subjects, the basic subject-matter, carefully selected topics	5
Problem solving	Problem education, science problem solving, problem methods, problem tasks	4
Team education	Two or more teachers' teaching, creative science teachers' team, improper one-teacher education, teamwork	4
Tandem education	Tandem education	3
Inclusion of technology in education	Technologies (IT), computers, digital technology, working with instruments (measuring)	3

2nd round

Eleven respondents added their comments to the original statement about science teaching. The comments aimed to improve the text, but also offered their authors' thoughts about concrete realization of such a conception.

For space reasons, only a sample of the 2nd round's SWOT analysis is presented in tables below. Table 2 shows the Strengths and Table 3 shows the Threats.

Table 4 The most relevant strengths according to the study participants

Order	***Statement***	***Median***	***Mean***
1.	Offers connection of knowledge across the fields (subject-matter), leads to a complex view of the field, prevents topic duplication,	5	4,8
2.	Strengthens the possibilities to realize inquiry-based activities or project-based education.	5	4,4
3.	Enables broader connection to practice. Education is this closer to real scientific practice.	5	4,1
4.-5.	Offers opportunities to include more actual or relevant topics.	4	4,1
4.-5.	Aims at higher-order thinking development and critical thinking.	4	4,1

6.	Develops teamwork in teachers' collective.	4	3,9
7.	Makes education more attractive for both students and teachers.	4	3,7

Table 5 The most relevant threats according to the study participants

Order	***Statement***	***Median***	***Mean***
1.	Teachers' refusal in case of central introduction into the system.	5	4,3
2.	Misunderstanding from parents and wider society (conservative-thinking people's criticism).	4	3,8
3.	Insufficient support by the Ministry.	4	3,6
4.	Educational system rigidity (Science would bring more bureaucracy than positives).	3	3,0
5.	Financial costs (tools, chemicals, laboratory sets, etc.)	3	2,8

3rd round

The final round resulted in the refined list of arguments which are placed in Table 4. As far as the overall description of integrated science education is concerned, the following ideas were the result of teachers' Delphi process:

- Delivers educational content in a broader context
- Provides more scope for activating methods' inclusion
- Allows students to develop competences, understand and acquire all the necessary knowledge to solve assigned tasks/problems
- Through more complex tasks, encourages the use of new technologies, measuring instruments, information retrieval (in Czech and foreign languages)
- Supports the creation of a teacher's team involved in its implementation
- Is suitably implemented in longer blocks composed of the original teaching hours of individual integrated disciplines
- Gives space to perform more time-consuming activities (laboratory work, research tasks, projects, excursions) when teaching in blocks

Despite there is no doubt integrated science offers these options, it seems the teacher mythicize the approach. The omnipresent question „And will they learn something" is valid also for the integrated approach (Vonášek & Rusek, 2013). At least the first five bullets stress features which can be easily employed in an ordinary separate-subject approach too. As an example, integrated thematic education (Šindelková et al., 2016) or basically any units placing students in the centre correspond with these recommendations (cf. Janštová & Rusek, 2015).

Integration of science disciplines remains a controversial topic (cf. Hejnová, 2011) which is also seen in some of the teachers' arguments. When looking at them closer, it is evident that some of the arguments mentioned in Tab 3 (repeatedly assigned relevance by the teachers), are ill-founded. Student motivation together with higher-order thinking development contrast with findings about increased cognitive load (cf. Haslam & Hamilton, 2010; Paterson, 2017) or reported teachers' tendency to break down more complex problems for their students (Son & Kim, 2015).

Also, the argument about teacher team creation or merging lessons into larger blocks is surprising as the contemporary curriculum offers these options already. The findings therefore suggest, it might be reasonable first to implement integrated science units, organise "science days", test tandem or team science teaching first and only then take the next step once the entire curricula are prepared.

CONCLUSION

This study shed more light on a very important agent in the contemporary debate about integrated science teaching – teachers' opinions. The study participants provided arguments in favour of this efforts, but also shared some concerns regarding hurdles which might interfere. Analysis of their written arguments resulted in a list of pros usable in later debates, but also some and cons which need to be considered carefully. However, after a more thorough evaluation, even the enthusiastic teachers selected to the study because of their strong opinion showed it might be too soon to integrate science disciplines. Instead, the authors offer some steps which seem more feasible at the moment.

The findings may be affected by several limitations. First, it is the participants' selection. The voice of those less active and perhaps less enthusiastic to make a change remined unheard. Second, it is the number of participants which does not allow results' generalisation. On the other hand, 15 participants for a three-round qualitative study offered a lot of valuable data. Third, the participants' practice was not observed to describe an idea of their conception in practice. However, the ideas they shared may not have been put into practice yet as it is easier to plan than put the plans into reality.

A follow-up study should consider voices of school management, policy makers and students so the whole picture – at least as long as the "public attunement" to integrated science teaching is concerned.

Table 6 The final top 5 arguments in the SWOT analysis

Strengths		**Weaknesses**	
1.	Offers connection of knowledge across fields (subject matter), leads to a more complex look at problems, limits topic duplicities.	1.	Time demandingness on preparation of: lessons and thematic plans (revolution in the traditional division of structures, demands on thematic plans).
2.	Enables broader connection with practice, thus is closer to real scientific practice.	2.	Insufficient teacher preparedness on integrated science teaching (teachers are experts on two fields).
3.	Strengthens the possibilities to realize inquiry- or project-based education.	3.	School management's reluctancy to change.
4.-5.	Has the potential to motivate students more	4.-5.	It is difficult to include in an ordinary school's schedule
4.-5.	Aims at higher-order and critical thinking development	4.-5.	Lack of supporting materials (textbooks, guidebooks)
Opportunities		**Threats**	
1.	Presentation of a more complex and real view of the world.	1.	Teachers' refusal under complex implementation.
2.	Supporting teamwork among students, teachers and among teachers and students.	2.	Education system's rigidity.
3.	A greater possibility to develop competences for learning and problem solving (opportunities to establish oneself on the labour market).	3.	Parents' lack of understanding (criticism from the conservative thinking)
4.	Teaching modernization (increasing effectivity, shift from traditional teaching)	4.	Insufficient support by the Ministry of Education
5.	Possibility to find inspiration abroad but also in some Czech schools which already use this conception	5.	Bureaucratic burdens when incorporating the integrated subject into the school curriculum

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What essential concepts and applications in nanotechnology should be taught in school science? A Delphi study of the expert community

Sohair Sakhnini

Abstract

Aiming at methodological examination how to integrate nano scale science and technology (NST) into middle and high school science teaching, the current research sought to identify: what (NST) concepts and nanotechnology applications should be taught in middle and high school science, how to teach these concepts and where to integrate them in the Israeli middle and high school science curriculum. Three sequential stages of research were conducted, using different methodologies on each stage. Eight NST essential concepts and five nanotechnology applications intended for middle and high school level, were identified, followed by connections between the NST concepts needed for teaching the selected applications. The results provide three vital dimensions that are important for a research-based development of nanotechnology education. They can also constitute as guidance for constructing comprehensive nanotechnology program and can serve as a tool for analyzing and evaluating existing nanotechnology programs intended for middle and high-school levels.

Key words

Nano-education; delphi study; community of experts; secondary and high-school; nanotechnology essential concepts

INTRODUCTION

The need for Nano-Education

Cutting edge and exciting new areas of science, typically, do not appear in science classrooms and textbooks until many years after their inception. This pattern leaves undergraduate and high school science education lagging scientific advances. As a result, students are rarely afforded the opportunity to learn about the cutting-edge discoveries and the revolutionary applications that make science so exciting (Jurkowski et al., 2007). This was, discovered also for the Czech curriculum in comparison with the Finnish and Turkish (Elmas et al., 2020).

From educational perspectives, Integrating new fields of scientific research into school science (*e.g.*, nanotechnology, brain research, biomedical science studies) and exposing students to modern scientific contents make them perceive science as more relevant and engaging to their life (Blonder

& Sakhnini, 2016). Already Dewey (1902) mentioned that exposing students to new scientific and technological developments is fundamental for their learning progress and change. Exposing students to nanotechnology applications show them and greatly explain how modern science works and how helpful it is in finding solutions to everyday life problems, that couldn't be resolved in other ways (Jones et al., 2013). Consequently, their continuous motivation to study sciences and related subjects increases. In addition, it is of great importance for preparing future citizens that will soon need to achieve a certain level of scientific literacy in order to navigate the science-based issues related to their everyday lives (Laherto, 2010; Blonder & Sakhnini, 2015) and to intelligently question and understand the ethical and societal implications of the revolutionary technologies they are dealing with (Toth & Jackson, 2012).

The idea of integrating nanoscience into middle and high school science curriculum faces many difficulties, and to integrate it in classrooms effectively, teachers must feel confident in their understanding of the content areas that they teach to their students (Blonder, Benny, & Jones, 2014). But content knowledge alone is not sufficient to prepare teachers to provide high-quality instruction (Marshall, 2005). Professional development should integrate content with pedagogy in order to provide teachers a vision to guide the design and implementation of their lessons (Weiss et al., 2003). Jones et al. (2011), claimed that bridging the gap between existing knowledge of school science teachers and the knowledge and pedagogy required to teach nanotechnology should be the heart of professional development programs created for teachers.

Although many educational programs in nanoscale science and technology were developed throughout the world. Many studies and projects have been conducted worldwide, aiming to develop formal and informal nanoscale science and technology educational programs (e.g. Ambrogi et al., 2008; Blonder, 2011; Harmer & Columba, 2010; Parchmann & Komorek, 2008; Stevens et al., 2009; Tirre, 2015; Walters & Bullen, 2008), each program focused on a certain aspect of nanotechnology not necessarily based on a thorough analysis of the field of nanotechnology and what should be taught to school students But, there was a need for systematic approach to establish an adequate basis for developing the educational aspects of NST. There is a need to determine the NST essential concepts that should be taught in order to construct suitable NST educational programs for high school level based on them.

RESEARCH RATIONALE AND LEADING QUESTIONS

To address the above-mentioned needs and the challenges of bringing emerging science areas (e.g., NST - nanoscale science and technology) into the classrooms, except the nature of science itself (Mallya et al., 2012), there is a need for systematic approach to establish an adequate basis for developing the educational aspects of NST. This includes (1) identifying the NST essential concepts that should be taught at high school level for constructing suitable NST educational programs, (2) identifying the insertion points of these concepts within the existing curricula, and (3) understanding the nature of learning environments that best promote coherent and durable understandings. These issues are the basis of the current research.

Aiming to provide answers to the above-mentioned needs when the main goal of the research is to methodologically examine how to take the NST field and integrate it into high school science teaching. The following research questions were formulated:

1. What are the NST essential concepts that are perceived by science teachers and nanoscience researchers as important to be taught at middle and high school science level?
2. What nanotechnology applications are perceived by science teachers and nanoscience researchers as important to be taught at middle and high school science level?
3. What are the differences in how the two different communities of experts (nanoscience researchers and science teachers) perceived the importance of the essential NST concepts and the selected applications?
4. Which of the essential NST concepts are needed for teaching each of the selected application?
5. What are the insertion points for essential NST concepts in existing middle school science and high school chemistry curricula in Israel?
6. How to teach NST essential concepts (three examples: the making of nanotechnology, size and scale, and size dependent properties)?

ORGANIZATION OF THE RESEARCH STAGES

The research was implemented in three sequential stages. Each stage was focused on a different aspect:

Stage 1- was designed to identify the essential NST concepts and nanotechnology applications that should be taught in high school science and to evaluate the differences between teachers and researchers in the way they perceive the importance of these concepts and applications.

Stage 2- was focused on identifying the nature of learning environments that best promote coherent and durable understandings, for three chosen essential NST concepts: *size and scale, size-dependent properties, and the making of nanotechnology*.

Stage 3- aimed at determining the insertion points of the essential NST concepts in existing middle school science and high school chemistry curricula in Israel.

For each of the three research stages, different methodologies were implemented. Therefore, a brief description for each stage will be presented consecutively.

METHODOLOGIES AND FINDINGS

Stage 1-The method chosen for eliciting the expert community's views was a three-stage Delphi study (Murray & Hammons, 1995). It is based on gathering data from respondents within their domain of expertise without face-to-face interactions (Hsu & Sandford, 2007) involving a multiple-iterations process to collect and distill the anonymous judgments of experts, interspersed with feedback, using a series of data collections and statistical analyses (Delbecq et al., 1975). The Delphi methodology is well suited as a research instrument when there is incomplete knowledge about a problem or phenomenon (Custer et al., 1999; Skulmoski et al., 2007; Rusek et al., 2022) and it is useful for consensus-building by using a series of questionnaires. An adopted representation of a typical Delphi process (Skulmoski et al., 2007;) was applied, as presented in Figure 1.

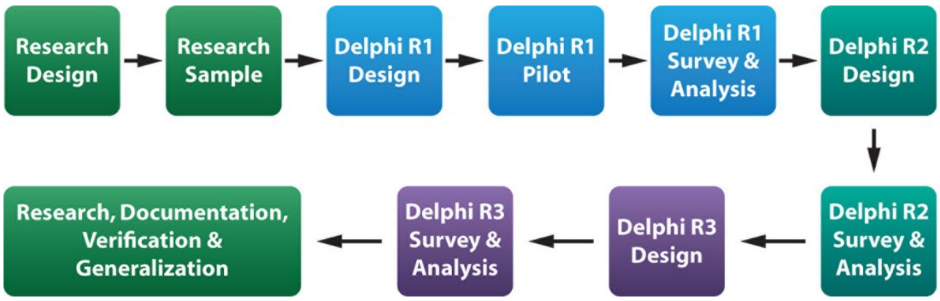

Figure 1: Delphi process, based on Skulmoski et al. (2007)

Research sample

The first-round Delphi questionnaire was sent to 82 participants (n=82), from two groups of experts. Twenty-one researchers who are experts in nanotechnology (n=21) out of 41, and 21 teachers (n=21) out of 41 science teachers that have knowledge in nanotechnology replied to the first-round Delphi questionnaire, as graphically presented in Figure 2.

The aim of choosing these two different groups of participants was to combine those factors that, in our opinion, play a fundamental role in developing the NST education field from different aspects (e.g., research, education).

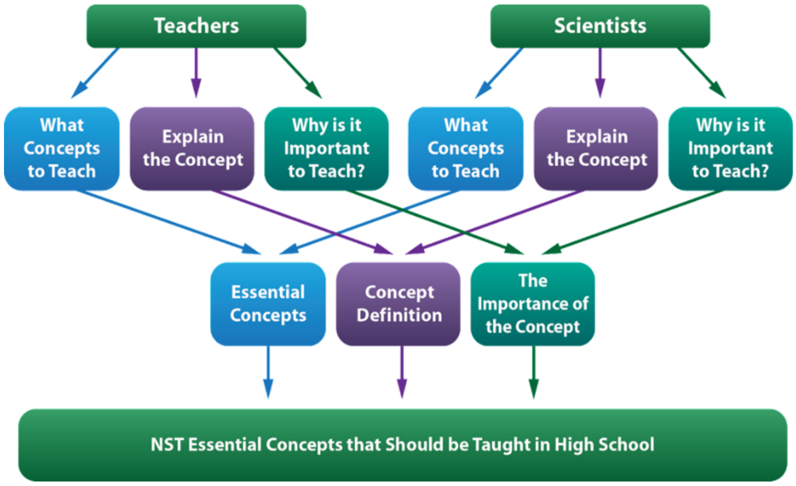

Figure 2: The process for reaching a consensus about the essential concepts in nanotechnology that should be taught in high school

Eight essential concepts in NST and five nanotechnology applications were identified and the connection between them as presented in Tab-1, Tab-2, and Tab-3 respectively.

Tab.1: Delphi results: The Means of the importance of the essential NST concepts and variances between the teachers and researchers

CONCEPTS	TOTAL		TEACHERS		RESEARCHERS		T[1]
	Mean	Variance	Mean	Variance	Mean	Variance	
1. SIZE-DEPENDENT PROPERTIES	4.619	0.583	4.43	0.857	4.81	0.262	-1.65
2. INNOVATION AND APPLICATION OF NANOTECHNOLOGY	4.41	0.393	4.57	0.257	4.24	0.490	1.77
3. SIZE AND SCALE	4.29	0.843	4.48	0.562	4.10	1.09	1.36
4. CHARACTERIZATION METHODS	4.1	0.771	3.91	0.790	4.29	0.714	-1.42
5. FUNCTIONALITY	3.72	1.038	3.62	1.048	3.81	1.062	-0.60
6. CLASSIFICATION OF NANOMATERIALS	3.57	0.983	3.72	0.814	3.43	1.157	0.93
7. FABRICATION APPROACHES OF NANOMATERIALS	3.5	0.695	3.62	0.448	3.38	0.948	0.92
8. THE MAKING OF NANOTECHNOLOGY	2.88	1.327	2.76	1.290	3	1.400	-0.67

The resulting connections indicate that the suggested applications can serve as natural and authentic contexts for teaching the essential concepts of NST, will support students' understanding of the field, and enhance their interest in science (Gilbert, 2006).

Tab.2: Delphi results: The consensus percentage (%) for the essential NST concepts that are needed for teaching each of the top-rated NST applications according to all Delphi participants

ESSENTIAL CONCEPTS / CATEGORIES OF APPLICATIONS	1. NANO-MEDICINE	2. NANO-ELECTRONICS	3. PHOTO-VOLTAIC CELLS	4. NANO-BOTS	5. SELF-CLEANING
SIZE-DEPENDENT PROPERTIES	83.3[1]	81[1]	81[1]	83.3[1]	69[1]
SIZE & SCALE	83.3[1]	95.2[1]	81[1]	57[1]	73.8[1]
FABRICATION APPROACHES OF NANOMATERIALS	45.2	71.4[1]	52.4[1]	21.IV	40.5
CHARACTERIZATION METHODS	78.6[1]	66.7[1]	73.8[1]	59.5[1]	78.6[1]
INNOVATION& APPLICATION OF NANOTECHNOLOGY	71.4[1]	71.4[1]	71.4[1]	50[1]	54.8[1]
CLASSIFICATION OF NANOMATERIALS	31	50[1]	38	21.I	35.7
FUNCTIONALITY	42.9	54.8[1]	54.8[1]	42.9	38

Note. [1] Agreement among participants regarding the needed NST essential concepts is ≥ 50

Stage 2- Identifying the nature of learning environments that best promote coherent and durable understandings for three examples of the identified essential NST concepts: Size and scale, size-dependent properties, and the making of nanotechnology and how these environments affect the students' attitude and the way they perceive nanotechnology learning and understanding.

A nanotechnology teaching module was developed for 60 (30 males/30 females) 9th grade students, divided into two groups (four groups of 15 students). Each group had one weekly lesson of 45 minutes for 12 consecutive weeks during the first trimester. The module implemented wide spectrum of instructional methods for teaching the three NST concepts mentioned above, for supporting students' understanding as well as various teaching environments, formal and informal environments that effectively support the learning goals of each lesson (Blonder & Sakhnini, 2012; Blonder & Sakhnini, 2015). It was found that using a wide spectrum of teaching methods greatly improved the students understanding of difficult subjects of nanotechnology. The combination of different teaching methods was shown to be effective for students having different learning levels (Blonder & Sakhnini, 2012; Blonder & Sakhnini, 2015).

Stage 3- Determining the insertion points of the essential NST concepts in existing middle school science and high school chemistry curricula in Israel.

The methodology used to answer this question contained two stages: The identification stage and the validation stage. The participants in both stages underwent designed courses (Cohen et al., 2016) that included the NST essential concepts. After learning each of the NST concepts the participants (middle and high school teachers) were asked to individually find insertion points for the essential NST concepts in the curriculum and give an explanation why they think the concept is suitable to be integrated in the suggested insertion points, each, according to their groups. After writing the individual suggestions of the insertion points for each essential concept a discussion was held during the next lesson in which the teachers were able to clarify their ideas of integrating the essential concepts in the curriculum and to share them with the research team and their colleagues. Then, follow the researchers' categorization and classification of the teachers' suggested insertion points, for each concept and their related explanations, according to the curriculum topics.

The participants were experienced middle school science teachers (N = 4) and experienced high school chemistry teachers (N = 11), who underwent a new designed course, tailored for teachers, and included the NST essential concepts. In *the validation stage*: Twenty-five teachers (5 middle school teachers and 20 high school chemistry teachers) participated in the online nanotechnology course that included the NST essential concepts for the validation process. In both stages (*the identification stage* and *the validation stage*) the participants were experienced teachers (5-15 years of experience)

Middle school teachers suggested insertion points of all the NST concepts in the existing middle school science curriculum subjects (Figue-3). The middle school curriculum contains four subjects: Chemistry, life sciences, physics-energy and technology systems and products. All the 7 essential NST concepts and *the making of nanotechnology* concept were suggested to be integrated in all four subjects

All the NST concepts were found suitable to be integrated in high school chemistry curriculum (Figure-4). All of them were suggested in several topics of the curriculum. Each of the concepts was suggested at least in five of the nine chemistry curricular topics and in four of the five optional curricular modules of the Israeli high school chemistry curriculum

CONCLUSION

When comparing the resulting NST essential concepts to other studies and projects such as the NSE big ideas document (Stevens et al., 2009), one can learn about the contribution of the current study to the field of NST education. The big ideas document of Stevens et al. (2009) was partly guided by US science education reform, which might have influenced what the authors assert as an approporiate solution for the question of nanoscale science and engineering big ideas. Further more, the big ideas included many science fundamental concepts that are critical for building general science literacy and for the connection of the new field to existing US science curricula. The current research, attempted to find what are the essential concepts of NST, that high school students (grades 10-12) and middle school students (grades 7-9) need to understand. We included only those concepts that are unique for NST and are not general scientific concepts. The results of the study are based on two groups of experts the NST experts (science education researchers) that bring with them the comprehensive understanding of the NST, and the group of the teachers that bring their expertise in teaching high school science. Different studies used different methodologies to identify the NST concepts, However, there are differences in the components composing these concepts (Stevens et al., 2009; Jones et al., 2015; Huang et al., 2011). The current study, provided eight NST concepts with their detailed sub - categories and their diffinitions comprehensively. The results of the current study serve as a supporting pillar and a framework that links four areas in nanotechnology, mentioned by Wanson, et al,. (2009): Processing (how nano-materials are fabricated), Nanostructure (how the structure of nano-materials can be imaged and characterized), Properties (the resulting size-dependent and surface-related properties of nanostructured materials and devices), and Applications (how nano materials and nano devices can be designed and engineered for the benefit of society). The study of Wanson et al., (2009) resulted in an organizing framework for NST programs for undergraduate students. The essential NST concepts resulted in our study, provide the students with primary understanding of all four nanotechnology areas. The resulted identified NST essential concepts and applications, their insertion point in the existing curriculum, and the different instructional method for selected concepts, can guide nano educators how to construct a comprehensive nanotechnology program that includes all the vital dimensions that are important for the development of nanotechnology education field: What NST concepts are needed to be taught in nanotechnology education? How to teach these NST concepts? Where to integrate them with another basic scientific concept. These components with the identified nanotechnology applications as the context for teaching the NST concepts will support students' understanding of the field and engage them with its implications on their life.

Acknowledgement

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Appendices

Figure 3: Insersion Points of the Essential NST Concepts in the Israeli Middle School Science

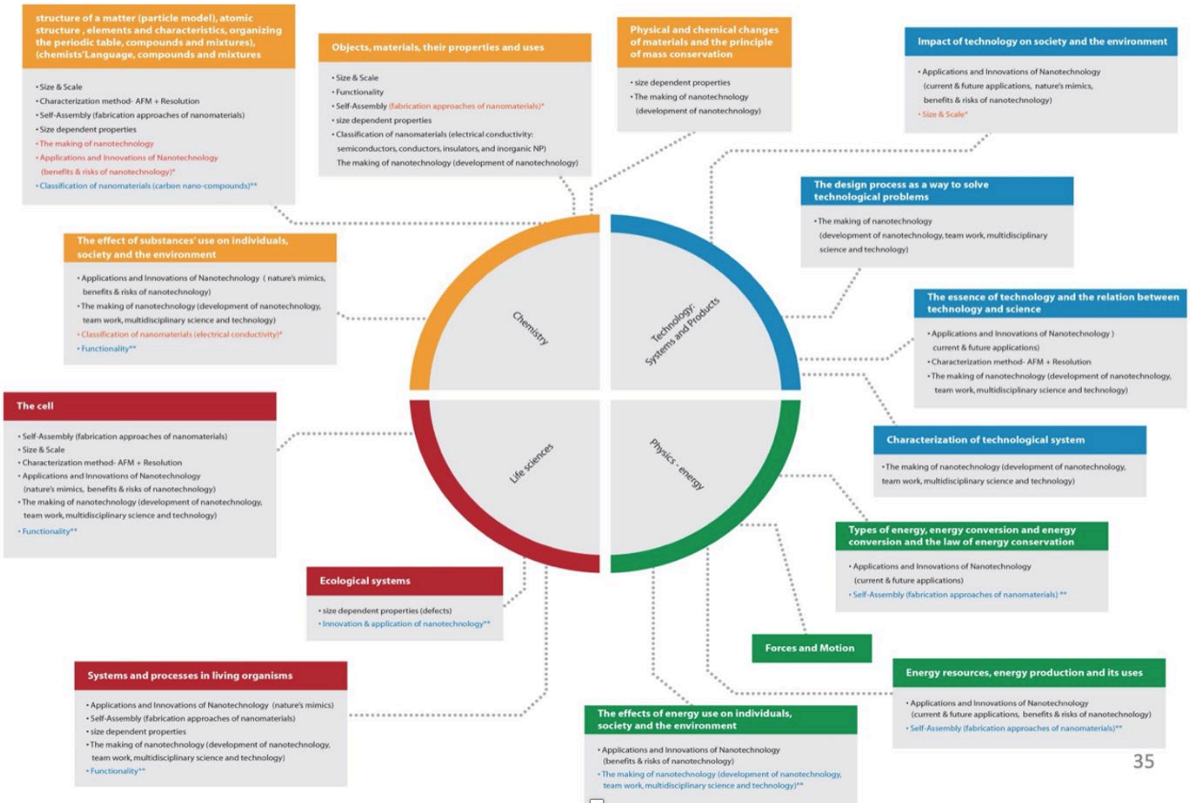
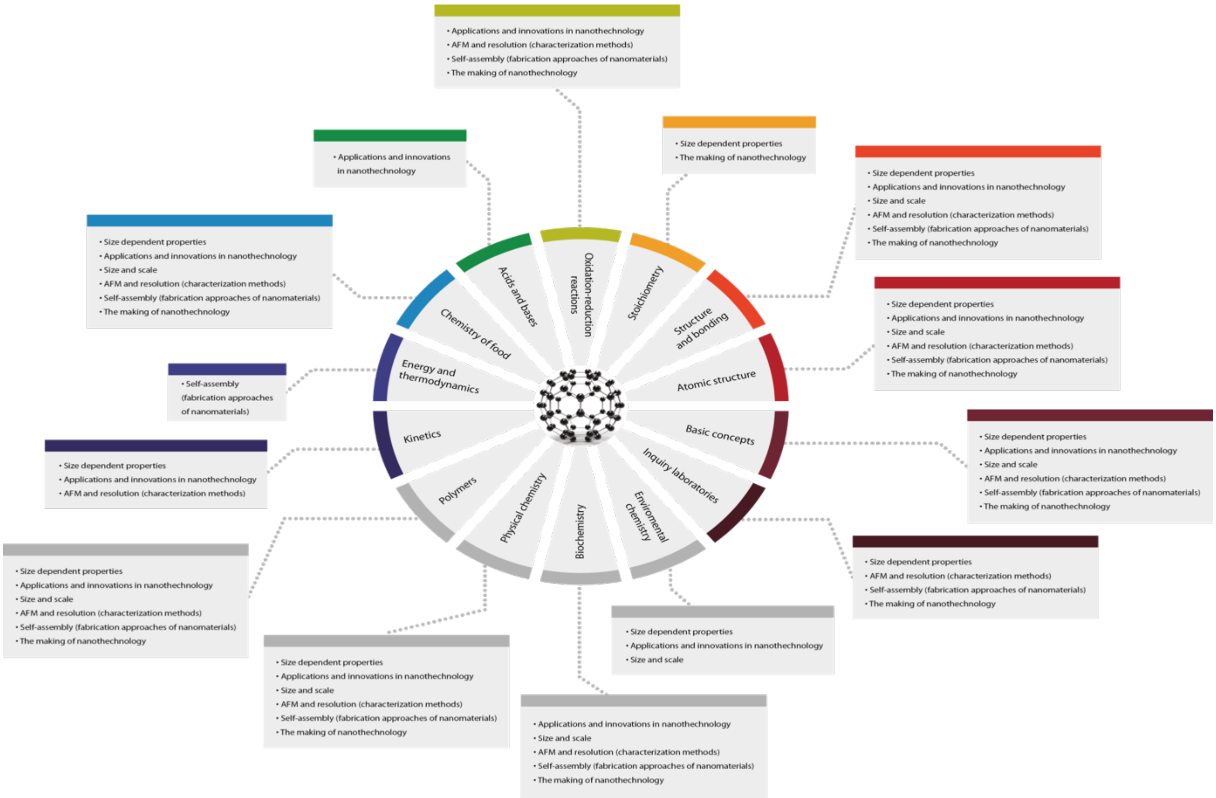


Figure 4: Insersion Points of the Essential NST Concepts in the Israeli High- School Chemistry Curriculum



Oxidation-reduction reactions
• Applications and innovations in nanothechnology
• AFM and resolution (characterization methods)
• Self-assembly (fabrication approaches of nanomaterials)
• The making of nanothechnology
Stoichiometry
• Size dependent properties
• The making of nanothechnology
Structure and bonding
• Size dependent properties
• Applications and innovations in nanothechnology
• Size and scale
• AFM and resolution (characterization methods)
• Self-assembly (fabrication approaches of nanomaterials)
• The making of nanothechnology
Atomic structure
• Size dependent properties
• Applications and innovations in nanothechnology
• Size and scale
• AFM and resolution (characterization methods)
• Self-assembly (fabrication approaches of nanomaterials)
• The making of nanothechnology
Basic concepts
• Size dependent properties
• Applications and innovations in nanothechnology
• Size and scale
• AFM and resolution (characterization methods)
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Inquiry laboratories
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Enviromental chemistry
• Size dependent properties
• Applications and innovations in nanothechnology
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Biochemistry
• Applications and innovations in nanothechnology
• Size and scale
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Physical chemistry
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• The making of nanothechnology
Polymers
• Size dependent properties
• Applications and innovations in nanothechnology
• Size and scale
• AFM and resolution (characterization methods)
• Self-assembly (fabrication approaches of nanomaterials)
• The making of nanothechnology
Kinetics
• Size dependent properties
• Applications and innovations in nanothechnology
• AFM and resolution (characterization methods)
Energy and thermodynamics
• Self-assembly (fabrication approaches of nanomaterials)
Chemistry of food
• Size dependent properties
• Applications and innovations in nanothechnology
• Size and scale
• AFM and resolution (characterization methods)
• Self-assembly (fabrication approaches of nanomaterials)
• The making of nanothechnology
Acids and bases
• Applications and innovations in nanothechnology

Aquaponic – from an idea to an educational concept

Martin Lindner, Chris Wenzel

Abstract

The idea to making aquaponic a tool for classroom education began at a visit at Boston College in 2014. In the following years, many student projects, also in Spain and planned in Egypt, shaped the ways for implementing it into everyday school life: the com via the incorporated STEM aspects. Also the German aquaponic plant in Berlin contributed to the idea. Based on the experience made in the last 7 years, this paper gives an example of a multidisciplinary approach towards the realization of a simple project. The underlying theoretical concepts, like motivation theory, or interest, as well as design research methodology are explained by examples of our practical work.

Key words

STEM project; aquaponic; self-efficacy

INTRODUCTION

The combination of both plant production and fish farming is not only an example for sustainable farming both of plant and animal protein at the same spot. It also offers a fascinating opportunity to learn about basic ecological connections and environmental issues. The system could be scaled down to a model, which could be easily displayed in classrooms, and which does not consume much time for maintaining the system. Thus, it conveys ecology in a small scale, comparable to an aquarium, but much more rewarding for the pupils who take care of it, as it provides at least herbs or fruits.

Our research on the use of aquaponic systems as tools for education started a few years ago, when one of the authors reviewed a contribution sent to an American educational congress (Pathchen et al. 2014). Later he visited the author´s lab in Boston and was impressed by the small aquaponic system, consisting of small aquariums and swimming contains with basil.

Another impulse came from an artist in Spain, who just mentioned the idea in an area, which is rich in water, but only during winter. Thus, the installation of an aquaponic system would lead to the storage of water during the whole year and is supported by high solar energy input (Fig 1).

Supported by these two ideas we started to build model systems at the greenhouse of our university. Different models of water cycles, different plants, and a varying number of fishes were explored, and the model was discussed also with teachers. We fostered collaboration of students in teams, made excursions to an aquaponic farm in Berlin, and gained field experience in Spain, which led to a quite solid experience about fostering and hindering factors of aquaponic systems for schools.

During the first years (2017-2020) we described our results in small reports, however, did not start to evaluate them with scientific methods. We started in Summer 2021 to research on a group of students, who conducted two projects on constructing aquaponic systems for schools (Fig. 2). The outcomes of this research is presented in this paper.

Fig. 1: In Spain students investigate on the use of solar panels the for pumping the water

Fig. 2: Simple Aquaponic system at greenhouse of our university

This research followed the long tradition of similar work by the research team (Lindner & Kubat, 2014; Lindner, 2015; Rusek & Lindner, 2017). It combines a hands-on character with a non-trivial topic which proved to be effective in the past (Janštová & Míková, 2019; Vojíř et al., 2019).

THE EDUCATIONAL VALUE OF AQUAPONIC

As mentioned, aquaponic combines food supply of fish and plants. Some authors call the product "tomato-fish" to indicate the double use of the system (e.g., Viering 2020). In a small version, the system represents the natural combination of animals and plants in the nitrogen cycle. Fish's excrement nitrogen compounds, mostly as NH_3 compounds. Nitrogen compounds are existentially necessary for plants to grow, as they need nitrogen to build up amino acids and nucleotides for DNA and RNA. And, equally important, the photo-respiratory systems of chlorophyll need nitrogen as well. This is easily indicated by field crops: the more nitrogen fertilizer is applied, the greener the wheat or the rice will grow.

As ammonium is quite dangerous for all living creatures, the content of ammonium should be reduced in aquafarms. Usually this is done by replacing 5-15% of the water by fresh water. In the aquaponic system the ammonium is turned into nitrate by bacteria and then displayed to the plants. This conversion is done by bacteria in two steps, Nitrosomonas turns ammonium into nitrite, and Nitrobacter turns nitrite into nitrate. This is collected through the roots of the plants and enables the plants to grow.

Aquaponic systems at schools could illustrate the cyclic structure of ecosystems, in this case the connection between excrementation of animals and the use of this as fertilizer. It enables also the measurement of these compounds by indicator sticks, but more, enables measuring the ecological factors as temperature, pH, conductivity. More data collection is possible by observing the growth of the fish and the plants.

The installation of the whole system requires more activities: the aquarium has to be filled, the growth bed for the plants must be filled, and the compartments of the system have to be fixed. Where could we use gravity to move the water, and where are pumps – best solar powered – needed? This installation already is an ideal STEM activity including Engineering, Biology, Physics and Chemistry, and it could be enriched by IT tasks e.g., to measure the ecological data like temperature, pH, conductivity and solar radiation. Computer based sensors could also be used to monitor water flux and other relevant data.

The use for classroom was already broadly explained by Toth (2018). He conducted a six week intervention in an 8th grade class in Denmark, and researched the outcome by focus group interview. He could confirm the assumptions on learning outcomes and on many aspects of a modern classroom, concerning constructivism, motivation and STEM learning aspects. Other authors interviewed teachers about her experience on aquaponic (Hart et al. 2013), and an extensive overview on aquaponic in the classroom is given by Junge et al. (2019).

RESEARCH METHOD

During the teacher studies students of our program have to work on their own projects during one semester. During the summer term 2021 two groups prepared in teams of 2 or 3 students two workshops for other students, which lasted 1 and 3 days. 20 student teachers aged between 19 and 35 from the Martin Luther University in Halle-Wittenberg took part in the study. Of these, 10 were female. They were between the 2nd and 16th semester.

To assess self-efficacy in relation to aquaponics and science projects, the participants were researched by pre- and post-questionnaires and a smaller group with interviews in mixed method setup. The two workshop (1 or 3 days) were attended by 9 respective 10 students.

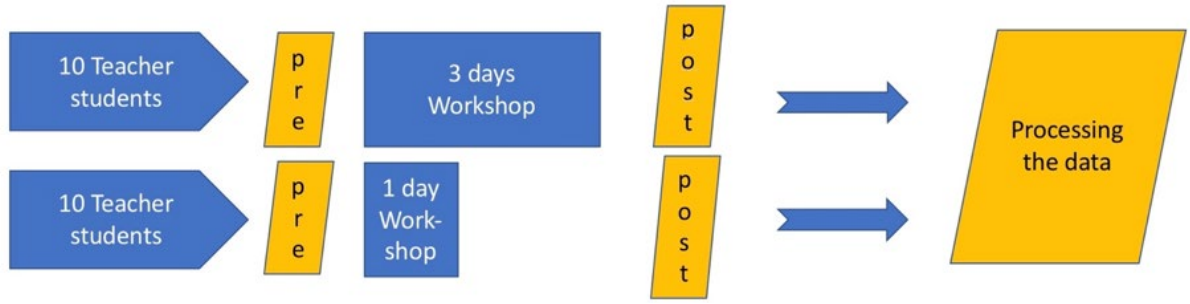

Fig. 3: Research design of the intervention study

The research focused on motivation and self-efficacy (Bandura 1997), on STEM projects in general.

The items were developed on the basis of the scale of teachers' expectations of self-efficacy (SWLE) according to Schwarzer and Schmitz (1999).

The results seem to be quite positive (Fig. 4 and 5). Regardless on the duration of the workshop, the students reported a higher motivation on conducting such projects at schools in their future practice. This indicates the value of project work as a preparation for a renewed school practice. Most participants already have a high level of self-efficacy before the workshop begins.

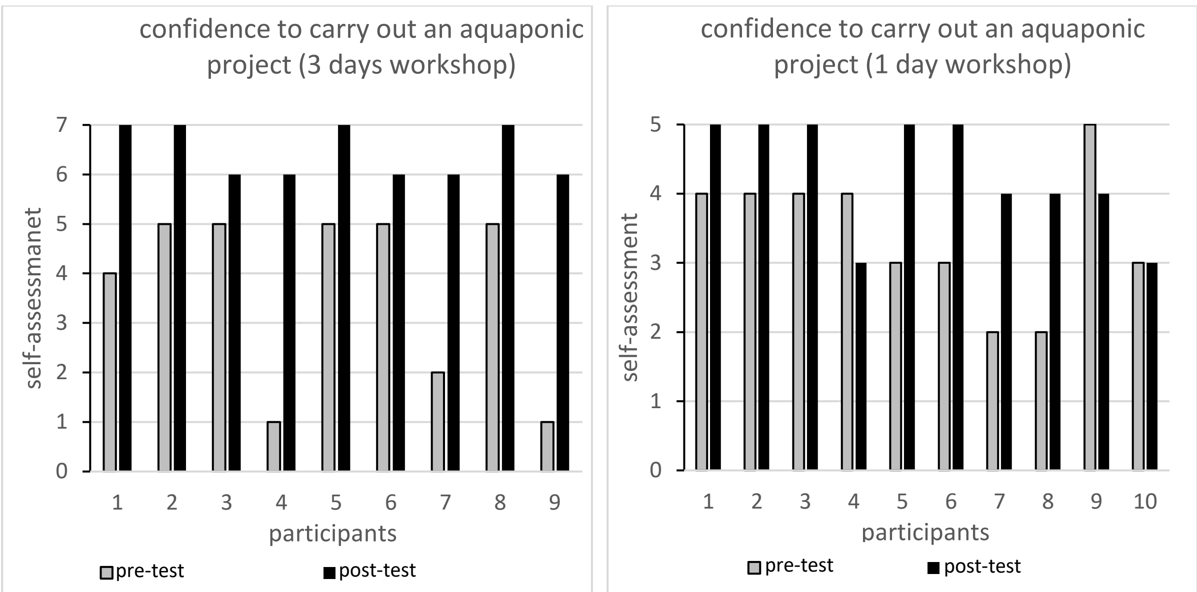

Fig 4: Data of 10 teacher students´ pre- and post-record on a 7 respective 5 scaled Likert-scale on carrying out an aquaponic project joining a 3 days workshop (left) or a 1 day workshop (right)

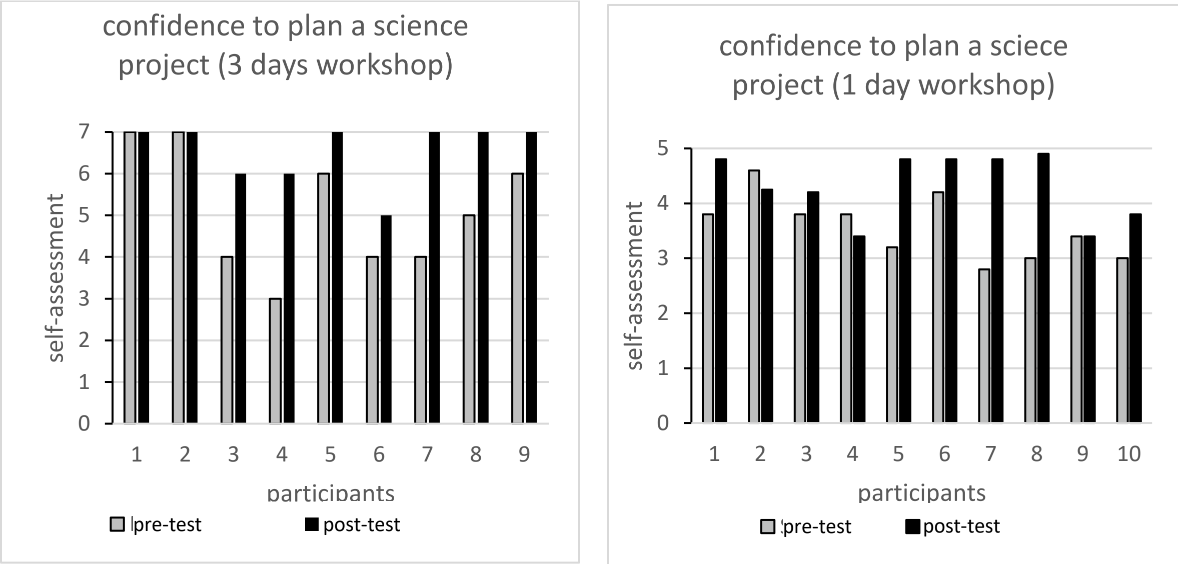

Fig 5: Data of 9 and 10 teacher students´ pre- and post-record on a 7 or 5 scaled Likert-scale on planning any STEM-project joining a 3days workshop (left) or a 1 day workshop (right)

CONCLUSION

The project among teacher students at a German university indicate the value of project work during university teacher preparation: the participants of two workshops prepared by two teams of other students showed a clearly increased confidence in the sense of self efficacy, not only to conduct similar workshops at schools, but also to other topics in the STEM field. The duration of the workshops is irrelevant for increase. Even if negative experiences were made, the basis for self-efficacy was improved because of the feedback loop that shapes the genesis of self-efficacy. Participation in the aquaponic workshop promotes a more precise assessment of one's own abilities to carry out scientific projects and an aquaponic project is suitable for investigating the influence on the self-efficacy of student teachers in carrying out scientific projects.

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