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Editorial

The PBE 2022 proceedings follows the, considerably long, line of books which have been shaping the landscape of student activation methods in Central Europe and beyond. In this year's proceedings, authors yet again targeted original project and inquiry-based topics, nevertheless, new issues emerged too. The idea of chemistry (science) escape room or field trips were inspected. Moreover, authors brought STEM topic to the mix, others focused on the phenomenon of open schooling.

It is obvious, the topics spread from original chemistry and biology foci as disciplines' integration brings the much needed context to sometimes too school-like topics.

The authors published in this proceedings used variety of research methods from both quantitative and qualitative areas. The contributions therefore offer some more inspiration how to grasp the effect of student-activation methods in education.

Hand in hand with the aforementioned development of other topics appearing in the proceedings are several papers which did not focus directly on the student activation methods but rather on the "other issues of science education". This trend will continue to be supported in the years to come as the impact of the PBE conference is steadily growing.

Martin Rusek

For the team of editors

Designing an Acid-Base Strength Interactive Screen Experiment (ISE): App Development with Upper Secondary School Students

Rita Elisabeth Krebs

Abstract

Recently, simulations and interactive screen experiments (ISEs) have not only been a feasible but in many cases also an essential alternative to hands-on experiments. Whereas numerous simulations, particle models and instructions for experiments exist, there has so far only been a minor focus on combining the two. This project aims at constructing and evaluating such a combination by designing an ISE with a 'magnifying glass' offering insight into the particle level. The topic of acid-base strength was used as it is known to be a problematic topic of chemistry education. This paper gives insight into the construction of this digital learning environment (iOS, Android and WebApp).

Key words

Acid-base chemistry; Interactive screen experiment; App development; Chemistry education; Innovation in education

INTRODUCTION

As has become apparent during the heights of the Covid-19 pandemic, simulations and interactive screen experiments (ISEs) are a useful and necessary addition in the chemistry classroom. The reasons for this are, for example, that some experiments cannot be conducted safely at the students' homes, or special equipment is needed that is not available to them. Other simulations offer an added value to hands-on experiments by including particle models and the like to support learners in interpretating an experiment. Numerous of these simulations exist (e.g., PhET Colorado, 2023; RSC, 2023). In general, these simulations offer a computer-animated insight into the chemistry lab, i.e. a digitized experiment that learners can set up and conduct. Interactive Screen Experiments, or ISEs, on the other hand, are usually based on photographs of real-world experiments (Kirstein, 1999; Kirstein & Nordmeier, 2007). These types of experiments thus offer both authenticity and the opportunity to repeat an experiment without the hassle of setting it up several times (Kirstein & Nordmeier, 2007). Consequently, ISEs offer more opportunities to observe for the learners which explains that their development and use is quite common in physics education (tet.folio, 2013).

In order to utilise the benefits both of these types of visualisations have to offer, this project was created. Based on an existing simulation of a relatively simple experiment (Lancaster et al., 2021;

Watson et al. 2020) and a beaker particle model (Barke, 2015), we aimed at creating an app that combines aspects of an ISE and a simulation. The topic chosen for this approach was that of acid-base reactions, as they play an important role in the history of chemistry, in the chemistry classroom and in our everyday lives (Krebs & Hofer, 2022). The purpose of this paper is to report on the first steps of an on-going design-based research project. It offers an innovative digital learning environment for upper secondary students teaching about acid-base reactions and, in particular, acid/base strength, whilst simultaneously increasing its likelihood of acceptance by cooperating with learners from the intended target group. The paper is structured as follows: First, we give an overview of the overall study design, followed by introducing the parties involved in the project. Subsequently, we will describe the learning environment with a focus on the visualisations we used followed by a conclusion and outlook on future research and development planned in the course of the project.

DESIGN & METHOD

Overall, the aims of the project are the following: We intend to construct a combination of interactive screen experiment (Kirstein, 1999; Kirstein & Nordmeier, 2007) and PhET simulation (Lancaster et al., 2021) that shows users which aqueous solutions of strong and weak acids and bases are conductive of electricity, and which are not, and depicts a model of the particle level by integrating a 'magnifying glass'. Methodology-wise, the project follows the design-based research approach (e. g. Anderson & Shattuck, 2012; The Design-Based Research Collective, 2003; Wang & Hannafin, 2005). As such, its design is polycyclical and characterised by the dual goal of developing both a design as well as generalizable theories about learning, or design principles (see Figure 1).

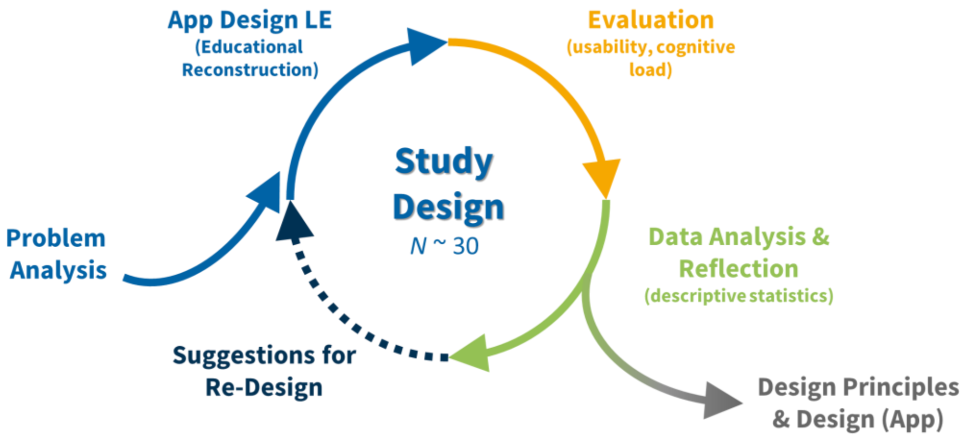

Fig. 1 The Design-Based Research Cycle Overview of the study design (Reeves, 2006), based on The Design-Based Research Cycle, © Sarah Zloklikovits, CC BY-SA 4.0, https://creativecommons.org/licenses/by-sa/4.0, via Wikimedia Commons.

An initial problem analysis of the topic acid-base reactions (see Fig. 1; Krebs et al., 2022; Krebs & Hofer, 2022; Krebs & Lembens, 2021) led to the definition of key ideas, i.e. central concepts of a topic adapted to target group and context (Haagen-Schützenhöfer & Hopf, 2020):

1. Acid-base reactions are protolysis reactions (Brønsted, 1923; Lembens et al., 2019).
2. The Electron Pushing Formalism (EPF) can be used to better comprehend the movement of electron pairs and bond formation in acid-base reactions (Sieve & Bittorf, 2016).
3. Particles which have a positively polarised hydrogen atom can react as Brønsted acids. Particles that have at least one free electron pair to bind the positively polarised hydrogen atom can react as Brønsted bases, if they attract the hydrogen more strongly than its bonding partner(s) (Brønsted, 1923; Lembens et al., 2019).
4. Acid-base reactions can be reversible, especially if they take place in an aqueous solution and the equilibrium constant K and modified constants for aqueous solutions can be calculated (Brønsted, 1923; Jiménez-Liso et al., 2020).
5. Strong and weak acids and bases exist, and their relative strength can be quantified in aqueous solutions (Brønsted, 1923; Lembens et al., 2019).
6. Simulations and experiments such as the one by PhET Interactive Simulations (Lancaster et al., 2021; Watson et al., 2020) can highlight the connection between the particles (acids, bases) and substances (acidic and basic solutions).

Based on these, a six-unit learning environment about acid-base reactions was created and evaluated (Krebs et al., 2023; Krebs et al., 2022; Krebs & Lembens, submitted). The results were used as a foundation for this project. Parts of this sequence influenced the development of the new design, another digital learning environment in the form of a smartphone App (Android and iOS) and WebApp. Overall, this app is aimed at supporting students in learning about acid-base strength by showing which aqueous solutions of strong and weak acids and bases are conductive, and which are not. In addition, it depicts a model of the particle level by integrating a 'magnifying glass' to include the visulise the particles responsible for the conductivity of the solution. As shown in Figure 1, next steps in the research design are the evaluation of the learning environment via questionnaire (Usability, cf. Brooke, 1995, 2013; Cognitive Load, cf. Leppink et al., 2013) with university students of chemistry education ($N \approx 30$) and the statistical analysis of the data followed by a possible re-design and refinement. Due to the fact that the project is on-going, the paper will focus on the design stage of the project, which we will describe in detail below.

WHO IS INVOLVED IN THE PROJECT?

In order to explain the scope of the project, it is first necessary to give an overview of the parties involved in it. Overall, there are two groups of stakeholders: (1) students and teachers from the IT department of a higher federal technical college in Lower Austria, and (2) chemistry education researchers from universities in Vienna and Prague. Whilst the researchers and teachers coordinate the project and offer subject-specific and methodological expertise, the responsibility of developing the learning environment mostly rests on the shoulders of the students with the support of an IT teacher at the higher federal technical college participating in the project. In Austria, students have the option to attend a so-called college for higher vocational education at the upper secondary school level from year 9 to 13. There, their school leaving qualifications include completed school-leaving exams (A levels) and a diploma examination as well as access to legally regulated professions in accordance with the Austrian Trade and Industry Code (OeAD, 2022). In order to do so, the students must complete a project in their area of expertise – in this case, design and programming – spanning around 200 hours of work per participating student. The topic of the project can be chosen by the students themselves or offered by a client or teacher, as was the case here. Using the framework Ionic[1], the three students involved in this project design and create the digital learning environment under the supervision of IT and chemistry teachers and researchers.

CONDUCTING A PROBLEM ANALYSIS AS A STARTING POINT

For the digital learning environment, modelling acid/base strength was chosen as the topic. In general, teaching about acid-base chemistry proves to be difficult for both teachers (Alvarado et al., 2015) and learners (Hoe & Subramaniam, 2016). The concept of weak and strong acids and bases in particular seems difficult to grasp for learners, as they often assume a connection between pH and acidity or basicity, or even between the number of an acid's hydrogen atoms and its acidity (Özmen et al., 2009). Inconsistencies in textbooks (Lembens et al., 2019) exacerbate the problem. One approach to teaching about the concept of acidity and basicity includes using beaker models (Barke, 2015; Krebs et al., 2022) or simulations (Lancaster et al., 2021) to illustrate the submicroscopic level. In order not to confound acid/base strength with pH (Özmen et al., 2009), these approaches seem more prudent than solely focussing on hands-on experiments with acidic and basic solutions (e.g. determining pH or conductibility of a solution). Combining an experiment or simulation thereof with a visualisation of the particle level, however, may be an approach that supports learning and learners' conceptual understanding of acidity and basicity (cf. Watson et al., 2020 for a similar study on conceptual understanding of pH). We aim at offering such a combination and add the innovative aspects of making the model of the submicroscopic level dynamic as well as including real-world aspects in the form of an ISE to increase authenticity in comparison to computer simulations.

[1] Ionic is a framework that allows programmers to develop an application that can be used both as a web and mobile application. The programming languages necessary for using the framework are HTML, CSS, and JavaScript, thus making Ionic versatile and easily accessible.

DEVELOPING AN APP PROTOTYPE VISUALISING ACIDITY AND BASICITY

In this project, we intend to focus on combining a digitalised experiment (determining whether a solution conducts electricity via LED) with a 'magnifying glass' allowing an insight into the submicroscopic make-up of several different aqueous solutions (distilled water, vinegar, tap water, gastric juice and drain cleaner containing soda lye). In the prototype of the app, we decided against using a solution of a weak base as the solutions of weak bases most common in our households are solutions of salts such as sodium bicarbonate. These, however, dissolve into ions, which means that at the same concentration, a sodium bicarbonate solution is more conductive than vinegar. As a consequence, this is an aspect of the learning environment we aim at re-working in the future. The subsequent description of the ISE focusses on both the experimental set-up and the visualisations included in the 'magnifying glass', i.e. the simulation aspect of the application.

Setting up the Interactive Screen Experiment (ISE)

When first accessing the application, learners can set up an experiment consisting of beaker, graphite electrodes, LED, battery and cables. When adding distilled water, the circuit is closed, but the LED will not light up as distilled water does not conduct electricity sufficiently. In a second step, the learners select one of the different aqueous solutions to fill the beaker with, i.e. table vinegar, gastric juice, tap water and drain cleaner. To simplify the chemical background, only one of the solutions can be added at a time. Depending on the added solution, the LED will light up softly (table vinegar, tap water) or strongly (gastric juice, drain cleaner), depending on the amount of ions, or charge carriers, present. The change in conductibility is due to the fact that:

- distilled water is mostly free of ions (cf. autoprotolysis of water),
- table vinegar is the aqueous solution of acetic acid, a weak acid, and thus contains a negligible amount of ions,
- tap water consists of mostly water, but also contains traces of ions such as hydroxide and oxonium ions,[2]
- gastric juice mostly consists of hydrochloric acid, which reacts as a strong acid, and thus produces a considerable amount of ions, and
- drain cleaner contains soda lye, which means that it contains a large amount of hydroxide and sodium ions.

It is important to note that change in conductibility in solutions is also dependent on ion concentration in general but also on temperature of the solution as well as the pressure. In another step to reduce

[2] In the case of Viennese tap water which was used as the basis for this app, the concentration of hydroxide ions outweighs that of oxonium ions. In other words, the water is slightly basic.

app complexity, the same amount of acid/base are assumed to be added to form the aqueous solutions in the simulation so that concentrations of reactants possibly forming ions are roughly the same.

Visualising the submicroscopic level

In comparison to distilled water, Viennese tap water contains traces of ions, such as ammonium (NH_4^+), chloride (Cl^-), nitrate (NO_3^-), hydroxide (OH^-) and oxonium (H_3O^+; cf. Stadt Wien | Wiener Wasser, 2022). In order to reduce the complexity of the visualisation, we only depict hydroxide (OH^-) and oxonium ions (H_3O^+; cf. Figure 2).

$$2\,H_2O \rightleftharpoons OH^- + \,H_3O^+$$

The trace amount of these ions leads to tap water conducting electricity rather poorly, but still enables the LED to light up.

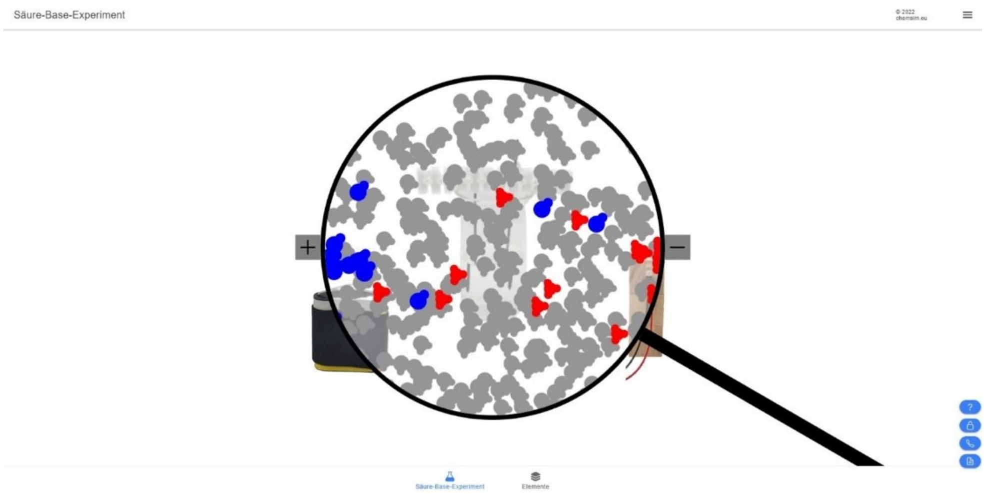

Fig. 2 Visualising a simplified submicroscopic 'make-up' of tap water (Nagy et al., 2022).

Acetic vinegar contains water molecules as well as the reaction products of acetic acid reacting with water: acetic acid molecules (CH_3COOH), oxonium ions (H_3O^+) and acetate (CH_3COO^-).

$$CH_3COOH + H_2O \rightleftharpoons CH_3COO^- + \,H_3O^+$$

In this reaction, the equilibrium is on the side of the reactions, i.e. acetic acid is a weak acid, thus resulting in a low ratio of ions compared to uncharged molecules.

The main components of gastric juice, or stomach acid, are pepsin (a digestive enzyme) and hydrochloric acid (Prayson, 2015).

$$HCl + H_2O \rightleftharpoons Cl^- + \,H_3O^+$$

Whilst the former is omitted to reduce complexity, the latter is visualised in the simulation as oxonium (H_3O^+) and chloride ions (Cl^-) acting as charge carriers in the solution. In comparison to vinegar, this aqueous solution mostly consists of water molecules (H_2O) and ions (H_3O^+, Cl^-), thus supporting it in conducting electricity excellently.

Different types of chemical drain cleaners exist, although their active ingredients are usually either lye (sodium hydroxide) or bleach (sodium hypochlorite) (Sidey, 2004). In this case, the drain cleaner depicted is composed of sodium hydroxide, which leads to its aqueous solution containing water molecules as well as sodium and hydroxide ions.

$$NaOH_{aq} \rightleftharpoons OH^{-}_{aq} + Na^{+}_{aq}$$

Similarly to gastric juice, the solution conducts electricity exceptionally well due to the presence of a sufficient amount of ions as charge carriers.

CONCLUSION & OUTLOOK

This paper presented an overview of a larger project aiming at the design and evaluation of a digital learning environment. The learning environment combines the idea of an interactive screen experiment (Kirstein, 1999) with a particle simulation similar to the phet simulation about acidic and basic solutions (Lancaster et al., 2021). As simulations and ISEs have already become an indispensable alternative to student experiments in chemistry classes, this combination of both offers the dual possibility of experiencing a reaction and modelling the underlying processes on the particle level. The topic of acidity or basicity was chosen for the creation of the learning environment as it is known to be a problematic topic in chemistry education (e.g. Hoe & Subramaniam, 2016).

Fig. 3 Project timeline and next steps.

The integration of a 'magnifying glass' (cf. Lancaster et al., 2021) visualises the properties of aqueous solutions of strong and weak acids and bases in more detail. The learning environment was developed in cooperation with a higher federal technical college for computer science, and can be used as a smartphone app (iOS, Android) or as a WebApp. At this point, the lessons learned are that in such interdisciplinary projects with vocational school students the benefits hugely outweigh the coordination and planning needed. The students were motivated to complete the app as they were allowed to work autonomously and saw a practical application of their work. However, the development of such a resource takes more time than the students' allocated diploma project time, which is why the app prototype is not fully developed. After an evaluation using questionnaires on Usability (Brooke, 1995, 2013) and Cognitive Load (Leppink et al., 2013) with university students of chemistry education (Figure 3), we will re-design the app accordingly, possibly in a new diploma project (cf. Figure 1). In a next step, eye-tracking (cf. Tóthová et al., 2021) will be used to investigate the learning effectiveness of the ISE. In a future re-design, the app may also include a pH meter allowing the user to find out more about ion concentration but for now, the decision was made to focus only on one aspect of acidic and basic solutions.

Acknowledgement

I would like to express my deep gratitude, first and foremost, to the three students who made the development of this application possible as they agreed to undertake this ambitious project as their diploma project. I also thank my dear colleague Markus Reis from the HTL Wr. Neustadt, the higher federal technical college involved in this project, for his continued support and supervision of the students, and his technical expertise. This research was greatly supported by my colleagues from the *AECC Chemistry*, especially Anja Lembens, who provided insight and expertise that greatly assisted the research, and Martina Zodl, who developed the logo for the project. Finally, Martin Rusek from the Charles University Prague acted as a sounding board during the development of the application.

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Primary Student Teachers' Ideas about Active Learning in STEAM Learning Environments

Anssi Lindell, Pasi Nieminen &Terhi Mäntylä

Abstract

STEAM integration allows students to solve problems relevant to their lives, and which cannot be tackled in just single school subject contexts. We asked primary school student teachers to draw and explain their ideas of active learning in such STEAM learning environments before and after their project based course of science pedagogy. We analyzed the data regarding the elements of effective STEAM-learning. The results show that linking the topics in students' lives and STEAM integration is portrayed well. Less referred were the role of teacher as a guide of learning and unifier of the learning with the community. These can be focused on in the future projects with external actors.

Key words STEAM Integration; Learning Environments; Collaboration; Active Learning

INTRODUCTION

STEAM-Integration for solving problems relevant to students' life

Have you ever heard students asking, "what is the point of studying this?" or saying, "I'll never need this knowledge in my life, after I have finished my school"? All the teachers and most of the former students probably have heard that sometimes. How can we response to hearing these kinds of questions? Common sense suggests starting teaching competences needed in everyday life. However, real-world problems are way too complex to solve applying just the knowledge of a single school subject (Lesh & Zawojewski, 2007). One solution is to learn about phenomena utilizing the knowledge of several school subjects together as we have done in combining Science, Technology, Engineering and Mathematics (STEM) for years by now. Further, as in real-world contexts all the knowledge is connected, we may include everything else which is needed to solve the problem in hand. This leads to STEAM education, where the letter A used to link STEM with Arts or humanistic sciences, but nowadays stands for linking STEM with All the other subjects (Hazelkorn et al., 2015).

Integrative Teacher Education (ITE, https://www.jyu.fi/edupsy/fi/laitokset/okl/integraatio/en) has been applied in primary teacher education in our university since 2003. An inquiry based approach is applied in ITE in order to reach beyond the traditional learning of the subject core contents. In learning pedagogy of natural sciences, we have ended up to STEAM education to integrate it with all the other school subjects.

In ITE, the student teachers are systematically guided to take responsibility for their own learning as individuals and as a collaborative group. The ITE student teacher group who participated in this study set their goal for the science pedagogy project in the course of Environmental and Science Education "to learn teaching outdoors" (meaning: to learn teaching outside of classrooms). In ITE, we have created learning partnerships among the student teachers, teacher educators, and the community. The learning environment of the project also covers diverse human out-of-classroom resources such as museum staff and parental unions, and inspects how these can be connected to formal curriculum based education. This presented us with a research problem: How to get student teachers to utilize non-formal out-of-classroom learning environments more effectively? To achieve that, we set two research questions (RQ): RQ1: What ideas do ITE student teachers have about STEAM learning environments and learning in them? RQ2: How does their thinking about STEAM learning environments change during the project?

The objective of the course was to bring students, environment and community together in the process of active collaborative learning. The assignment for the students was to document their learning experiences "as a guidebook for teachers to design out-of-classroom non-formal STEAM learning environments to support formal learning". They also had to include three examples of such active collaborative STEAM learning situations in the guidebook.

The project-based working in this course included nine meetings instructed by the first author of this article. Four meetings included visits and visitors from the SteamBox-project (http://steamboxproject.eu/), School of Resource Wisdom (https://www.jyu.fi/en/research/wisdom), LUMA Centre Finland https://www.luma.fi/en/ and the Jyväskylä University Natural History Museum (https://tiedemuseo.jyu.fi/en/natural-history-museum). These visits included a short introduction of the organizations' collaboration with schools and active hands-on examples of multidisciplinary inquiries in non-formal settings and learning environments. The student group met between the instructed meetings and worked in a self-directed way on their assignment.

THEORY

Interdisciplinary Problems are Tackled by Teams of Experts

Collaboration is one of the key skills that students need to learn to be successful in today's world (Rotherham & Willingham; 2010). Almost all experimental science is collaborative in nature. The growth of scientific knowledge is a consequence of linking both cognitive and social learning strategies (Thagard, 1994). Thus, we need to evaluate all science learning strategies and environments in part based on how well they promote the collaboration. Solving problems in everyday life are tackled by collaboration with experts of different specialities (Hamilton et al., 2008). Just think about the areas of the experts you use to consult with the issues of your household improvements, well-being, or hobbies, for example. Students' collaboration with out-of-school community engages them to learn (Dewey, 1916; Diefes-Dux et al., 2004). The members of the collaborative teams have different roles and responsibilities in the processes of active learning. In interdisciplinary learning, students collaborate in different roles, conduct experiments to solve problems, and provide explanations and solutions to real-life questions (Hatisaru & Fraser, 2021). The teachers' role is to facilitate and guide learning, rather than to impart information. The experts of the out-of-school community completes the communities of learners.

Conceptual Understanding is Revealed in Translations between Modes of Representations

According to Dewey (1938), the effective learning environments encourage students to think creatively and independently. In his theory, experiences make a progressive continuum influenced by the interaction during the current experience. Similarly, according to Dienes (1960), the new concepts and abstraction is built upon the existing knowledge. This takes place by manipulating systems of concrete objects. However, mere playing is not enough. Students need to learn to control variables systematically to find the reasons for the observed consequences and correlations. The perceptual principle states that these patterns of new concepts should be presented in as many ways as possible, and the conceptual understanding can be assessed from the readiness to translate between the representations. This issue has been emphasized in a guided inquiry approach called representation construction, where students are instructed actively to generate and negotiate the representations (text, graphs, models, diagrams) that constitute the discursive practices of science, rather than focusing on the teacher giving the knowledge of text-based, definitional versions of concepts (Hubber, et al., 2018).

METHOD

This case study was conducted during the fall semester of 2022 and the ITE group consisted of 15 female primary student teachers (all the applicants were female) who all gave their permission to participate in the research. Two of the student teachers were absent during the pre-task data collection (N = 13) and one of them during the post-task data collection (N = 14).

We used a D-STEAM-test (Draw STEAM) as a pre- and post-data collector. The test is the same as the D-STEM (Draw a STEM Learning Environment) research instrument (Hatisaru & Fraser, 2021), except explaining the meaning of the additional letter to the sample. In the pre-D-STEAM test we first defined STEAM education as including all the other subjects in science education (Hazelkorn et al., 2015), and learning environment as an academic ambience: physical location, context, and culture in which teaching and learning take place (Eduglossary, 2022). The elements of management and affective issues (Evans et al., 2009) are beyond this study.

After these definitions we asked the student teachers first "Consider your job as a STEAM -teacher. Sketch your vision of a STEAM learning environment and learning in it". We also asked them to explain their drawings and learning in it, with guiding questions "What is happening in the picture?", "What are the persons doing?", and "How does learning take place"? The post-task was the same, but with two additional reflection questions: "How did your ideas about STEAM learning environment change during the course?" and "How did your ideas about students' and teacher's roles, methods, and materials change during the course?"

Tab. 1 The Rubric adapted from Hatisaru & Fraser (2021) used to categorize the elements of effective STEAM learning environments and learning in them in students' D-STEAM tasks.

ELEMENT	DRAWING OR TEXT INCLUDES A REFERENCE OF
STEAM integration	Context that allows students to use knowledge and skills from at least two disciplines
Collaboration with roles	Collaboration among students, in which members have different roles and responsibilities
Tasks linked to students' lives	Tasks linked to the real world and students' lives and interests
Multiple representations	Context that supports multiple representations, and At least two representational models
Community integration	Linking with industry, the community, or families
THE TEACHING AND LEARNING	
Tools and technology	Using multiple teaching and learning tools;
Role of the teacher	Using other methods than lecturing
Role of the learner	Students actively involved in learning

The student group was assigned to collaboratively produce a guidebook for teachers: "Out-of-classroom non-formal learning supporting the formal learning" as an artefact of the project. This guidebook material was used to triangulate our findings. The answers to the RQs were surveyed from the students' pre- and post-task drawings and explanations using the Rubric modified from the D-STEM instrument (see Table 1). We did not use the D-STEM category of strong reference, as the line between existing and strong category was vague. We also combined the elements of "Personal experience" and "Realistic problems" into one item "Tasks linked to students lives", because we cannot define the links to students' lives in a consistent way and such problems need to be realistic anyway. We also combined the "Student centered teaching and learning practices" and "Roles of the learners other than receiving knowledge" in the Rubrik. In the student-centered instruction, the role of the student is never just to receive knowledge. The post-task reflection questions were also used to answer RQ2. In the results, the students' names are pseudonymized.

RESULTS

The analyses of the D-STEAM drawings and the written explanations are presented in Table 2.

Tab. 2 Percentages (and amounts) of students' references to the STEAM elements and the teaching and learning practices in their pre- and post-D-STEAM-tasks of the project-based science pedagogy course

ELEMENT	PRE (*N*=13)	POST (*N*=14)
STEAM integration	62% (8)	71% (10)
Collaboration with roles	38% (5)	21% (3)
Tasks linked to students' lives	92% (12)	100% (14)
Multiple representations	46% (6)	43% (6)
Community integration	23% (3)	64% (9)
THE TEACHING AND LEARNING		
Tools and technology	31% (4)	79% (11)
Teacher as a guide	0% (0)	14% (2)
Learner in active role	54% (7)	79% (11)

A great deal of the ITE student teachers linked the tasks in STEAM learning environments to students lives (92 %) and saw learners in active roles (54 %) prior the project. On the other hand, none of them did not express the teacher's role as a guide of active learning, 23 % integrated the learning environment with the community, and only about one third of the student teachers brought out technology and collaboration. The student teachers' linkage the tasks in the STEAM learning environments is evident both before and after this project. References to STEAM-integration were found in most of the pictures, but in one third of the cases only science or even just botany was presented. On the other hand, the explanations of the role of the teacher were vague. In most of the drawings and explanations, it was not drawn or mentioned at all. Seeing students as active learners showed in four more student teachers' drawings/explanations but giving different roles for the students in the STEAM learning environments regressed a bit. Using tools and technology showed in seven more students' drawings/explanations, nevertheless including multiple presentations did not change much. The most positive impact of the course was the positive development in the community integration in the student teachers' drawings/explanations. An example of that can be seen in the Figure 1, where Maria's learning environment has expanded from the classroom and school yard to the utilization of local and even national resources.

The student teachers' written responses to the questions about the development of their thinking about STEAM learning environments also exposed the impacts of the project on the STEAM-D elements. The sample answers below were translated from Finnish language. As we did not use these responses to quantitative content analyses, we do not see backtranslations of these simple statements necessary to assure the quality of translations. Anna wrote: *"I learned to combine science topics better with the other subjects, and I believe that STEAM is a more meaningful and interesting way to learn,* *both for the students and the teachers. Visitors have a great role in learning*". Despite of the rare references to the ideas of teachers' and students' roles in STEAM learning environments, features of development were exposed in these responses. Ella wrote: "*Teachers' role as a guide and students' role as an active learner and inspector became stronger. Especially the museum and the visiting experts were most educational.*" Sofia wrote "*Now I can see science teaching in a big picture, and I understand that it can be much more than just doing the tasks from the textbook*". Finally, Laura wrote: "*In environmental education, you can do almost anything in diverse environments if the goals for the work are clear and the work is safe. One may cooperate with other teachers and professionals. The teacher is not in the center and the student is an active learner and observer. Many kinds of materials, tools and methods can be used*".

Fig. 1 Maria's idea of a STEAM learning environment developed from school and its near yard (left drawing) to cover the resources of the whole school district and national facilities (A bus is heading to Heureka national science center) (drawing on the right).

The guidebook for teachers "Out-of-classroom learning supporting the formal learning in the classroom", produced by the group as an assignment of the course, is a 47-page overview of the course. The title of the book itself refers student teachers thinking STEAM learning environments something that connects the learning in the classrooms with the community outside of the classroom. The guidebook includes separate chapters to introduce a curriculum analysis of STEAM education, an introduction to inquiry-based science education, a digest of the visits and three lesson designs: "What are the stars?", "How to survive in the forests?", and "What do we need to cope with natural catastrophes?" These chapters reveal student teachers' ideas about STEAM education as implementing curriculum as active inquiring the phenomena relevant to students or teachers lives.

CONCLUSIONS

Our project-based education in the ITE primary student teachers' science pedagogy course "Environmental and Science Education" focused on STEAM-integration and included visits of external experts and visits to diverse resources of education. The project theme originated from the student group's wish to learn to "teach outdoors". After a theoretical review of integrative STEM and STEAM learning environments, we decided to use D-STEAM, a modification of the D-STEM instrument, to identify the student teachers' initial ideas of the learning environment elements and teaching and learning in them. It turned out that student teachers can link the tasks to the real life and students' lives (Hamilton et al., 2008) even before the course, but it seemed that they do not see the possibilities that the collaboration and community offers (Diefes-Dux et al., 2004). and their own role as teachers in instructing active learning. We wanted to focus mainly on these learning outcomes during the project.

The post D-STEAM drawings revealed that the number of student teachers presenting external STEAM learning environments had increased, but still, only two student teachers saw the teacher in a role other than just the lecturer. However, in the post reflections, several students discussed the teacher's role in supporting or guiding learning. We found similar evidence in their artefact produced as part of the project. This could suggest that when drawing a learning environment, the students viewed the environments as insiders and therefore they excluded the teacher from the drawings.

We also wanted to emphasize the importance of representation construction during the project (Hubber et al., 2018), but we did not see any collective change in student teachers' thinking about STEAM learning environments supporting that.

The D-STEAM instrument is a slight modification of an existing D-STEM research instrument. The difference might be critical if we were comparing STEM and STEAM -education, but it is negligible while answering the RQs to develop our ITE. The D-STEAM Learning Environment modified from the D-STEM instrument may be used in education both for diagnostic mapping of student teachers' pre-conceptions about elements of STEAM learning environments and for summative assessment for learning interdisciplinary STEAM pedagogy in project-based teacher education.

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Open schooling through the eyes of experts

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Abstract

Open schooling is a new concept used in policy making based on cooperation between schools and wider society. Students in cooperation with other stakeholders are actively involved in solving real-life projects related to their community. Thinking retrospectively, connecting experts with open schooling projects, there appears to be challenges involving the students, the schools and the communities. Because such obstacles need to be overcome in order to successfully implement open schooling projects, we share experience of experts and schools on how to deal with these barriers.

Key words

Open schooling; Sustainability; Community stakeholders

INTRODUCTION

The world has been facing several environmental and social crises recently. One of the most discussed crises is the climate change causing *i.e.* food and water insecurity or weather extremes. These fuel socioeconomic tensions, for example, leading to migration from the most affected countries. Moreover, there have been additional environmental and social challenges dealing with waste management, biodiversity loss, water and air pollution, social cohesion loss or housing problems that need to be solved. The response to these challenges was adoption of the 2030 Agenda for Sustainable Development representing the global plan on how to protect the planet and improve lives and prospects of everyone and everywhere (Desa UN, 2016).

Another challenge discussed nowadays is the lack of science-literate people at all levels of society. Since scientific literacy involves the capacity to identify scientific problems underlying political decisions and to express coherent viewpoints using scientific arguments (see e.g. Miller, 1983), it is obvious that science literacy is an important condition for understanding, accepting and probably achieving at least some of the 17 Goals established by the UN 2030 Agenda. However, the research shows that students' scientific literacy level does not achieve the desired level (Nodzyńska, 2020). One of the possible ways for acquiring scientific literacy (and key sustainability competencies) are the approaches connecting real-life experience and its reflection with sustainability topics (see e.g. UNESCO, 2015; Kováčová, 2016; Queiruga-Dios et al., 2020; Janoušková & Bílek, 2022). However, day-to-day (science) education at school is often found detached from real-life issues (Maass et al., 2019). This considerably weakens educational potential and thus also decreases in the long run the number of scientifically and environmentally literate citizens. Therefore, an approach initiating and maintaining effective cooperation of stakeholders in communities is needed (cf. Dalton et al. 2007).

It is possible – *e.g.* by introducing education practices in schools connecting teaching and learning - to identify, explore and tackle key sustainability problems in collaboration with local community stakeholders. Such practices might be employed by schools as agents of the community well-being by being able to import external ideas that challenge internal views and beliefs possessed by school. In turn, the students can affect the community with their ideas on sustainability issues they perceive as important. These are, for example, more sustainable public spaces, sustainable mobility plans, or energy savings. Such an approach is called open schooling (open schooling model) (Mauer et al., 2017).

Such a radical change in the sense of being so open and taking on the role of community agents can be difficult for schools. Therefore, we believe that schools can start with smaller open schooling projects connecting the school with the community and gradually expand this approach to the level satisfactory for both the school and the community. By this level, we mean that both the schools and the communities will benefit from open schooling. It will move the community towards the sustainable goals it sets for itself. Students will feel part of the community and agents of the community. They will also gain knowledge and competencies they will see as well connected to everyday life. Because even this step can be difficult for some schools, we analysed the barriers that may hamper the open schooling projects implementation and we also identified the drivers instrumental in schools advancement.

METHODOLOGY

In our study we used a retrospective think-aloud method to collect experts´ reports on the open schooling projects implemented at schools in 2022. Although there are concerns about validity of self-reports of thinking (see e.g. Ericsson, 2006; Ramey et al., 2006), this method is widely used for this purpose in different research fields – education, medicine, sport, etc. In the retrospective think-aloud method, participants recall thoughts ideally immediately following completion of the task (open learning project implementation) (Eccles & Arsal, 2017). In our study we interviewed the experts after completing their open schooling projects. The interviews were completed no longer than one month after the project implementation. Therefore, it can be assumed that the experts had a good recollection of all important aspects of the project implementation process. Some authors even argue that the introspective or retrospective think-aloud methods seem to be appropriate when having experts as subjects because they yield more rational knowledge than the ad hoc reasoning that appears in practice (Van Someren et al., 1994).

Among the interviewed experts there were five teachers implementing open schooling projects in their schools. Two other interviewed scholars were from the university, and they were involved in a Horizon 2020 project "Meaningful Open Schooling Connects Schools To Communities" that introduced the teachers at schools with the open schooling principles and provided them with a project theme (waste management). The role of the scholars was also to support teachers during the project implementation if necessary, and to monitor the implementation. The interviewed teachers have the experience with the school project implementation; however, they had not implemented any open schooling project before.

As usual for a think-aloud method, written transcripts of the teachers´ verbalization (think-aloud protocols) were acquired and coded through an inductive way by two coders independently. Thereafter, the codes (a codebook) were discussed among the coders, adjusted according to their mutual consensus and written transcripts were recoded again. The adjusted codebook was used for coding of the written transcripts of scholars´ thoughts and new codes were looked for. The interviews with scholars were to ensure that no new themes emerge because their role was more holistic than the teachers´ role. The scholars´ verbalization should prove the achievement of theoretical saturation. Since no new codes were detected the study was finished as sufficiently theoretically saturated.

RESULTS

Three clusters of barriers were identified. The first cluster was related to the teachers' role. The number of teachers who take part in open schooling projects and their experience with at least some school projects were often mentioned in the interviews. Some of the teachers mentioned possible barriers on the school management side although they did not meet such a barrier in their open schooling project implementation. It can be documented by this statement: "*We are used to doing this type of project. However, some teachers I met on different occasions doubt the open-schooling support at their schools*" All the teachers mentioned the necessity in changing their mindset in order to accept curriculum changes, especially teaching program changes. One of the teachers stated: *"… such projects are time-consuming. I always need to convince myself that it is anything that fits into my educational plans, and I will manage to fulfil the school curricula*." They struggled with the feeling that the project would take too much time and that it would not be possible to deliver all knowledge and skills provided by school curricula to students. Most teachers considered a possible failure to fulfil the school curricula as the biggest obstacle and two scholars agreed with them. All the identified barriers and drivers are listed in Table 1.

Tab. 1 Barriers and drivers in open schooling implementation related to teachers´ role.

BARRIER IDENTIFIED	DRIVER IDENTIFIED
JUST ONE TEACHER INVOLVED IN THE SCP	It is better to cooperate with one or two other teachers in order to support each other
LACK OF EXPERIENCE WITH PROJECTS	Since experience from school projects helps a lot it is recommended to start with purely school projects and then continue with the open schooling projects
LACK OF SUPPORT FROM SCHOOL MANAGEMENT	Start the open schooling with usual school partners (families, NGOs, etc.) or become a part of a larger project – it is more acceptable for the school management
LACK OF TIME DUE TO THE SCHOOL CURRICULA SETTING	Change the mindset – different already taught themes can be delivered to students in another way and more competencies can thus be developed

Another cluster of barriers was uncovered regarding students. Lower interest in open schooling projects was recognized by older students (lower secondary education) and by boys. Two teachers stated that girls like working with outside community regardless of content – Teacher 1: "*I see more interest in girls. They are willing to spend time planning the project solution, and it is also easier for them to communicate outside the school"*. Teacher 2 - *It is always hard to convince the boys to work on it. Girls are more motivated."* Another obstacle was identified as misunderstanding of the teacher´s role just being a mediator of the project implementation process and not a leader. Three teachers mentioned the necessity of continuous control of particular steps in order to successfully achieve the goal of the project in a proper time. One teacher stated for example: "*They have too many ideas sometimes. I need to temper their enthusiasm to get the project done*. *Sometimes I have to remind them of the completion date".* All the mentioned barriers are summarized in Table 2.

Tab. 2 Barriers and drivers in open schooling implementation regarding the students.

BARRIER IDENTIFIED	DRIVER IDENTIFIED
OLDER STUDENTS ARE LESS MOTIVATED FOR OPEN SCHOOLING PROJECTS IMPLEMENTATION	Start with the primary school students and they will possibly adapt to do projects during the lower secondary education
BOYS ARE LESS MOTIVATED FOR OPEN SCHOOLING PROJECTS	Try to find appropriate role for boys and less motivated girls (e.g. Website or leaflet designers, technical arrangement of the project)
CLEAR AND REPEATED EXPLANATION OF THE TASK AND ROLLES OF DIFFERENT PROJECT STAKEHOLDERS IS NEEDED	Teacher should not hesitate to implement the continuous control and explain the project several times Teachers should put emphasis on the pupils´ responsibility for the implementation of the project

The third major challenge identified in our study dealt with finding appropriate stakeholders on the community side. People in the community are perceived as overwhelmed with various activities and they report themselves that way. It can be documented by this statement "*We had made arrangements with one organization, and the students were enthusiastic. After all, no one from that organization had time to work with us because they were overwhelmed with their responsibilities. Fortunately, parents helped."* Several possible ways to overcome such a barrier were recognized. First, it is advantageous to cooperate with families/parents. They support their children, especially the young ones in primary schools. The teachers can also try to involve parents who are "community agents"– members of non-governmental organizations (NGOs), charitable society, church association, policy-makers, company leaders etc. Another option is to cooperate with existing school partners, for example NGOs dealing with sustainability themes. In all interviews the need to address current topics of interest to the community was repeated.

CONCLUSION

The aim of our study was to analyse barriers that may hamper implementation of open schooling projects and to identify drivers helping the schools succeed. The study indicates that all the identified obstacles can be overcome. In particular, we would like to draw attention to two barriers emphasised by the interviewed experts. The first barrier is defined as a lack of time in subject/school curriculum for open schooling implementation. The severity of this is also evidenced by the fact that when we were looking for the schools/teachers for the open schooling project implementation, this was the most often mentioned reason to decline participating. One of the teachers described it as an inner struggler that needs to be overcome. We believe that imparting a large amount of facts is still considered a sign of quality teaching and the limitation of facts at the expense of soft skills and other competencies is perceived a negative and improper change.

Another often cited challenge was to find a teacher peer partner at school. Nearly all teachers mentioned that cooperation with one or two other teachers helps a lot. A peer mentoring possibility enable problems to be discussed, communication outwards from the school is easier and a diversity of ideas for working with students, community and open schooling topics can emerge. Moreover, students seem perceiving projects as more serious when more teachers are involved.

In our view these two barriers should be considered rigorously when thinking about open schooling implementation. Although other issues are also important, it seems that these two may decide whether or not the open schooling projects are implemented at all.

LIMITATIONS OF THE STUDY

Several limitations need to be considered regarding this study. Our findings cannot be generalised to all schools since the research was conducted with a limited number of them. Moreover, we did this research just in the Czech Republic. Although it can be viewed as a strong limitation we have shared our findings during the Horizon 2020 "Meaningful Open Schooling Connects Schools To Communities" project meeting and our findings are consistent with those in other countries.

Another limitation that needs to be considered is the willingness of teachers to participate in the open schooling project implementation. This is for sure limitation in uncovering barriers in project implementation. However, considering that one of the study goals was identification of the drivers for overcoming the barriers, the respondents sample selection is appropriate. For getting a more complete picture, another study with the teachers a priori refusing open schooling should be conducted.

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Project-based learning: Exploring the conditions for learning under the constraints of an epidemic

Gabriel Bánesz & Danka Lukáčová

Abstract

The use of project-based teaching in natural science and technically oriented school subjects is of great importance. Very important is mainly a coherence between the content of the project and situations of the real life. Such a situation was undeniably also the COVID-19 pandemic. The authors in their paper present their experiences with the use of project-based teaching under these conditions. The students were given a project-based assignment to collect objective data related to their working environment and physical conditions. A comparison of objectively measured (**ambient temperature, carbon dioxide content, relative humidity, combined lighting, noise)** variables with subjective opinions of students showed that assessment of work well-being is a very subjective matter.

Key words

Project-based teaching; Working environment; COVID-19

INTRODUCTION

The proven methods of teaching at universities include project teaching, which has its beginnings in the views and works of the American pragmatic educator Dewey from the beginning of the 20th century. According to Dewey, students in schools should learn precisely through solving problem situations, concrete activities and by their own activity (Dewey & Kilpatrick, 1935). Kilpatrick later contributed to the development of these ideas, who says that a project is any planned and independent activity in which a task is solved with the aim of solving it (Grecmanová & Urbanovská, 1997).

The main benefit of including project-based teaching in education is:

- Delivering contextualised learning by embedding technology into the natural environment and adapting learning content to context and learner reflection.
- Achieving the absolute interest of students, as the student solves the issue that concerns him as well as his pupils.
- Increasing student engagement during lessons by using real things instead of virtual ones. A physical thing provides immediate feedback that helps the student to gain knowledge and gives him the opportunity to correct mistakes (Damaševičius et al., 2017).

Future teachers of science and technical subjects should acquire relevant knowledge and skills related to project making (Lasauskiene & Rauduvaite, 2015). The most important thing is the harmony between the content of the project, its topic and real-life situations. Such a situation was undoubtedly also the COVID-19 pandemic, during which face-to-face teaching took place under special conditions (spring 2020-spring 2022).

The COVID-19 pandemic affected all areas of human activity for some time. Each industry responded to the constraints in its own way. Restrictions were set by the authorities in industry, in trade, services and in education. In education, there were basically two methods of education in Slovakia at all levels of education, from kindergartens to universities.

The first method of education was distance learning. This was done synchronously, i.e. in real time, or asynchronously. The second method of education began to be used after the release of some restrictions. At that time, the full-time form of education was renewed, with certain restrictions that the school set itself according to the instructions of the Public Health Office (Ploj Virtič et al., 2021; Šebo & Tureková, 2021).

At the University of Constantine the Philosopher in Nitra, the guidelines and recommendations of the Regional Office of Public Health were followed. The number of participants per lesson was limited to 20 people and everyone had to use an FFP2 respirator with reasonable distances between individuals. Only persons who met the VTO condition (V-vaccinated, T-tested, O-overcome the disease of COVID - 19) were allowed to enter the university premises.

Students often complained about the restrictions and said they felt uncomfortable. From these complaints came the idea for the students to prepare a project, the aim of which was to find out how the given situation affected the well-being of students during their studies at school (Alves at al., 2020).

RESEARCH DESIGN

The project was designed and realized by students of the 1st year of master's studies. They worked on it within the subjects *Measurement and measuring instruments* and *Statistical methods*. The project was created in such a way that, on the basis of measurable quantities (ambient temperature, carbon dioxide content, relative humidity, combined lighting, noise), subjective and objective factors that affect the well-being of students at work were evaluated.

A questionnaire taken from Marchand et al. (2014) was focused on subjective perception of factors of work environment during lectures. We supplemented the questionnaire with two items that were related to wearing respirators during lessons.

The pulse frequency, blood oxygenation of the students (measured together with an oximeter) and factors of the working environment (temperature, air humidity, CO_2 content, lighting and noise) were chosen as objectively measurable variables (Sadick & Issa, 2017). Temperature, air humidity and CO_2 were measured with a psychrometer, lighting with a luxmeter and noise with a sound level meter.

The assumption of the students was that the monitored values heart rate and blood oxygenation could be influenced by wearing FFP 2 respirators (Neuschlová, 2021).

Subjective perception of well-being was also monitored by the relevant items of the questionnaire. Each factor of the work environment was monitored by two questionnaire items.

The items of the questionnaire in Slovak language were formulated in the form of statements, while students were able to take a stand on the individual statements with the choice of answer: 1 - strongly agree, 2 - agree, 3 neither agree or disagree, 4 - disagree, 5 - strongly disagree. 102 university students were involved in the research. 86 students submitted the correctly completed questionnaire.

The aim of the project was to compare the results of objective measurements of work environment factors and subjective evaluations of students. Authors of this project formulated a prediction that wearing respirators would be perceived by university students as a very disturbing factor, as they were not used to this protective equipment. At the same time, it was necessary to find out whether measuring the oxygenation of students' blood while breathing through a respirator would show differences during the teaching unit. For the purposes of the project, we measured the oxygenation values of the blood of students at the beginning and at the end of the teaching unit (90 minutes). The main aim of the project can be divided into sub-aims:

A1: Measure the objective values of working environment factors (ambient temperature, carbon dioxide content, relative humidity, combined lighting, noise). A2: Measure the oxygenation of the blood of students at the beginning and end of the teaching unit. A3: Measure the heartbeat of students at the beginning and end of the teaching unit. A4: Measure whether there is a statistically significant difference between the oxygenation of students' blood at the beginning and at the end of the teaching unit. A5: Determine whether there is a statistically significant difference between students' heart rate at the beginning and end of the unit. A6: Assess students' subjective opinions on their well-being during lectures.

RESULTS OF THE PROJECT SOLUTION

Aim A1: Work environment factors were measured in the middle of the room during each teaching unit at a time interval of 10 minutes (Bilčíková et al., 2021). From the obtained data, we calculated an average value for each factor: ambient temperature - 23.2 °C, carbon dioxide content 1,573 ppm, relative humidity 44.4 %, combined lighting - 587.7 lx, noise - 55.9 dB (Bánesz & Lukáčová, 2022).

All the measured values of work environment factors did not exceed values designed by university classroom norms.

Aims A2 and A3: The obtained data on the students' blood oxygenation and heart rate were compiled into a table and the students evaluated them using the methods of descriptive statistics. Students were finding out whether the average blood oxygenation of students changed or not during a lesson. The average blood oxygenation of students was exactly the same at the beginning of the class and at the end of the class, 97.5 %. Thus, on average, there was no decrease in blood oxygenation. The mode, i.e. the most common measured value of students' blood oxygenation, was 99 % at the beginning of the class and 98 % at the end of the class.

Aim A4: The basis for evaluating the fulfilment of the A4 goal were the results of measuring blood oxygen saturation in students carried out in each group at the beginning and end of the teaching unit (90 minutes). We assumed that the oxygenation of the students' blood would be the same before and at the end of the class. Based on this assumption, we determined and subsequently verified the null hypothesis: H_0: The oxygenation of the blood of students at the beginning of the class is not different from the oxygenation of the blood of the same students after the end of the class.

We had two measurements of blood oxygenation from the same person, so we used a paired t - test. We performed the test in the MS Excel environment at the significance level $\alpha = 0.05$. The value of $p = 1$ is too high for us to reject the null hypothesis. The difference between the first and second measurements of student blood oxygenation is not statistically significant because the p value is not less than 0.05. There was no significant reduction in the oxygen content of the students' blood during the course.

Aim A5: The basis for evaluating the fulfilment of goal A5 were the results of heart rate measurements of students carried out at the beginning and end of the teaching unit (90 minutes). We assumed that the heart rate of students would be the same before the start of teaching and at the end of teaching. Based on this assumption, we determined and subsequently verified the null hypothesis: H_0: The pulse of students at the beginning of the class is not different from the pulse of the same students after the end of the class. We performed the test in the MS Excel environment at the significance level $\alpha = 0.05$. Value $p < .001$ indicates that we reject the null hypothesis. The heart rate of students at the beginning of teaching differs statistically significantly from the heart rate of students after the end of teaching. By comparing the averages and modes of the heartbeat before and after teaching, we can conclude that the heart rate of students decreased statistically significantly. The reduction in heart rate was due to the students being physically active (walking) before the start of the class, sitting during the class and virtually not doing virtually no physical activity. There was no increase in students' heart rate during the class due to the use of a respirator.

Aim A6: After six teaching units while the duration of each unit was ninety minutes, students completed a questionnaire to determine their attitudes towards selected work environment factors. The questionnaire was created in electronic form in Slovak language (Google form) according to Marchand (Marchand, 2014). Students commented on each item of the questionnaire on a scale of 1 strongly agree, 2 agree, 3 neither agree or disagree, 4 disagree, 5 strongly disagree. We assigned a numerical value to the individual statements in order to be able to process the results of the students' statements obtained by the questionnaire. We calculated the average ratings of individual questionnaire items (Fig. 1), while a lower value signals a higher influence of the factor on the student.

All items of the questionnaire, with the exception of items 3 (*SD* = 1.1), 5 (*SD* = 1.2), 6 (*SD* = 1.1), 11 (*SD* = 1.1) and 12 (*SD* = 1.1), have a higher average rating than 3, while item 3 is only 0.2 points away from the average rating. This means that the respondents' statements were more disagreeable in all other items, hence the monitored environmental factors did not limit them in their work performance.

All the items except 3, 5, 6, 11 and 12 have average grading above 3. This means that respondents´ expressions were in all other items more disagreeable. This means that they do not see the factors as restricting. Air humidity, lighting and noise were marked by these respondents as ones that do not affect work well being during classes.

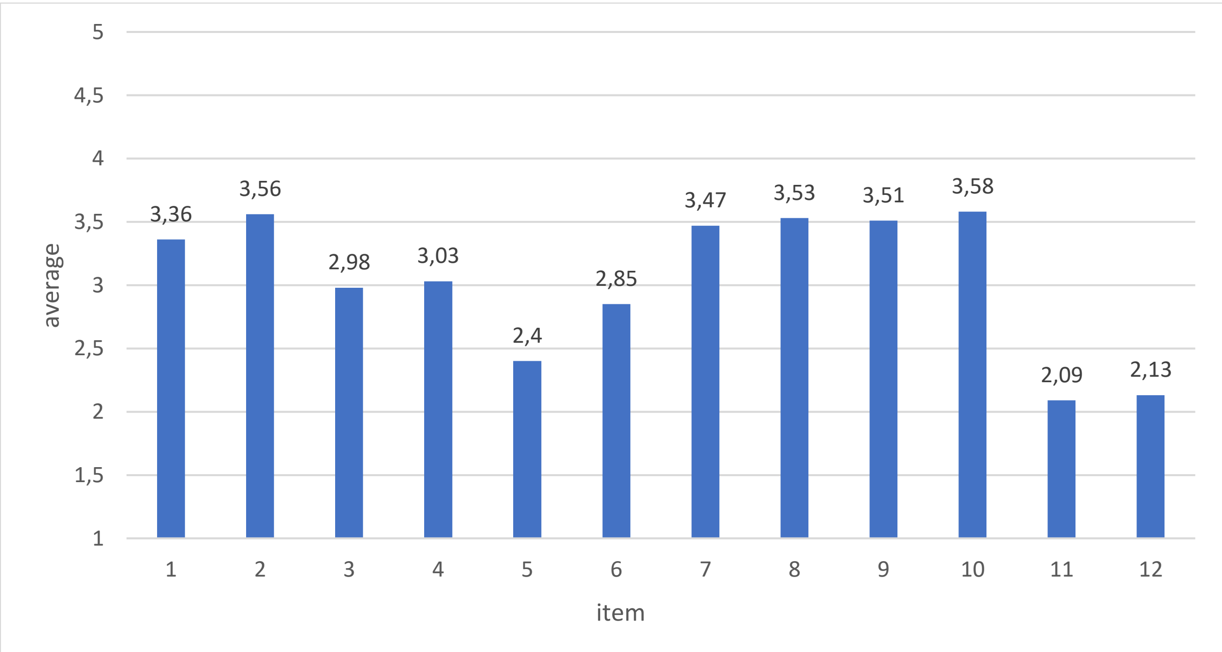

Fig. 1 Average values of respondents' answers to questionnaire items

Humidity, ambient temperature, lighting and noise were identified by respondents as factors that do not affect their attention and well-being in the classroom. Item 5 examined whether the exhaled air in the classroom negatively affected the students' work performance. Similarly, item 6 was aimed at determining whether students' concentration in the development of assignments was negatively affected by the exhaled air in the room. Apparently, it was the wearing of a respirator during teaching that caused most students to evaluate the air in the room as exhaled and negatively affecting their learning performance (2.40), resp. when concentrating on solving assignments (2.85). From the graph shown in Figure 1 we see that the last two items of the questionnaire, which focused on determining the effect of the respirator on the work performance of students, achieved the lowest scores of all items of the questionnaire (2.09 and 2.13). It follows that of all the factors monitored, students were most affected by respirators. According to their subjective evaluations, they had a significant impact on their performance in the interpretation of the curriculum and independent work (item 11).

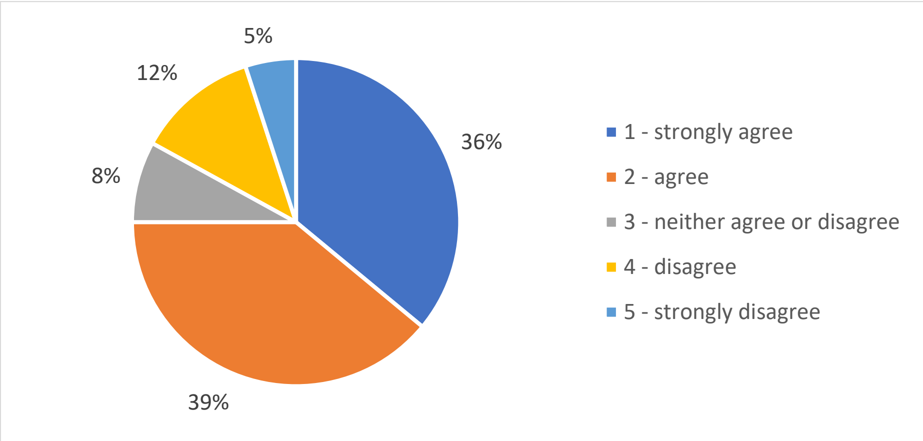

Fig. 2 Respondents' answers to item 12

As many as 65 students, which is 75 % of respondents, strongly agreed, resp. agreed that the use of a respirator had a negative effect on their performance in class (Figure 2). Similarly, 75 % of students in item 12 reported having difficulty concentrating and working independently due to the use of a respirator.

DISCUSSION AND CONCLUSION

An interesting observed factor was the heart rate of the respondents. It was an objective value, which was measured using an oximeter in the participants of the training in the given period. The measured values showed that the heart rate in the students decreased. The students did not perform any difficult physical work. During the lessons, they sat for 90 minutes and watched the teacher's explanation, wrote notes, or worked out assignments on computers. Wearing of respirator did not cause an increase of heartbeat.

Another objectively measured value was the value of blood oxygenation. Based on the results of the statistical test, we can say that there was no statistically significant difference in the values of blood oxygenation at the beginning and end of the lesson (the null hypothesis was confirmed). Wearing of respirator did not cause an increase of heartbeat.

The analysis of objectively measured values (blood oxygenation and heart rate) and the subjective attitudes of students to selected environmental factors show that the evaluation of students themselves is very subjective. According to the respondents, wearing respirators was perceived as restrictive. Objective values showed that wearing a respirator did not affect heart rate or blood oxygenation. Nevertheless, the subjective opinions of students cannot be underestimated, because their personal feelings may have influenced their performance at school, such as concentration, concentration on working with a computer, etc. (Tureková & Marková, 2018) which could cause for example: headache, fatigue etc. The effect of long-term wearing of a respirator can according to other authors cause unwanted symptoms such as fatigue, headache and the loss of concentration (Geiss, 2011).

A project focused on the evaluation of subjective and objective factors, that influence the well-being of students at work, implemented by the students themselves, showed how simple and easily accessible means can be used to realize a project with a practical impact on students' lives. The results of the project surprised even the students themselves. Even those students whose opinions were the subject of measurement in the project had the opportunity to confront their subjective feelings with the objectively conducted measurement and very often changed their opinion about wearing respirators. Among other things, the project thus contributed to calming down the difficult work atmosphere caused by non-traditional teaching restrictions. Through the implementation of the project, the students learned that the project can also be made from current situations. In our case, it was to " make the best out of a bad situation". Such a project can be conducted with simple technical means, the project needs to be evaluated and its results interpreted. The authors of the article showed their students how even an unpleasant life situation can be used to implement a meaningful project.

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Integrated STEM task and its use in the pre-service teachers' training and in-service teacher professional development: How do they understand and assess it?

Veronika Rajtmajerová & Lukáš Rokos

Abstract

This paper provides an introduction of an integrated task that was created as an example of linking the content of the educational areas Man and Nature and Mathematics and its applications in the *National Framework Educational Programme for Elementary Education*, so it follows the STEM approach. The task was primarily created for use at the lower secondary level, but we describe its further use in the pre-service teacher training and in-service teacher professional development courses. We focussed on understanding the goals of the selected parts in this task, as well as the purpose of the integration and approaches to its assessment. In total, 58 pre-service teachers and 43 in-service teachers worked with this task and were involved in the following discussions. There were found differences between pre-service and in-service teachers in the identification of the goals, purpose of integration, as well as approaches in the assessment of this task.

Key words

Integrated task; STEM; expected outcomes, pre-service teachers, in-service teachers

INTRODUCTION

In recent years, integrated teaching has come to the attention in (not only) STEM subjects. One of the purposes was to increase the students' activation. Specifically, we can talk about cognitive activation which is a state of harmony between the motivation of students to learn and well-connected content in subjective reality and reconstruction in intersubjective reality (Slavík et al., 2017). The tasks with cross-curricular content have been implemented in the textbooks step by step, but sometimes their contexts are plausible, and the integration of contents is very low (Rokos et al., in prep.). Thus, it is necessary to precisely define the essence of integrated tasks, the principles of their creation, and the expected goals for effective implementation. For this reason, it is essential to familiarise pre-service teachers as well as in-service teachers with integrated tasks. It is also important to discuss their understanding of integration, personal perspectives in relation to challenges and limits.

INTEGRATED TEACHING AND CROSS-CURRICULAR RELATIONS

Integrated teaching is understood as teaching of multiple educational contents in one integrated subject, with the aim of implementing cross-curricular relationships (Koldova et al., 2020). The aim of integrated teaching is to achieve greater interconnection of learning content in subjects (Koldova et al., 2020) and at the same time to obtain complex and comprehensive knowledge from the scientific field (Rakousova, 2008). Integrated teaching enables the application of various (cross-curricular, logical, structural, and analogical) links in the content of individual educational areas and the interconnection of theoretical knowledge with practical activities of students (Kelley & Knowles, 2016). The implementation of integrated teaching in schools can be based on integrated topics included in traditional teaching subjects, which may later be the basis for integrated forms of teaching and the content core for newly created integrated subjects, in which the interconnection of the contents of several scientific areas will be used in a more complex way (Podrouzek, 2002).

Cross-curricular relations are defined in the Czech pedagogical dictionary (Prucha et al., 2009, s. 155) as links between individual subjects that exceed the subject framework, supporting the understanding of the context of partial contents. Cross-curricular relations are therefore a means of integration in which students acquire complete knowledge.

STEM

STEM is the acronym for the integration of science (S), technology (T), engineering (E), and mathematics (M) education. The ideas of this approach date back to the 1990s (Holmlund et al., 2018). Research in this area is relatively intensive (Johnson et al., 2020), but especially abroad (English, 2016), and interest in this field is increasing in the Czech educational environment now (Janouskova et al., 2019; Koldova et al., 2020; Rusek et al., 2022). The STEM approach allows us to use similarities in individual disciplines, but also their diversity, to look at the issue from different perspectives (Hallström & Schönborn, 2019). It is also necessary to take into account the difficulty of problem and/or integrated tasks because the workload can be significantly higher for students in such cases (Ruiz-Gallardo et al., 2011) and the successful implementation of the task is more dependent on the ability of teacher to present the phenomena clearly (Keiler, 2018). Another big question is how to approach the assessment of student performance (Rönnebeck et al., 2018).

METHODS

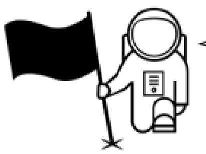
Identification of the topic for the integrated task

At the beginning, a content analysis of the National Framework Programme for Elementary Education (MSMT, 2021) was performed, in which suitable places for the integration of educational contents were identified. That means topics with cross-curricular content and/or repeating topics in different subjects. Based on this analysis and comparison of the findings, the topic Space was chosen, because it connects the educational area Man and Nature (specifically Biology, Geography, and Physics), and educational area Mathematics and its applications (e.g. the area Dependencies, relationships, and work with data) and it repeats in various subjects and is presented from different perspectives, so it seems to be suitable for the integration of educational contents. A subsequent content analysis (Mayring, 2021) of selected school educational programmes (N = 16) with the same foci and textbooks from Biology, Geography and Physics (N = 8) had been performed and it supported the previous finding and also helped to select the specific topic, the Moon. We also worked with the results of other textbook analyses (e.g. Vojíř, 2021; Maňák & Klapko, 2006). Following the results, an integrated task was created and it combines knowledge from different areas into a functional unit. The created task is a complex task designed for students at the lower secondary level and the time allocation for the implementation of the task is 2 x 45 minutes (or more – based on the situation how many topics are new for the students), or it can be used within a project day.

A few examples of activities included within the whole task are presented below. The activity in Figure 1 includes content from the educational area Man and Nature, specifically from the subject Physics and the education area Mathematics and its applications (Dependencies, relationships, and work with data).

1. Calculate:

a) How big gravitational force will a man weighting 80 kg be attracted to the Earth?
b) How big gravitational force will a man weighting 80 kg be attracted to the Moon?



Help:
The gravitational force is calculated using the formula $F_g = m \cdot g$, in which F_g is the gravitational force (N), *m* is the weight (kg) and *g* is the acceleration of gravity (m/s²).

Since the gravitational force of the Moon is six times less than on the Earth, the gravitational acceleration on the Moon is equal to 1.6 m/s², while on the Earth this gravitational acceleration is equal to approximately 10 m/s².

Record your results in the table:

	m (kg)	*g* (m/s²)	F_g (N)
Earth	80		
Moon	80		

2. Calculate the following two tasks and record the results in your own table.

a) How big gravitational force will attract an 80 kg astronaut with 90 kg of equipment on the Moon?
b) What is the weight of an astronaut if he is attracted to the Moon by a gravitational force of 112 N?

Table:

Fig. 1 Illustrative example No. 1

The activity in Figure 2 extends to the educational area Man and Nature (subject Biology) and the cross-curricular theme Environmental Education (thematic area Basic Conditions of Life).

3. There is neither atmosphere nor liquid water on the Moon. The temperature rises to 123 °C during the day and drops to -230 °C at night there. Is it possible for vegetation to grow on the Moon? Justify your response.

Fig. 2. Illustrative example No. 2

This activity (Fig. 3) deals with solar and lunar eclipses. Students should draw the positions of the Sun, Moon, and Earth and describe these drawn objects after scanning the QR code. The activity connects the educational area Man and Nature (subjects Physics and Geography) with the educational area Informatics (Data, information, and modelling).

8. The Moon orbits Earth in approximately one calendar month. During the orbit, the Moon is illuminated by the Sun, and there is an alternation of phases. If the Moon, Earth, and Sun are in a straight line, an eclipse occurs. However, it is important to distinguish between a solar eclipse and a lunar eclipse.

Use the animation under the QR code to plot the position of the Sun, Moon, and Earth.

a) during a lunar eclipse
b) during a solar eclipse

Fig. 3. Illustrative example No. 3

Pre-service and in-service teachers focus groups

We worked with two research questions in this pilot study: 1) To what extent are respondents able to identify the goals of the activities included in the task? and 2) Are there differences in understanding the purpose, opportunities, and limits of integrated task between pre-service and in-service teachers?

In order to answer these questions, we introduced the created task to pre-service teachers (N = 58) and in-service teachers (N = 43). All respondents attended courses at the Faculty of Education of the University of South Bohemia in Ceske Budejovice. At first they solved the task in seminar lessons (N_1 = 20; N_2 = 21; N_3 = 17; N_4 = 12; N_5 = 16; N_6 = 15) step by step as students do at school and filled the worksheet. After that four focus groups with 5 members each were established (two with pre-service teachers, and two with in-service teachers for the open discussion about specific aspects related to task and integration of educational contents. The discussion took approximately 30 – 35 minutes.

RESULTS

It can be said that no significant difference in solving the task was observed between pre-service and in-service teachers at this phase. When the worksheets were analysed, there was found that in-service teachers were a bit more creative in their ideas how to solve selected issues and tried to find various solutions.

The next step was critical work with the task in relation to identifying expected outputs. In this case, the respondents could use the National Framework Programme for Elementary Education (MSMT, 2021). There are selected expected outcomes identified most often in Table 1 as well as the comparison between pre-service and in-service teachers.

Tab. 1. The most often identified expected outcomes of the National Framework Programme for Elementary Education in relation to created tasks (MSMT, 2021).

EXPECTED GOALS FROM NATIONAL FRAMEWORK PROGRAM FOR ELEMENTARY EDUCATION STUDENT…	Pre-service (N = 58)	In-service (N = 43)
ILLUSTRATIVE EXAMPLE NO. 1 (SEE FIG. 1)		
▪ **(F-9-2-03) Determine, in a specific simple situation, the types of forces acting on the body, their magnitudes, directions and resultant,**	44	41
▪ **(M-9-2-01) searches, evaluates, and processes data,**	50	39
▪ **(M-9-2-04) expresses the functional relationship using a table, equation, or graph,**	55	40
▪ **(M-9-2-05) mathematizes a simple real situation using functional relationships**	29	37
ILLUSTRATIVE EXAMPLE NO. 2 (SEE FIG. 2)		
▪ **(P-9-1-01) Distinguishes the basic manifestations and conditions of life and orients in the given overview of the evolution of organism,**	52	43
▪ **(P-9-3-02) explains the principle of basic plant physiological processes and their use in plant cultivation,**	43	41
▪ **(P-9-7-02) clarifies the basic principle of the existence of living and non-living components of an ecosystem by using the examples,**	48	37
▪ **(Z-9-2-03) compares the effect of internal and external processes in the natural world and their impact on nature and human society.**	23	39
ILLUSTRATIVE EXAMPLE NO. 4 (SEE FIG. 3)		
▪ **(F-9-6-05) Uses the law of straight-line propagation of light in a homogeneous optical medium and the law of light reflection to solve problems and tasks,**	45	39
▪ **(F-9-7-01) explains (qualitatively) by knowledge of gravitational forces the motion of the planets around the sun and the moons around the planets,**	53	42

▪ **(Z-9-1-01) organizes and adequately evaluates geographic information and data sources from available cartographic products and articles, graphs, diagrams, statistical, and other information sources,**	24	38
▪ **(I-9-1-03) defines the problem and determines what information will be needed to solve it; models the situation using graphs or similar schemes; compares designed model with other models to solve the same problem and selects a more suitable one, justifying the choice,**	15	38
▪ **(I-9-1-04) evaluates whether all the data needed to solve the problem are in the model; finds a mistake in the model and corrects it.**	10	35

Legend: F – Physics, M – Mathematics, P – Biology, Z – Geography, I – Informatics

The list in Table 1 is not complete; the respondents identified more areas in partial activities (including non-STEM subjects). We can see that the selection by pre-service teachers and in-service teachers was not the same. In-service teachers tried to find more inter-curricular connections and identified more expected goals. They very often went into non-STEM subjects too (only 6 pre-service teachers selected expected goals out of STEM subjects). It is clear from Table 1 that the expected outcomes from Chemistry or Technology did not appear anywhere, but Technology was mentioned in the activity related to the tide and the possibilities of its use. One teacher suggested including more chemical content in the activities (e.g., structure of the Moon and the elements in it).

These findings could be a partial answer for the second research question, whether there are differences in understanding the purpose, opportunities, and limits of integrated task between pre-service and in-service teachers. We addressed another two key questions to four focus groups: I) Where should the task be placed in the curriculum?; II) How can we assess student performance? Most of the respondents (80% pre-service teachers and 60% in-service teachers) stated that they would implement in the 9th grade because students already have all necessary knowledge to solve individual tasks. We can assume that pre-service teachers as well as some of in-service teachers do not understand the purpose of integration properly because they explained their response that they would include these activities as project days at the end of the school attendance. This decision seems to lose the potential for integrated learning because it is only a repetition of the students' knowledge. Pre-service teachers had a problem with the question related to assessment, but it is not a surprising finding because they do not have enough experience with this issue. They were still more focused on summative assessment. In-service teachers also agreed that the assessment approach in such a complex task is crucial point that has to be taken into consideration, especially with the emphasis on the potential for use of the formative assessment. They would support the idea of providing some guidelines and an example of good practise related to the assessment of integrated tasks.

CONCLUSION

Of course, we perceive the presented study as a pilot one, as the sample of respondents is not very large. On the other hand, we have verified that this way of working with integrated tasks is suitable not only in the pre-service teachers training but also in professional development course. If we want to effectively implement the integrated task in teaching, it is necessary to communicate its key features, especially in relation to the expected outcomes and goals of such activities. Pre-service and in-service teachers should get familiar with such type of tasks and teachers educators are able to receive the feedback and have opportunity to see the ideas and concerns connected to this topic. These ideas and concerns could help if we want to prepare courses for these target groups in the faculty and put emphasis on the selected issues. It seems that it would be very useful to increase the time allocation dedicated to the integrated and cross-curricular issues in the courses in pre-service teachers training and in-service teachers professional development courses so we can discuss the purpose and assessment issues related the integrated tasks.

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High school students' perception of selected activating teaching methods

Valerie Chvojová & Edvard Ehler

Abstract

Activating teaching methods are effective strategies for improving the education processes in natural sciences. Their popularity was reported to significantly differ between teachers and students. This contribution presents the results of students' subjective perception of eleven selected activating teaching methods which were evaluated by the students themselves using an attitude questionnaire created from the IMI tool. An Index of Subjective Evaluation of Teaching Methods was introduced for the complex evaluation and comparison. According to the index, inquiry-based education received the highest score of all methods mentioned while the critical thinking method obtained the lowest score.

Key words

Activating teaching methods; Inner motivation; High school; Attitude questionnaire

INTRODUCTION

Activating teaching methods are classified as effective teaching methods that focus on each student and develop his/her abilities, skills and also shape his/her personality. These methods are therefore important for integration of different types of thinking, intuitions and experiences with new knowledge and experiences from practical life. Using these methods students learn to search for valid information and connect it to the existing network of knowledge (Sieglová, 2019). The importance of activating teaching methods in teaching is irreplaceable, as these methods most often target a problem that the students are trying to actively solve. By solving the problem, students use different ideas, develop their creativity, independence and also responsibility. Another important feature of activating teaching methods is that unlike traditional teaching methods they don't just provide complete information beforehand, but they help students understand the information, which they adopt and sort themselves (Uitto &Kärnä , 2014).

The topic of activating teaching methods is being discussed more and more, not only at universities and international conferences, but also in many research papers. Researches have focused on a large scale to find out the effectiveness, popularity and the use of activating teaching methods among teachers, but they do not focus in the depth on their evaluation by students (Al-Bayati & Mizban, 2022; Ismail, 2023; Khasawneh et al., 2023; Le & Nguyen, 2022; Orosz et al., 2023; Rafailovna , 2022; Setianingsih et al., 2021; Utami et al., 2023; Wahid & Sudirman, 2023). Research by Vácha and Ditrich

(2016) shows that inquiry-based education increases the interest in discussed topic and increases the popularity of the subject. Another research carried out by Al-Bayati and Mizban (2022) indicates that using brainstorming increased academic achievement of students. Khasawneh et al. (2023) detected that students taught by inquiry-based education had overall better results than student taught by traditional teaching methods.

In general, there is the insufficient amount of information about how students perceive and evaluate different activating teaching methods. That is why we have carried out our study.

RESEARCH AIM AND QUESTIONS

This research was carried out as the research project the master thesis by Chvojová (2022). The main aim of the work was to compare eleven activating teaching methods through an attitude questionnaire among students of the Medical High School (SVZŠ) in Kladno, the Czech Republic and for this purpose to design a learning block for the topic of the muscular system, in which the selected methods were implemented. Furthermore, some several sub-goals were determined: a) to compare a pre-test and a post-test results to assess students' knowledge b) to analyze how students evaluate individual activating teaching methods. For accomplishing the stated goals, the following research questions were set:

1. What effect does a completing the educational program have on students' knowledge?

2. How the students evaluate the individual proposed activities on the monitored scales: interest/pleasure, perceived competence, effort/importance, pressure/tension, and value/usefulness?

METHODOLOGY

A quantitative approach was chosen to answer the research questions. The research was carried out on a sample of 112 students aged between 15 and 18, of which there were 100 women and 12 men at the Medical High School (SVZŠ) in Kladno. Altogether, there were four classes taught, where there were three classes with the specialization of Practical sister (1^{st} year) and one class was from the Medical Lyceum (2^{nd} year).

For our study, we selected and tested the following activating teaching methods: brainstorming (M1), guided discussion (M2), snowball method (M3), inquiry-based education (M4), I.N.S.E.R.T. method (M5), work with text (M6), concept map (M7), mind map (M8), critical thinking method (M9), rounds (M10) and CLIL (M11). These methods were chosen because of their frequent representation in the Czech didactic literature, and also because of their important functions in the learning process of students (Sieglová, 2019). Most often, the selected teaching methods were implemented in the organizational form of the group, since this organizational form develops cooperation between students, and they have the opportunity to solve problems with more demanding tasks and use critical thinking (Zormanová, 2014).

The selected methods were used in the topic of the muscular system, which was taught at the time of the research according to the thematic plan in the classes provided. A total of five lessons were taught in each class and the sixth lesson was devoted to the discussion and evaluation of the entire learning block. Students completed a pre-test in the first lesson before the start of the learning block, which was used for the subsequent one comparison in the shift of knowledge with the completed post-test from the fifth lesson. The tests were issued online, and contained 10 closed questions with four answer options, for one question with eight options. Each question had only one correct answer. There was 1 point for each question thus the maximum number of points was in total 14. Both tests were compiled from identical questions however the individual answers were interspersed. The difference between the results of the pre-test and post-test was tested by a paired t-test (Mowery, 2011).

After each lesson (5 in total), students received 5-10 minutes before the ending of the lesson an attitude questionnaire, from which the feedback on the used activating teaching methods was obtained. The first attitude questionnaire was compiled for methods M1, M2, M3. The second was compiled for method M4, the third for methods M5, M6, M7. The fourth was compiled for methods M8, M9 and the last one for methods M10 and M11. The attitude questionnaire was compiled from the IMI tool (Inventory of Intrinsic Motivation) and had united structure for every method (available for viewing) (McAuley et al., 1989). In each questionnaire, students evaluated activating teaching methods in the scales of interest/pleasure, perceived competence, effort/importance, pressure/tension and value/usefulness. Four statements were selected for each scale for which the students chose values from 1 to 7, with the number 1 meaning completely false, the number 4 to some extent true and number 7 absolutely true. Cronbach's alpha, average and standard deviation were calculated for all items in the attitude questionnaires.

To summarize the results of each activating teaching method across all questionnaire categories an Index of Subjective Evaluation of Teaching methods (ISET) was introduced:

$$ISET = \sum \frac{(\bar{x} - avg)}{SD}$$

The ISET was constructed as the difference in the average score of each method ($\bar{x}$) against the total average of all methods in the given scale (avg), normalized by the standard deviation of the given scale. These values were added up for the subjectively positive scales such as interest/pleasure, perceived competence, effort/importance, value/usefulness, while the value of the subjectively negative scale pressure/tension was subtracted.

In detail:

$$ISET = \left[\frac{(\bar{x} - avg)}{SD}\right]_{\frac{interest}{pleasure}} + \left[\frac{(\bar{x} - avg)}{SD}\right]_{percieved\ competence} + \left[\frac{(\bar{x} - avg)}{SD}\right]_{\frac{effort}{importance}} + \left[\frac{(\bar{x} - avg)}{SD}\right]_{\frac{value}{usefulness}} - \left[\frac{(\bar{x} - avg)}{SD}\right]_{\frac{pressure}{tension}}$$

RESULTS AND DISCUSSION

The total number of students from all classes was 112, but some of them were absent due to the covid pandemic, therefore the number of students varied from the set number. The completed pre-tests and post-tests were obtained from 88 students (78.6 %), of which there were 10 men and 78 women. No student had a worse post-test knowledge score than the pre-test knowledge score, 7 students had the same point result in both tests and 81 students had a higher point result in the post-test than in the pre-test, that means 92 % of the students improved and had a better knowledge result (t = XY, $p < 0.005$)

The first attitude questionnaire was completed by 101 students (90.12 %), the second by 103 students (91.96 %), the third by 101 students, the fourth also by 101 students and the last one by 91 students (81.25 %). See table 1 for the results of the selected teaching methods from the attitude questionnaires. Activating teaching methods were labelled as M1–M11 and these abbreviations mean M1 for brainstorming; M2 for guided discussion; M3 for snowball method; M4 for inquiry-based education; M5 for I.N.S.E.R.T. method; M6 for work with text; M7 for concept map; M8 for mind map; M9 for critical thinking method; M10 for rounds and M11 for CLIL.

Tab. 1 Results of average, standard deviation and total average from attitude questionnaires for each activating teaching method

SCALES	INTEREST/ PLEASURE		PERCEIVED COMPETENCE		EFFORT/ IMPORTANCE		PRESSURE/ TENSION		VALUE/ USEFULNESS	
	avg.	SD	avg.	SD	avg.	SD	avg.	SD	avg.	SD
M1	4,650	1,637	4,537	1,679	4,032	1,636	2,220	1,847	4,713	1,840
M2	4,452	1,610	4,265	1,505	3,725	1,561	2,319	1,927	4,713	1,740
M3	5,010	1,961	4,723	1,731	4,228	1,703	2,260	1,848	4,936	1,910
M4	4,951	1,964	4,585	1,738	4,240	1,710	1,956	1,586	4,854	1,853
M5	4,327	1,947	4,441	1,883	4,168	1,673	2,146	1,739	4,386	1,873
M6	4,373	1,994	4,062	1,788	4,169	1,778	2,280	1,849	4,760	2,040
M7	4,356	2,060	4,334	1,760	3,933	1,721	2,176	1,810	4,455	2,008
M8	3,944	1,496	4,366	1,641	4,307	1,496	2,881	1,642	3,903	1,556
M9	3,832	1,445	4,005	1,663	4,141	1,581	2,324	1,835	3,916	1,535
M10	4,982	1,603	4,547	1,826	4,390	1,640	2,091	1,709	4,585	1,942
M11	4,802	1,699	4,451	1,747	4,456	1,658	2,324	1,833	4,769	2,006
TOTAL AVG.	4,516		4,392		4,163		2,271		4,545	

Activating teaching methods were evaluated differently in individual scales by students. In the scale of interest/pleasure the highest score received the M3 and the lowest score the M9. The same result was detected in the scale of perceived competence. In the scale effort/importance it was M11 that received the highest score and M2 the lowest score. In the scale of pressure/tension M8 received the highest score and M4 the lowest score. These results show that students felt most under pressure during M8 and on the other side most relaxed during M4. During M4 students worked independently and tried to work with the microscope. They had a whole lesson to do this activity, which cannot be said for M8 where they had limited time. Presumably that the teacher's limited time and personality may have created a perceived sense of pressure since teacher has significant effect on how students feel (Blazar & Kraft 2017). In the scale of value/usefulness M3 had the highest value and M8 the lowest value.

The summarized results for all methods for ISET are presented in table 2, together with the partial results for each method ($(\bar{x} - avg)/SD$). The results of the subjective index are shown in order in table 3. In this table, the activating teaching methods are sorted from the highest value of ISET to lowest - from the students' best-rated method to the worst.

Tab. 2 Results of the index of subjective evaluation of teaching methods (ISET)

	INTEREST/ PLEASURE	PERCEIVED COMPETENCE	EFFORT/ IMPORTANCE	PRESSURE/ TENSION	VALUE/ USEFULNESS	ISET
M1	0,331	0,663	-0,629	-0,217	0,477	1,060
M2	-0,159	-0,584	-2,109	0,209	0,477	-1,629
M3	1,222	1,514	0,313	-0,047	1,109	4,205
M4	1,077	0,883	0,374	-1,354	0,878	4,566
M5	-0,469	0,224	0,027	-0,535	-0,449	0,337
M6	-0,355	-1,513	0,030	0,039	0,610	-1,267
M7	-0,396	-0,267	-1,106	-0,409	-0,253	-1,613
M8	-1,417	-0,119	0,694	2,629	-1,818	-5,289
M9	-1,695	-1,775	-0,104	0,231	-1,784	-5,588
M10	1,152	0,707	1,096	-0,775	0,115	3,846
M11	0,708	0,267	1,414	0,230	0,637	2,795

The highest value of the ISET was obtained for M4 and the lowest for the M9. Through M4, students had the opportunity to try out a new activity and also freedom at work, which could be the reason for such a positive evaluation. M3, M10 and M11 were also among other highly rated teaching methods. M3 is interesting since at the beginning every student works alone and then students gradually join together and thus the size of the groups increases (Sitná, 2013). None of the other selected activating teaching method has this type of structure. We assume that this could be the reason why students rated snowball method in these scales the best.

Tab. 3 Comparison of the results of the ISET of teaching methods

ORDER	METHOD CODE	METHOD NAME	ISET
1.	M4	inquiry-based ed.	4,566
2.	M3	snowball method	4,205
3.	M10	Rounds	3,846
4.	M11	CLIL	2,795
5.	M1	Brainstorming	1,060
6.	M5	I.N.S.E.R.T.	0,337
7.	M6	work with text	-1,267
8.	M7	concept map	-1,613
9.	M2	guided discussion	-1,629
10.	M8	mind map	-5,289
11.	M9	critical thinking	-5,588

M10 belongs to discussion methods, it is not as cognitively demanding for students as other activating methods used (Sieglová, 2019; Sitná, 2013). This may be the reason why students rated it highly. Interestingly, guided discussion had a significantly lower score even though it is an equally challenging method. We believe that the shape of the circle and the close contact of the students within it, make rounds more attractive method than guided discussion. In M11 is used English as a main language and for students it could be challenging to use a foreign language in a subject where only Czech is normally used. It is proven that students who have worked with CLIL method have improved significantly foreign language knowledge and also better understood new information in lesson (Le & Nguyen, 2022).

In contrast the lowest rated activating teaching methods were M9, then M8 and M2. M9 could have these results due to its high level of cognitive demands (Carbogim et al., 2019). Nonetheless, author Utami et al. (2023) indicated that it is crucial that teachers use the critical thinking method, because it helps students to develop their competences for a future career. Students who participate in activities aimed at developing critical thinking should be able to understand the logical principles of reasoning and metacognition, be able to better solve problems, search for information, use knowledge, and evaluate the quality of claims found (Carbogim et al., 2019). The lowest perceived usefulness of M8 was likely to be that students wrote their thoughts in it, which were not of equal value to them as the information dictated by the teacher, as most of the students reported a preference for long notes from classes. According to the authors Buzan & Buzan (2006), Sitná (2013) and Zormanová (2014), the mind map should be a fun and useful method that develops key competencies as well as all brain functions. For the scale of effort/importance was the lowest rated M2. M2 was a familiar method for students, that they had already tried several times and therefore did not have to put in as much effort as with other methods that they have not yet tried and had no practice with. The aim of this method is to develop communication between students so that they are able to express their own ideas, opinions and feelings, to teach students to listen to others and to structure a logical response. Again, these skills are essential in students' everyday and professional lives (Gokhale & Machina, 2018).

Many studies indicate that students prefer methods in which they could be active, manipulate objects and solve problems (Aminov et al., 2021). In this case the highest ISET score received M4 and we assume it was caused by manipulation with a microscope, withing M3 it was working with information and combining into groups of different sizes, with M10 it was actively answering the given question and writing down the ideas of classmates and for M11, it was working with flashcards and finding their correct classification for a given muscle in both languages (Czech and English).

We would like to mention that it surely does not mean the lowest rated activating teaching methods should not be used. Each method is essential in teaching, it is up to the teacher how to use it, but it is necessary to use activating teaching methods and thus develop the students' key competences (Konopka et al., 2015). Quality teaching and learning take place in a research-rich environment, where students use the latest knowledge and improve their research skills. This leads students to complete higher cognitive goals and encourages them to develop academic literacy as well as general skills that can directly applicable in the labour market (Ćirić, 2022).

CONCLUSION

This research aimed at finding which activating teaching methods are positively perceived among students of the Medical High school from the age of 15 to 18. The learning block built on these methods proved to be efficient in acquiring new knowledge in human biology topics. It also provided us a basic insight into students' opinions about these modern methods. Our results indicate that in the interest/pleasure and perceived competence scale the students rated the highest snowball method (M3) and the critical thinking method (M9) the lowest. In the scale of effort/importance, the CLIL method (M11) had the highest score and the guided discussion (M2) the lowest score, in the pressure/tension scale, students rated inquiry-based education (M4) the highest and the lowest mind map (M8) and in the value/usefulness scale, students rated the snowball method (M3) the highest and the lowest mind map (M8). Our overall results summarized by ISET index clearly stated that the students subjectively rate inquiry-based education (M4), snowball method (M3) and rounds method (M10) as methods with the highest score, while the critical thinking (M9), mind map (M8) and guided discussion (M2) with the lowest score.

Our results could help in the selection and the usage of some of the teaching methods. Furthermore, they could also serve to motivate teachers not to be afraid to use activating teaching methods and also as an inspiration to prepare an active teaching lesson. We are aware that our pilot study has its own limitations, to be precise it is the low number of respondents, the application of research to only one type of high school, and the use of merely one topic. We intend to alleviate these limitations in our future research of activating teaching methods.

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Data availability

Attitude questionnaire:

https://docs.google.com/document/d/17hX6clXFOBWgcSpQk_z8Ui7uukbZrSmAfrcm5DWFbqU/edit?usp=share_link

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Project and Problem-based Lessons in Computer Science from the Perspective of 6th Graders in Slovenia: A Case Study

Katja Krecenbaher Mernik

Abstract

In this study, we examine how project-based and problem-based learning affect teaching Computer Science in 6th grade in lower secondary school. The focus was to assess the lessons and students' work. Students were tasked with programming an application for younger students. They were mostly working in pairs. We conducted 4 hours of school lessons for each of two groups while students were being observed by two or three teachers each time. We analysed the information using qualitative research methods, specifically content analysis. All students encountered some sort of problem while working on their application and choose different ways to solve their problems such as by asking a classmate for help, googling their problems or just by trying different commands. Student collaboration varied. Most students collaborated well and divided their work equally, while others barely communicated. In the interviews, we gathered different strategies they used for solving the problem and found that many wished to work in groups of three.

Key words

Problem-based education; Project-based education; 6th grade primary school; Case study

INTRODUCTION

Computer Science as a subject is being introduced into the curricula of several countries in primary, middle and high school education as the modern society is becoming aware of the importance of Computer Science for its success (Beriša, 2020). Rusek (2021) mentions many authors who suggest that only when students are actively learning, will their education be successful. Hands on activities also lead to increased student motivation (Todd, 2020). Several methods effectively do just that, such as problem-based learning, inquiry-based learning etc. Project-Based Learning (PBL) is a teaching and learning methodology where students develop projects under real conditions to acquire the knowledge and develop the skills required for their profession (Quesada-López & Porras, 2019). In PBL, student learning is focused on a complex problem that does not have a single correct answer (Hmelo-Silver, 2004). PBL not only activates students with a real-world task, but also makes use of students' previously acquired knowledge and building new knowledge. It also encourages investigating and collaborating (Rusek, 2021). Students need to feel connected to the topic they are learning (Todd, 2020). In Slovenia Computer Science is only offered as an optional subject, but its goal is to teach students fundamental concepts of computer science, develop algorithmic thinking and learn problem solving strategies (Učni načrt, 2013). The Digital Competence Framework for Citizens (DigComp) is a reference model that defines digital competences and is the base for framing digital skills. In 2022, the European Commission released the newest and revised version of this document, which now also includes new, emerging technologies such as artificial intelligence, robotisation, the internet of things and other new phenomena (Vuorikari et al., 2022). Digital competences are also included in eight key competences for lifelong learning. These competences are recognised as essential for a citizen's personal fulfilment and suitable lifestyle (Union, 2019). These core competencies should be taught concurrent with the content of the curriculum. Students gain these skills by thinking critically and applying skills in conjunction with basic computer science concepts. PBL organises learning in a way that combines skills and computer science knowledge (McManus & Costello, 2019). According to authors Chen and Yong (2019) as well as Kokotsaki et al. (2016) PBL is an alternative teaching method that has a large positive effect on students and their academic achievements, especially cooperation, communication and reflection on real life problems and topics. It also allows students to learn by searching for solutions, debating their ideas, designing plans, and collaborating with others (Choi et al., 2019). In such lessons, it is important for the teacher to know different ways of algorithmic and computational thinking and that he can teach the students to use them as well (Redecker, 2017). In our case study, which focused on lessons based on problem-based and project-based learning, we analysed different strategies the children used to solve their problems.

GOALS OF CASE STUDY

The focus of this case study was to study different aspects of these computer science lessons and the students' work. We wanted to observe students' motivation in the lessons, achieving of set goals, their understanding of instructions, problems they faced while working on the project and how they solved them.

METHODOLOGY

After transcribing the interviews and observation forms, we analysed all the information using qualitative research methods, specifically content analysis. First, we made a list of categories for each of the forms and then filled the data in a frequency table.

Sample

The research was conducted in two elective courses of computing. Children in those classes are 6th graders. The first group, group A, has 21 students, but only 17 decided to participate in this research. Group B has 15 students and all of them participated. Most of these students (about 95%) have already been in this class last year. Students had to give a notice to their parents, who signed consensus that their child could participate, be observed, and later interviewed for the purposes of this research. Students worked on their tasks in pairs. Due to some unexpected issues, a student from group A had to work alone and in group B tree students had to work together.

Research process and lesson plans

At the beginning of the school year in 2022, we revised what we have learned last year programming in Scratch. We planned a game of Ping-pong together and then the students had two lessons to make the game themselves. This is how we revised programming in Scratch and the basics of programming such as repetitions, if-clauses, and variables. Based on their performance we created pairs in which they worked on the project. Students were given instructions to visit a teacher teaching younger children, from 1st to 3rd grade who gave them their tasks. Teachers received instructions and the criteria for the assignment on paper and were to explain it and give it to my students upon visiting.

The goal of the first lesson we reviewed for this research, was to plan the application the students were asked to programme. They were given the same pre-prepared planning papers we used when planning the Ping-Pong game and asked to plan using algorithms. Next three lessons were spent making the application. Students were given further instructions on some of commands they were supposed to use in their applications.

We prepared 9 different applications for students in group A and same tasks were given to students in group B. The tasks included programming falling letters which is an application where younger kids can learn to type better, practicing addition and subtraction, practicing multiplication, translating words to English, guessing the artificial substances, practice clicking and double-clicking, guessing the time, recognizing the animals, and recognizing different shapes. The picture below (see Figure 1) is an example of how the task was presented to the students. It included instructions, the specific criteria for the application, and a hint to help them make it. In this example, we see instructions for the application for practicing addition and subtraction.

PRACTICE ADDITION AND SUBSTRACTION

The game is designed for children to practice addition and subtraction up to 100.

At the start of the game, have a character say the instructions and then give the equations. The student gets at least 5 addition accounts and at least 5 subtraction accounts. The numbers in the equations should be randomly selected. When subtracting, we must make sure that the second number is always smaller than the first. The main character asks the player for the result, and the player enters it in the line that appears. We need to check if the input is correct. If the student has solved the equation correctly, he gets one point. When they solve the equation incorrectly, one point can be deducted. We also have to say what the correct calculation result was. The character giving the task should say at the end how many points the student has achieved.

Application criteria:

- The game starts with instructions.
- We always choose random numbers for addition and subtraction.
- In total, the player should receive at least 10 bills.
- The application should count correctly solved equations.
- When the student makes a mistake, the character must tell him the correct result.
- The student provides correct numbers when subtracting (the second number is smaller than the first).
- At the end of the game, the player should know how many points he has scored.

Hint: When programming, use the command select random in range and join (green command). A question can be asked with the command ask.

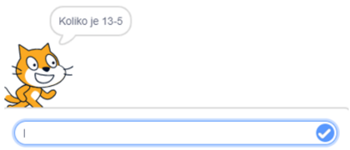

Figure 1: Instructions for creating the application

Evaluation of the lessons

All 4 lessons were evaluated. We used different ways of gathering information about the lessons and student progress. We preprepared a teachers evaluation form of the lessons, students' self-evaluation forms for each lesson, observation forms for the teachers that observed the lessons and some interview questions. We added the teacher evaluation form of the lesson, the observation form and transcribed interviews in the appendix.

For this research we also evaluated the plans students made for their application and their final products.

Students' application planning

Students had to carefully plan their application. They received a form they had to fill out. First, they had to sketch how their application will look like, then they had to list the characters that they were going to use in the game. They had to write down approximate algorithms for each of the characters. Lastly, they had to think about the variables they will need and how the application will end.

Teacher's evaluation of the lessons

The teacher leading the lessons had to fill out a self-evaluation form at the end of each lesson. Things he had to reflect on included whether the class was successful, how the instructions were given, whether the lesson goals were achieved, how was the time of the lesson managed, students' interest and motivation, their activity and whether the students were allowed to ask questions and how they were answered.

Student's self-evaluation

At the end of each lesson students had to answer some questions about their work in a shared Word document. Questions differed from lesson to lesson and included questions like what I have completed today, what will I do next lesson, where did I encounter issues, where do I expect to have issues, what did I do well.

Observation of students

This was the most important part of this study. We asked three teachers at the school to come and observe the lessons and take note of the students' work. Two of these teachers were primary teachers and the third is also a computer science teacher. While observing they filled out preprepared forms. The forms included commentary on whether students needed help, if they understood the instructions, if they were interested in their work, whether they paid attention, if they were active, how they solved problems, how they collaborated and communicated and whether they achieved lesson goals.

Interviews

We selected 12 students, six from each group. Those students were selected randomly as to not influence the gathered data. They were asked to answer additional questions about their work on the assignment. The main things we wanted to know was how they liked or hadn't liked the lessons, how they felt about working in pairs, how they liked the assignment and if they were satisfied with their work, what they learned and what difficulties they faced. Some questions were given to all selected students, but some were specific to that student and his or hers work during the lesson and their self-evaluation answers. They were asked to further elaborate on whether they used the plan they made, if they think they organized their time well and so on. Transcripts of the interviews can be found in the appendix.

FINDINGS

Most of the students' plans were lacking proper algorithms that describe what a character in their game must do. They usually just wrote what a character does but did not use proper algorithmic expressions. The students in group A barely finished their application to work for only one object in their task. That was because half the students were sick for one of the lessons and the remaining students had to work alone on their applications. Most students just followed the instructions and did not add any new ideas to the application, only one pair added sound to their project. The students in group B completed most of the criteria for their applications. More of them added their own ideas or designed the game to be more colourful and interesting. Some of them had issues with programming the feedback for the user. For example, when the user answers the question wrong, you need to tell them what the correct solution is. Figure 2 shows an example of a finished application for practicing multiplication.

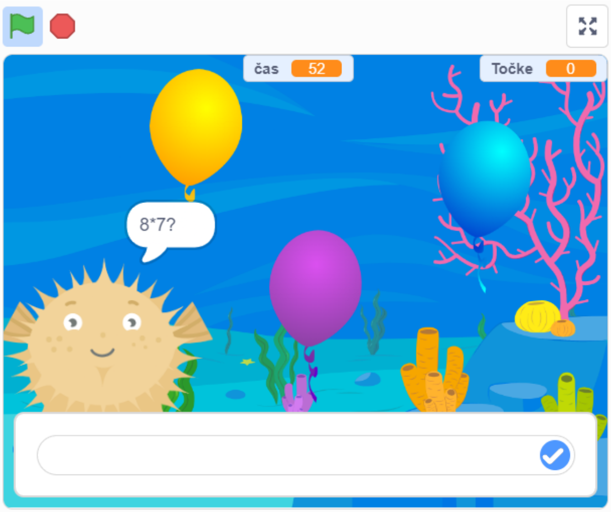

Figure 2: Application for practicing multiplication

Teacher's evaluation of the lesson

In group A, the teacher mentioned students' being motivated approximately as many times as he mentioned them not being motivated and focused. Students were more motivated when they were programming their applications then when they had to plan it. Motivation grew when they received additional explanation on some of the commands, they were not familiar with. Some students were less motivated because the lessons were scheduled for very early in the morning. Students that worked in pairs and always had a partner present to help with work were also more motivated than those who worked alone. Students had questions for the teacher in all their lessons. Goals were rarely achieved as predicted. They did not finish their plans in the first lesson and spent more time programming than planned.

In group B, students were motivated and only one pair of students showed less motivation in those lessons. As opposed to group A, students from group B were almost always present for the lessons and could successfully work in pairs as planned. Group B also had less student attending the class. This made it possible for the teacher to focus on each pair more thoroughly. Students were also actively participating in class. Goals were almost always achieved, except for the first lesson where some students were unable to finish their plan in time. Students in this group also asked questions in all the lessons. Questions were mostly focused on solving programming problems they encountered.

Tab. 1: Frequency table for teacher's self-evaluation

	Tally marks	Group a frequency	Tally marks	Group b frequency
Good motivation	|||	3	||||	4
Bad motivation	||	2		0
Goals achieved	|	1	|||	3
Active students	||	2	||||	4
Answered questions	||||	4	||||	4

In our analysis, we found little of significance in the teacher self-evaluation reports.

Students' self-evaluation

In Group A, around 90% of the students said they had encountered problems while working on the project. Many of them also said that the plan they made in the first lesson was of help with their work. Half of them also changed or added something to their plans for the application. All the students stated they were happy with at least one aspect of their work.

In group B, around 75% of the students encountered problems. Most of them made use of the plan they made and used it when programming, especially in the first hour of making the application. Half of the students changed their plans. In this group, students stopped bringing their plans to class when they were nearing their finished product. Students of this group were also satisfied with their work.

Observation of students

With the help of content analysis, we created a table od frequency for student observation (in appendix). We discovered that group A needed more teacher guidance and had a less positive approach to work. Only three pairs of students were focused and motivated in all 4 lessons. Some students were also less active. Three pairs out of 9 barely communicated while working and in 2 groups, one student did most of the work. Four pairs also worked without their plan as they forgot it at home. When encountering a problem, they mostly turned to the teacher for help, 6 pairs also sought out a classmates help, and 2 pairs looked for solutions online. In this group collaboration was most lacking. For example, one pair of students never spoke, one of the students in the pair was even showing his back to the other and refused to work with the partner.

In group B, students seemed to be more motivated and focused, even eager to work. They even shared additional ideas with teachers observing them. Then needed less guidance, more of them understood the instructions and fewer students needed the instructions repeated. Only two pairs out of 7 showed lack of initiative in only two lessons. Six pairs of students had positive attitude towards work and were active in most lessons. When faced with a problem they couldn't solve themselves they solved their problems by trying or asking the teacher. Only 5 instances of collaboration with other classmates were noted. They collaborated nicely and communicated almost every lesson. Only one pair of students was less motivated and didn't communicate as much.

Interviews

Interviews were conducted with 12 students, 6 from each group. When asked whether they liked such way of learning, all students said yes, but gave different reasons as to why. Some said they liked working in pairs, some said that they liked that they had to make applications for younger students. When asked, what they didn't like, half said that they wouldn't change anything. The rest stated that they wished for better collaboration with their partners who were either missing or did not contribute much to work or that they had learned all the needed commands before.

When asked what they liked and what they didn't like about working in pairs, they said that they liked to have help and that they could distribute help. They didn't like it when their schoolmates were missing or forgot to bring plans of their assignment or didn't help as much. When the students did work together, they didn't have problems and liked working in pairs. They divided their work differently, some communicated and then programmed what they discussed, some switched while working, some did research while other worked.

They were satisfied with their work but knew that some of their work was unfinished and wanted to add more things to their projects.

All the students said that they understood teacher's instructions, but some said that they needed further elaboration. The students that said this usually worked alone or have not attended my classes last year. One student said that he wished the teacher gave straightforward answers when they had questions and not just hint where to find it and where they have used it before.

When asked what they learned most of them said that they discovered new commands and how to use them such as the command ask, if – else and one student also said that she worked with operators for the first time. One student also stated that she learned that patience is needed when programming.

The difficulties they faced differed from using the variables, finding the correct commands, or using new commands. They solved those problems by trying different solutions to the problem, asking the teacher or a classmate. One student described his process of resolving the problem in more detail and said that when he programmed a solution, he copied it and tried again and helped improve other iterations of the solution.

Students expressed the desire of learning all the necessary blocks and commands beforehand. They wished to focus only on programming the algorithm and not researching new commands and how to use them.

DISCUSSION AND CONCLUSION

All students had to solve some problems while working. While many used the standard approaches such as consulting with a classmate or a teacher, others thought of their own solutions. For example, the student that had to programme subtraction and be mindful of the equations - the second number was supposed to be smaller than the first for the equation to make sense, came up with a different solution than we expected.

We can conclude that students need help in all parts of making a project. They needed help and guidance with planning, programming, and solving problems. They did not know how to search for solutions online. Only one pair in each group searched online after they were hinted to do so. The other two pairs that used the internet while working did so to find ideas for pictures to include in their app and not to solve problems.

All the students liked the idea of working in pairs or groups of three, but some had issues collaborating. Collaborating with others on the project had a positive effect on students' motivation.

Based on the results, we could conclude that students need some base knowledge before taking on a big project like this. They could not have finished their work without the things they learned in class in previous school year. We noticed that the students do not know how to look for information they need online without guidance. This is an important skill for students to have when using problem-based learning in class.

The research could be repeated next school year and students could pair themselves up as they wished or work in threes.

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The influence of alcohol models on students' perception

Małgorzata Nodzyńska-Moroń, Paulina Zimak-Piekarczyk & Danuta Jyż-Kuroś

Abstract

Students find chemistry a complicated subject. Because to understand the properties of how microscopic properties affect macroscopic properties, teachers use explanatory models. In teaching chemistry, we use different types of models of chemical molecules. However, the question arises: are all models equally effective? The research was conducted in 4 classes of upper secondary schools in the third year of study. 68 students took part in the survey. The students were divided into four groups, each using a different model type. It investigated whether working with different models affects students' perception of the structure of mono-alcohol molecules.

Key words

Models; Structural formulas; The shape of the molecule

INTRODUCTION

Students find chemistry a complex subject (Coll & Taylor 2001). This is due to the fact that there are three levels in chemical education: macro-world - that is what we see, hear and feel with our senses; microworld - the world of atoms, ions, molecules, the world where chemical reactions take place; and the world of symbols – that is, the world of summary formulas, structural formulas, models (Johnstone, 1991). This chemical equilateral triangle symbolizes the equal importance of each of the triangle's vertices and shows the connections between them necessary to understand chemistry (Lin et al., 2016). It is believed that the symbolic level can act as a bridge between the other levels, helping students to explain, for example, chemical reactions taking place in the macroworld at the level of the microworld (e.g. reaction mechanism). It is these explanations that make chemistry an exact science (offering explanations and predictions) and not just a "natural history" that catalogs and characterizes substances (Taber, 2013). To help chemists communicate and visualize the chemical microworld, specialized symbol systems (molecular formulas, chemical equations, molecular models, Fischer projections, etc.) have been developed (Hoffmann & Laszlo, 1991; Mathewson, 2005).

A review of the literature shows that many authors believe that the use of models of chemical compounds in chemistry education will allow students to better understand chemistry (Teplá, et al. 2020). For example, Zubitur and Sanchez (2017) believe that a correct idea of the spatial structure of molecules is crucial for understanding chemistry. It is necessary e.g. to determine the polarity of compounds, intermolecular interactions and to understand the relationship between the structure of a chemical compound and its physico-chemical properties. They believe that in chemistry textbooks, molecular structures are presented as two-dimensional objects, so students may have difficulty transitioning from 2D images to 3D structures. Using 3D models helps students better understand molecular geometry and encourages active learning. In turn, Stull, et al. (2012) noted that spatial ability was a much weaker predictor of performance than model use. The results suggest that models can be an effective tool for teaching chemistry, but some students need instructions on how to use them.

Organic chemistry poses particular challenges to students in this respect. Because it is challenging for students to master the many different schematic representations of molecules used in organic chemistry. According to Crucho et al. (2020), organic chemistry is especially challenging for students because it is abstract in nature and involves many concepts. They believe that teachers should use molecular models to represent molecules in three dimensions, yet many students may have misconceptions. The use of models according to these authors also contributes to the increase of interest in the subject, increasing motivation and understanding of chemistry by students.

The use of modelling in teaching organic chemistry to solve problems and increase student engagement is also described by Eastwood (2013). In contrast, Stull et al. (2016) report numerous studies showing that students' manipulation of 3D molecular models can help them understand organic chemistry. Johnstone (2000) writes that it is very difficult to introduce students to ideas at all three levels simultaneously. The results of the described research indicate that students are more effective in explaining chemical theories and phenomena. And the knowledge gained in this way is resistant to delays of several days and transfers the effects even when the models are no longer used.

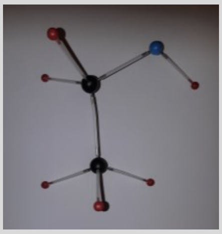
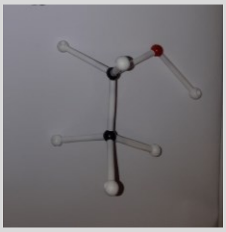
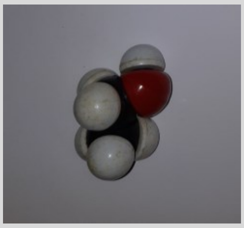
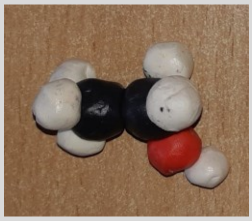
HYPOTHESIS

Our previous research (Nodzyńska, 2004; 2005; 2009; 2010; 2012; Zimak, 2012; 2014) have shown that the models shown to primary school students strongly influence their perceptions of the microworld. It was decided to investigate whether similar relationships exist in the case of older students - high school students. High school students should already be on the fourth level of reasoning (according to Piaget). And abstract reasoning should not be difficult for them. Therefore, they should not be so important to the models they use. It was hypothesized that the students' results would not depend on the model they used in the lesson.

RESEARCH

The study involved 68 students in four third grades of high school. These students declared that they had never built models of molecules of chemical compounds on their own in chemistry lessons before. But in four years of studying chemistry, they have seen different models of molecules drawn in their chemistry textbooks. Students were randomly divided into four groups. The task of each group was to build models of the first five monohydric alcohols. Each group used a different type of model.

Tab. 1 Models used in research.

Ball and spoke models	Skeletal models	Space-filling models	Models self-made by pupils from plasticine
			

In all four classes, the lesson was the same (see Table 2) and was taught by the same teacher.

Tab. 2 The course of the lesson.

1.	Pretest - consisted of seven closed-ended questions with multiple choice.
2.	The reminder of information from Primary School: • Discussion: how many bonds are carbon, oxygen and hydrogen? • Correlation between the sum and structural formula. • Definition of the homologous series and differences in the construction of successive terms.
3.	Work with models (tasks for students): • Methanol: o Selection of elements for the construction of a methanol molecule model. o Teacher approval of items. o Building a model of a methanol molecule. o Analysis of the structure of the model and its discussion. • Ethanol, propanol, butanol, pentanol: o Building a model of the alcohol molecule. o Analysis of the structure of the model and its discussion.
4.	Posttest consisted of 3 parts: • questions about the student's preferences regarding the way of working in the lesson (3 questions); • repeated pre-test questions (7 questions); • questions about the concept and misconceptions that may arise in the minds of students while working with a given type of model (4 questions).

Description of the research tool

The pre-test was created in Google Forms. It contained 7 closed multiple choice questions. Students could choose from different visualizations of models of monohydric alcohol molecules and their formulas. In the post-test, in addition to repeating the same questions about the models, students were asked 3 semi-open questions about evaluating this way of working. And 4 closed questions (yes/no/don't know) about popular misconceptions. The students answered on their mobile phones.

RESULTS

The obtained results were divided into 3 parts according to the parts appearing in the test: students' preferences, increasing students' knowledge, and misconceptions.

Students' preferences: The vast majority of students (approx. 90%) liked modelling very much and found the lesson interesting. As advantages, they mentioned: group work, good fun and ease of remembering the knowledge acquired in this way. They said modelling made it easier for them to understand chemical difficulties.

Increase of students' knowledge: Students scored higher results in the posttest (after working with models) than in the pretest. A comparison of test results before (*x = 37,5%*) and after (*x= 41%*) working with chemical models indicates the change that occurred with the treatment is greater than would be expected by chance. There is a statistically significant change *Wilcoxon matched-pairs test: Z = 2,76, p = 0,006, Spearman's r = 0,678 strong relationship*). It can therefore be concluded that, in general, the use of modelling in the classroom contributed to the increase in students' knowledge.

Tab. 3 Wilcoxon pairwise significance test - marked results are significant α = 0.05.

A pair of variables	N	T	Z	*p*
PRE-test & POST-test	68	720,5	2,7649	0,006

Wilcoxon's test was used to compare the test scores between the two samples, pre- and post-test. Since the tests indicate significant differences, the Kruskall-Wallis test was used for further analysis between the 4 groups of results that corresponded to the 4 types of models used. For this purpose, we compared the median pre- and post-test results among 4 model groups A-D separately (Tab. 4.). Statistical analysis (Kruskal-Wallis test) showed significant differences in medians in pre- and post-test groups. In the pre-test group, better results were achieved group working with the space-filling model than the skeletal model. The same results were observed in the post-test group. An additional difference was observed between the space-filling model vs the ball and spoke model.

Tab. 4. The results of testing the hypothesis that the compared populations (four model groups) have the same median, significance level α = 0,05. (Abbreviations: df -degrees of freedom, *p* - value). Results were calculated by Statistica StatSoft 13.1.

variable	group	Kruskal-Wallis test	df	*p*	statistical conclusion
pre-test results	type of model	8.680	3	*0.034	populations have a different median
				post hoc test: *0.033	space-filling model *vs* skeletal model
post-test results	type of model	13.568	3	*0.004	populations have a different median
				post hoc test: *0.024	space-filling model *vs* skeletal model
				post hoc test: *0.007	space-filling model *vs* ball and spoke model

The pre- and post-test results were also compared depending on the model used (pre-space vs post-space model, pre-ball vs post-ball, etc.). The difference was not statistically important or important on the verge of significance (Tab. 5.).

Tab. 5 The results of testing the hypothesis that the compared populations pre- and post-test according to the type of model have the same median, significance level α = 0.05. (Abbreviations: p - value). Results were calculated by Statistica StatSoft 13.1.

type of model	pre-test median	post-test median	Wilcoxon test	*p*	effect size *Spearman's r*
skelet	26.09	32.26	1.983	0.048	0,571 – strong effect
ball and spoke	30.44	32.26	0.283	0.777	------------------
space filling	34.78	67.74	1.647	0.100	------------------
plasticine self made	30.43	35.48	1.964	0.049	0,876 very strong effect

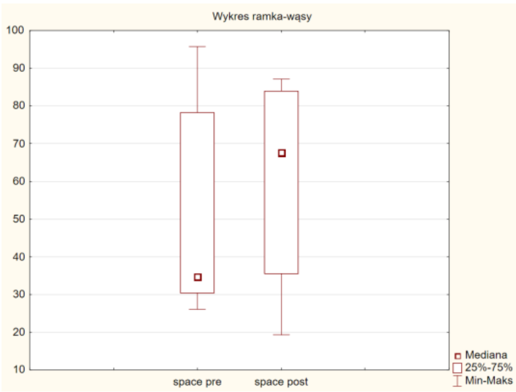


Fig. 1. Median and quartiles for pre- and post-test for space filling models.

Although the increase in knowledge for the group of students using the space filling model seems significant (increase in the median from 34.78 to 67.74), statistical calculations show that it has no statistical significance (see Fig. 1). It can therefore be concluded that none of the models turned out to be a more effective tool than others.

Students' misconceptions: Results for 4 questions concerning misconception indicate that students give similar answers despite working on different models. Distributions for all 4 groups are homogeneous (Tab. 6.).

Tab. 6 The results of testing the hypothesis that the compared distributions are homogeneous in 4 different model groups, significance level α = 0,05. (Abbreviations: df -degrees of freedom, p - value). Results were calculated by Statistica StatSoft 13.1.

variable	group	χ^2 Pearsona	df	*p*	statistical conclusion
Correct or incorrect answer on question 1. *Is an oxygen atom bigger or smaller than a hydrogen atom?*	type of model	3.679	3	0.298	distributions are homogeneous
Correct or incorrect answer on question 2. *Can atoms rotate relative to a bond?*	type of model	1.301	3	0.729	distributions are homogeneous
Correct or incorrect answer on question 3. *Are carbon atoms black?*	type of model	2.948	3	0.400	distributions are homogeneous
Correct or incorrect answer on question 4. *Are the atoms (their electron clouds) in a molecule far apart?*	type of model	7.676	3	0.053	distributions are homogeneous on the verge of significance

CONCLUSION

Students' preferences: The surveyed students, like many people (e.g. Coll & Taylor, 2001; Crucho et al. 2020), consider chemistry difficult. At the same time, they believe that modelling allows them to better understand it. Similar conclusions can be drawn from the studies of Zubitur & Sanchez (2017) and Stull et al. (2012). Students also find the use of models attractive and increase their motivation and engagement. Similar results were achieved by Zubitur & Sanchez (2017) and Crucho et al. (2020) as well as Eastwood (2013).

Increase of students' knowledge: However, our main goal was to check whether the use of a given, specific model results in a greater increase in knowledge. In general, the use of modelling in the classroom contributed students' knowledge increase. It can therefore be concluded that none of the models turned out to be a more effective tool than the others. We confirmed the hypothesis that the type of models used in the lesson does not affect the increase in students' knowledge.

Students' misconceptions: We also wanted to check whether the given models do not perpetuate misconceptions. It turned out that the type of models used in the lesson did not affect the imagination of the students.

In conclusion, it can be said that using models in teaching organic chemistry at the secondary school level brings positive effects. However, it is possible to use any models - even those created by students themselves. The type of models used does not affect the imagination of adult persons.

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Categorization of tasks with interdisciplinary content in selected textbooks for lower-secondary school level

Lukáš Rokos, Vladimíra Petrášková, Libuše Samková & Veronika Rajtmajerová

Abstract

This is a pilot study of a project aimed at preparing an integrated STEM curriculum in the Czech Republic. To create a categorization of tasks that would help implement the STEM concept, we analysed selected curricular documents and textbooks. We found the topic that was most often reflected in individual STEM subjects in curricular documents, and then we analysed qualitatively tasks in biology, geography, chemistry, physics, technical education, and mathematics textbooks according to this topic. On the basis of open coding and constant comparison, we have got a categorization of tasks reflecting the rendition, the level of interdisciplinarity, and the degree of interconnection of educational contents. Illustrative tasks are given to all the relevant categories.

Key words

Integrated task; STEM; Textbook; Categorization

INTRODUCTION

Reflecting recent trends in education and our own experience, Faculty of Education at University of South Bohemia in České Budějovice had chosen to respond to the growing demand for the implementation of STEM education in our country and prepared a project focusing on this issue. Our goal was to analyse the Czech educational environment and provide relevant materials that enable a meaningful integration according to the concept of STEM. This paper presents a pilot study of the project that aimed to start mapping the terrain by studying current curricular documents and textbooks. Our goal was to establish a primary categorization of textbook tasks that would arise from open coding and constant comparison and allow us to distinguish between suitable and unsuitable task for STEM education. We conducted a curriculum and textbook analysis addressing the following research question: "What qualitative criteria are relevant for textbook tasks with regard to their potential use in STEM education at the lower-secondary school level?"

STEM

The abbreviation STEM was created as a means of representing the integration of science (**S**), technology (**T**), engineering (**E**), and mathematics (**M**) education. The main idea of this approach was based on the similarity of the above-mentioned subjects, which if properly connected, can achieve an intensive integration as well as a diversity of mentioned disciplines that enables us to look at the world from a different perspective. The concept of STEM goes back to the 1980s, but has been established rather recently (Holmlund et al., 2018) and pedagogical research on the topic has been performed relatively extensively (Johnson et al., 2020), but the subject perspective is rather unbalanced (English, 2016; Maass et al., 2019). The research gap could be identified in the research on student performance because the studies hardly look at how students combine knowledge from different subjects or how general abilities and skills develop. The possibility to focus on representations and models that allow a clear view of individual STEM subjects despite their different content and different approach to didactics is the second field of interest (Hallström & Schönborn, 2019). STEM and its efficacy are still open space for systematic work.

In the Czech educational system, the STEM approach is related to the following school subjects and their alternatives: Elementary science, Biology, Chemistry, Physics, Elementary geography, Geography, Informatics, Computer technology, Practical education, Technical education, Technical drawing, Technical constructions, Technical design, Descriptive geometry, and Mathematics. Although the curricular documents are somehow prepared for the integration, they do not take it into account in detail (Janouskova et al., 2019).

So, the STEM approach is not well known or used in the Czech Republic, but, on the other hand, other educational approaches such as inquiry-based education and project-based education have been widely promoted here in recent years. When we look in detail at their ideas, they are in accordance with the STEM approach and could be very easily connected (Artigue & Blomhøj, 2013; Samkova et al., 2015; Gunstone, 2015). Several introductory studies and inspirations for possible Czech paths and approaches in the line with the STEM approach can be found in selected Czech publications (Samkova & Petraskova, 2022; Koldova et al., 2020).

METHODS

We explore the potential of tasks for a STEM approach in our study which distinguishes us from previous studies. Unlike Vojir & Rusek (2022), we do not compare textbooks but examine individual tasks. And unlike Vojir (2021), we do not focus on the form of presentation of tasks in the textbook but on the possibility of using the task outside its original purpose.

This pilot study had four phases. In the first phase, an analysis of the National Framework Educational Programme for Elementary Education (MoEYS, 2021) was carried out and places were identified where it might be possible to integrate various educational contents at the lower-secondary school level. Following this analysis, a content analysis (Mayring, 2021) of selected school educational programmes (N = 15) was performed focussing on different approaches to teaching the topics identified in the previous step. During the third phase, an analysis of often used biology, geography, chemistry, physics, technical education, and mathematics textbooks (N = 24) was performed where all tasks with interdisciplinary content related to the identified topic were searched. In the fourth phase, the tasks found during the third phase were qualitatively analysed, using open coding and constant comparison (Miles et al., 2014). We solved each of the tasks and then assigned open codes to all aspects that appeared relevant from the perspective of a potential use of the task in STEM education. During the constant comparison process, we repeatedly compared codes with each other, individual codes across all tasks, and individual codes between different researchers that made the initial coding (authors of this paper). We grouped codes that were close in their meaning into categories, while aiming for a concise set of code categories that would be dense in our data.

RESULTS AND DISCUSSION

It was found that the topic "Dependencies and Data" from the educational area Mathematics and its Applications is most often reflected in other educational subjects. The analysis of tasks found in the selected textbooks resulted in the establishment of three task categories that reflect the rendition, the level of interdisciplinarity, and the degree of interconnection of educational contents. These categories were the only ones dense in data.

Assignment

The first category reflects the way the task is assigned. Since we worked with tasks that were selected for their possible interdisciplinary character, all of them were connected to a specific practical situation that presented an interdisciplinary application. In the context of these tasks, our categorization distinguishes between **practical tasks** that are connected to a specific practical situation, and the link to the situation is justified in the sense that the student needs to study the situation to solve the task, and **purely school tasks** where the link to the practical situation may exist but is not justified. From the perspective of the potential for STEM education, we understand that the purely school tasks are problematic, as they do not show the reason for integration.

We can provide the following tasks from the Math textbook for the 8th grade as examples of a purely school task (Ex. 1; Laubeova et al., 2021, p. 14) and a practical task (Ex. 2; Laubeova et al., 2021, p. 13).

Ex. 1: The hydrometeorological station measures the air temperature during the week every day at the same time with an accuracy of tenths of a degree Celsius. The measurement results are recorded in a table (Tab. 1). Calculate the average temperature for this week and compare it with the average temperature for the previous week, which was 1.2 degrees Celsius.

Tab. 1 Measures in degree of Celsius provided in the task

	MON	TUE	WED	THU	FRI	SAT	SUN
TEMPERATURE	-2.3	-1.5	0	2.4	-0.6	-0.3	-0.5

Ex. 2: Mrs. Novak wants to send her tomato spaghetti to a culinary contest. One of the requirements is to write down the total cost of the ingredients used (the price for salt, spices, and herbs is not counted). Therefore, she wrote down the unit prices of each item of the recipe (Tab. 2). What was the total cost (in whole CZK) for the ingredients used in the recipe?

Tab. 2 Recipe and prices of ingredients provided in the task.

RECIPE	PRICES	
200 g spaghetti	500 g spaghetti pack	29.90 CZK
½ Dl of olive oil	0.5 l of olive oil	124.90 CZK
200 g of tomatoes	250 g of tomatoes	29.90 CZK
200 g of broccoli	500 g of broccoli	34.90 CZK
50 g of parmesan	100 g Parmesan	94.90 CZK
Salt, basil, oregano		

In Example 1, there is no specific practical situation presented that would justify the need for such a calculation or the need for the proposed comparison. In Example 2, the calculations are needed, otherwise Mrs. Novak could not participate in the competition.

Included contexts

The second category reflects whether the practical contexts included in the tasks are **plausible contexts** or not. When they are not plausible, we call them **pseudo-contexts.** An example from the Math textbook for the eighth grade is provided for both categories – a task with a pseudo-context (Ex. 3; Laubeova et al., 2021, p. 12) and a task with plausible contexts (Ex. 4; Laubeova et al., 2021, p. 17).

Ex. 3: *The river level was 15 cm above normal on Monday. Then it dropped by 4 cm every day. Answer the following questions: 1) On what day did the water level drop to normal? 2) What was the state of the water level compared to normal on Sunday? 3) What was the difference in water level between Monday and Saturday?*

Ex. 4: *Decide whether the following examples are direct proportionality (D), indirect proportionality (I), or another dependence (O) – see Table 3*.

Tab. 3 Examples of dependencies provided in the task.

	EXAMPLES	
A	The number of identical recycle bottles and the money received for them.	
B	The number of identical 3D printers and the time required to produce 100 parts.	
C	Human weight and age.	
…	….	…

The context of Example 3 is not plausible because the level drops by the same 4 cm every day. Also, in reality, it cannot drop indefinitely. The Example 4 is an example of a task with large number of different plausible contexts.

Interdisciplinary potential and interconnectedness of contents

The third category reflects the potential for the task to be handled in an interdisciplinary way. This means whether the given combination of thematic units has the potential for cross-curricular teaching and whether the topics behind the task are suitably interconnected. In relation to this category, we distinguish between different levels of interconnectedness of contents. The levels state to what extent the students have to switch repeatedly between different thematic units when solving the task. The following levels were found: **none** (the contents are not connected at all, no two-way switch between the topics is needed to solve the task; Ex. 5; Navratil, 2016, p. 106); **weak** (only one two-way switch is needed; Ex. 6; Navratil, 2016, p. 106–107); and **strong** (more two-way switches are needed to complete the task; Ex. 7; Skoda et al., 2006, p. 55; and Ex. 8, Navratil, 2016, p. 36–37). For a meaningful implementation of STEM, the two-way switches are essential since they support mutual understanding of the integrated contents.

Ex. 5: *What percentage did the proportion of hormonal contraceptive users increase? How much has the number of abortions decreased? See the graph below (Fig. 1).*

Ex. 6: *How does the proportion of people who have already had AIDS change compared to all HIV-positive patients? Can you provide an explanation? See the graph below (Fig. 2).*

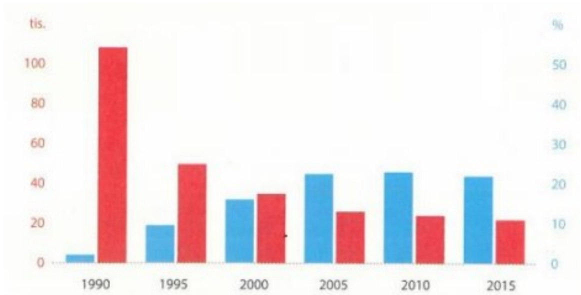

Fig. 1 Comparison of the development of the number of users of hormonal contraceptives (blue) and the number of abortions (red) in the Czech republic. (retrieved from Navratil, 2016, p. 106)

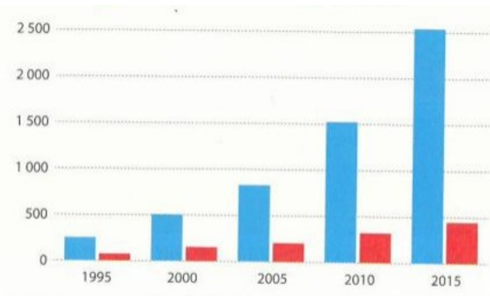

Fig. 2 The number of patients with AIDS in the Czech Republic is still increasing. The highest incidence of disease (tens of millions) is mainly in countries in Africa. (retrieved from Navratil, 2016, p. 106–107)

Ex. 7: *Find the boiling point of propane and butane in the tables. Try to explain why the so-called summer propane-butane contains 40% propane and 60% butane, while the so-called winter propane-butane contains 60% propane and 40% butane.*

Ex. 8: *A human heart rate changes throughout life and, depending on the activity, increases during physical exercise, fever, or excitement (see Tab. 4). The heart rates of different vertebrates also vary significantly. What do you think, what does the vertebrate heart rate depend on?*

Tab. 4 Heart rated of selected organism provided in the task

ANIMAL	HEART RATE (PULSES/MIN)	ANIMAL	HEART RATE (PULSES/MIN)
Blue whale	9	**New-born**	160
Hibernating bat	16	**Rabbit**	160–180
African elephant	25	**Sparrow**	500
Sleeping man	40	**Common shrew**	600
12-year-old child	90–100	**Flying bat**	800
Running man	120–160	**Flying hummingbird**	1200

Example 5 is an interesting interconnection of the mathematical topic of graph reading, the mathematical topic of percentages, and science topics related to contraception, but the potential is not exploited at all. When solving the task, the students are first in a scientific context and then move to the mathematics context and stay there (i.e., the switch between the topics is only one-way). If a scientific explanation/interpretation of the graph (e.g., why one colour rises and the other decreases) were required, the potential would be exploited. The switch to the second educational content and back but only once was found in Example 6. To solve the task in Example 7, the students have to understand three different educational contents: boiling points, mixtures, and percentages. During the solution process, they have to switch several times among the topics, and the switches are two-way. A very similar situation was found in Example 8 where the students need to work with a visual representation of body mass of selected animals and a human, understand differences between some animal and human activities, and handle data within the table. Again, to solve the task, the students have to switch several times between the three educational contents, and the switches are two-way.

CONCLUSION

In this study, we provide an introductory qualitative insight into the tasks of the lower-secondary school textbook and their suitability for STEM education. We have got a set of categories relevant for this purpose and accompanied them with illustrative examples. The goal of our study was not a quantitative evaluation of the occurrence of individual categories of tasks in textbooks; this procedure will be carried out in the following research, including monitoring the way students solve selected tasks themselves. The presented categorization is going to be verified with other textbooks for science and mathematics subjects at lower-secondary school level. The categorization that emerged from our explorative research may be considered not only the basis for further research as mentioned above, but also an essential contribution to the meaning of pedagogical content knowledge related to the STEM approach and its implementation. When implementing STEM or learning how to implement it, in-service teachers, as well as prospective teachers need to perceive the complexity of STEM tasks and be aware of the individual components of the tasks that make STEM implementation possible.

With this study, we address two different research gaps related to STEM education: we include textbooks from three different STEM content domains (S, T, M) and focus on the content from a general perspective that applies for all three domains while making the individual STEM subjects and their relations visible.

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Energy literacy as an interdisciplinary project

Josef Šedlbauer, David Syrovátka & Martin Slavík

Abstract

Application of school education leading to behavior that is consistent with scientific consensus may not be straightforward, namely in complex topics such as energy. An interdisciplinary approach is therefore recommended. We have developed and tested a school project for the upper elementary school students, aimed at understanding energy, its sources, and limits in a broader technical, environmental and socio-economic context. Students' understanding was later evaluated and compared with the control group. Most significantly the project-based education resulted in better orientation in energy externalities. Recommendations are provided for a more effective design of project-based education leading to the improved cognitive dimension of energy literacy.

Key words

Energy literacy; School project; Renewable sources.

INTRODUCTION

The physical essence of energy, various energy forms, and energy sources are all important and relevant educational topics. However, for most students (and future citizens) the crucial issue regarding energy is the understanding of trade-offs in energy production from different sources. Energy externalities are the key factor driving the energy sector from fossil fuels to renewable sources, with all the connected costs and inconvenience.

Achieving long-standing public support for energy transformation to renewable energy sources is an intricate task. Science and education are generally relied upon, but many other factors such as prevailing public and political discourse are at play. That is why it makes sense to apply a broader concept of *energy literacy*, encompassing three dimensions: cognitive (what do people know about energy – knowledge), affective (what beliefs and concerns they have, related to energy – attitude), and behavioral (how they use energy in their daily lives – behavior) (DeWaters & Powers, 2011).

The links among knowledge, attitude, and actual behavior (or some of these variables) regarding energy and various energy sources have been subject to a number of studies. One of the typical findings is the missing or insignificant correlation between knowledge, attitude, and/or behavior (Kardooni et al., 2018; Białynicki-Birula et al., 2022, Martins et al., 2020; Chiu & DeWaters, 2018; Lee et al., 2022). As better predictors of positive attitudes and practices towards energy-saving behavior and acceptance of renewable energy sources were identified gender, lifestyle, political views, and other features of societal structure (e.g. Ilham et al., 2022; Białynicki-Birula et al., 2022; Chiu & DeWaters, 2018). Considering climate change as an ultimate externality of energy production from fossil fuels, the interrelation between knowledge and attitudes may even become paradoxical. Based on the results from previous studies, Light et al. (2022) demonstrated that the people who disagree most with the scientific consensus on several more or less controversial issues know less about them, but they think they know more (knowledge overconfidence). The topics included climate change, genetically modified foods, nuclear power, vaccination, homeopathic medicine, the Big Bang, evolution, and Covid-19 measures. On the other hand, scientific knowledge was found in correlation to embracing scientific consensus, with the only notable exception - climate change. This is a clear sign of educational insufficiency on this particular topic.

Climate change education is more or less aware of this problem, and educational programs are often designed as interdisciplinary and targeting not just their participants' climate change-related knowledge, but also their concerns, self-efficacy, and willingness to engage in climate action (see e.g. Kolenatý et al., 2022, for review). School education on energy is typically much less holistic (Šedlbauer et al., 2023), although the situation is gradually changing and examples of interdisciplinary approaches are available (e.g. ASU; Meritt et al., 2019). An important limitation is the readiness of the teachers for such education. As noted e.g. by Murphy et al. (2021), teachers need professional training in sustainability issues in order to increase the frequency of sustainability topics in the science education in their classrooms.

In this contribution, we tested the hypothesis that interdisciplinary project-based education can lead to a better *understanding* of our dependence on energy, the connection between fossil fuels and the climate crisis, and the technologies that replace fossil fuels, compared to the common educational practices in the Czech Republic.

METHOD

To test the above stated hypothesis, we developed a project-based learning intervention, applied this action to a group of students (research/experimental sample), evaluated their cognitive performance and compared the results with their peers that passed standard curriculum (control group).

Our research sample was eight-grade students (aged 13 to 14 years) from two classes of a common public Czech primary school, the total number of participants was 39. The control group consisted of 244 students in the eight-grade from seven Czech primary schools where the students were not subject to any special intervention in energy education (Šedlbauer et al., 2023). The method of data collection and interpretation in both groups were the same, allowing for direct comparison. Five schools from the control group were from Liberec, one from Prague and one from a small town in the countryside.

Our research group is from another average Liberec elementary school. Evaluation tests were administered to both experimental and control groups of eight-graders at about the same time.

Energy is a part of the curriculum in the 8th grade in Physics and Chemistry classes. The school project was designed with a duration that approximately meets the allocated time for this topic so the change in educational intervention is not at the expense of other topics. Study materials used in the project relied on established sources such as ASU; EIA. Outline of the school project is as follows:

- One classroom lesson focused on explaining energy and its transformations. At the end, the students are presented with Two Stories (a description of the daily routines of two girls from either affluent or developing country with calculated energy consumption of their activities, taken over from ASU). For the next lesson, the students fill out their own daily activity diary.
- The second classroom lesson deals with the concepts of carbon footprint and externalities. Students have estimated the impacts of their daily activities.
- Project day, when students are divided into groups and provided with study materials (mostly online sources). Each group of students prepares a presentation of one energy source, commenting also its positive and negative impacts. After discussion, the class formulates its recommendations for a suitable energy mix in the Czech Republic.

The two introductory lessons correspond to project launch and ideation phases of the project-based learning (Larmer et al., 2015). Driving question was: "How to supply energy for our country in the years to come". Students developed, revised and presented their solutions during the project day, with the recommendation and justification of the energy mix as the main output.

For evaluation, we used an open question assessment adapted from Merritt et al. (2019). The questions test understanding rather than factual knowledge, and focus on renewable energy sources, they are solution-oriented and practically relevant. However, climate-energy links were not a subject of interest in Merritt et al. (2019). Therefore we omitted one question from the original set on listing renewable energy sources and added a question leading to the externalities of fossil fuels (Q4). The questions were as follows:

Q1 *Which renewable energy source do you think we should use more in the future and why?*

Q2 *Sarah told her friend that she wants to buy an apple from a local farm instead one from Italy. She said her food choice will help the environment. Her friend disagreed and said it doesn't matter which apple she picks. Whom do you agree with and why?*

Q3 *How is electricity produced from an energy source? Choose one energy source (e.g. water, coal, wind, etc.). Then, draw a diagram, and explain how it produces electricity.*

Q4 *What problems are connected with coal as an energy source?*

Students were tested four months after the project day in case of one class and six months in case of the other one. The reason is that this post-test was planned just before the end of the school-year and due to organizational reasons had to be re-scheduled with one class after the summer holidays. As we show below on the data from both classes, there is no indication of impact of this post-test shift on the results of evaluation. We consider 4-6 months of time pause sufficient to make sure that the demonstrated knowledge is of more permanent character.

Data analysis followed a similar procedure as described by Merritt et al. (2019). One member of the research team reviewed the students' responses, sorted the answers into categories, and entered into spreadsheet tables. In the following step, the first author served as a peer debriefer, asking questions on suitability and accuracy of the applied interpretation rules. Discussions were leading to some changes in the approach and re-analysis of the data. The procedure was repeated until the team agreed on the outputs.

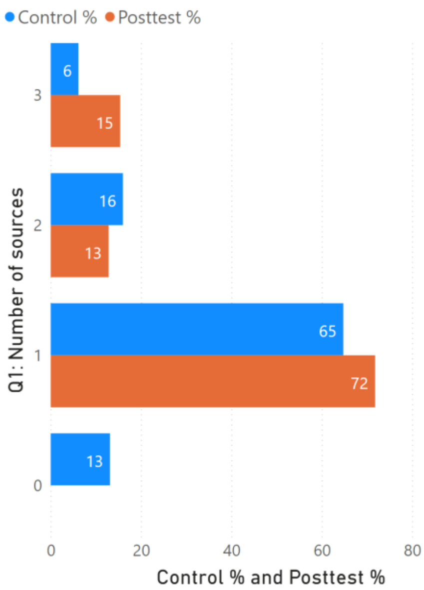
RESULTS AND DISCUSSION

The results are presented mostly in graphical format, displaying percentage of the respective answers for the experimental (labeled "Posttest") and control (labeled "Control") groups. Statistical evaluation of the results from the control group (Šedlbauer et al., 2023) produced the 95% confidence limits for each of the answers using two approaches. First, the confidence limits were estimated from relative frequency of a given answer in the whole control group. Second, the confidence limits were evaluated from sample variability, using the seven separate school results as the samples. In general, the latter approach resulted in larger confidence limits and was preferred for the sake of prudence. Results of the research group that fall outside these confidence limits suggest significant difference, such as this term is used in the following text.

Renewable energy sources (Q1)

All students were able to identify some energy source, and 28 % have given multiple answers (Figure 1). Out of the 56 answers, half identified sun, with hydrothermal and wind energy in the following (Figure 2). 5 answers refer to nuclear energy, which is not a renewable energy source. Nuclear energy is strongly present in the public debate on energy in the Czech Republic as it already provides about 40 % of electricity generation and is officially considered as one cornerstone of the future energy mix as well, along with renewable sources. That could explain this misunderstanding of nuclear energy. Reasons for using renewable energy generally reflected the omnipresence of sun, wind, and water.

In the control study, 13 % of respondents were not able to identify any energy source (no answer to this question). This is one of the significant differences as in the experimental group all students were able to name some energy source. In addition, 12 % of answers in the control group were wrong, citing nuclear energy, but also "electricity" or "electromobility" as renewable energy sources, showing the misunderstanding of the concept.



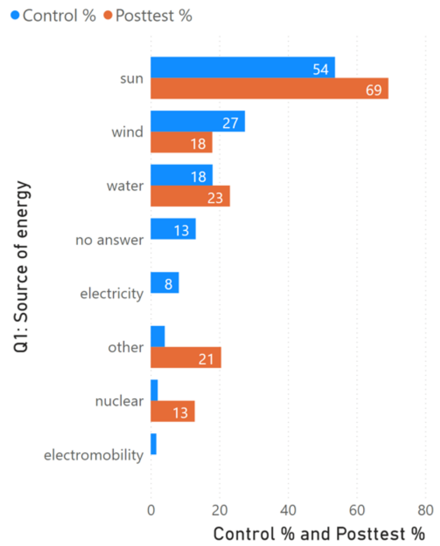
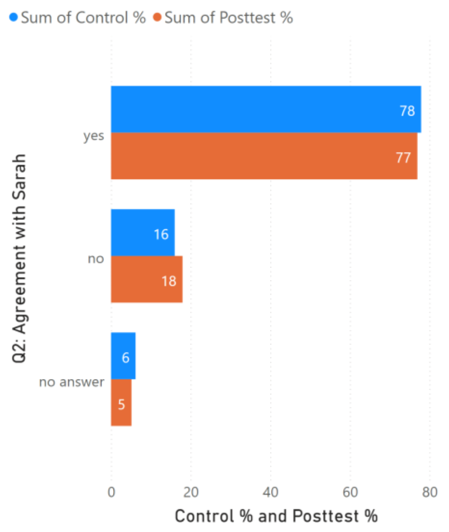


Fig. 1. Q1, number of sources by respondents. **Fig. 2. Q1, types of sources by respondents.**

Impacts of food choices (Q2)

Figure 3 shows that 77 % of students agree with Sarah, 18 % disagree and 5 % have not answered this question. The reasons are depicted in Figure 4. 15% of the students failed to provide any reason. Somewhat surprisingly, most students cite help to the local economy as the main reason for buying local produce, significantly more than in the control group. 12 answers identified international transport as the difference between local and imported apples. Up to 23 % of answers use a notion of better quality, making a (false) assumption that local produce does not use pesticides, and is healthier, a few students even put an equal sign to "local farm" and "bioproduct". Again, "buying local" and "local farm = bioproduct" narratives reflect prevailing notions in the public debate rather than school-based education. This may be illustrated by the much-debated law on mandatory quotas of the Czech-made foods in stores that passed through the House of Representatives in 2021. The law was later blocked in the Senate and did not enter into force. This question was evaluated in three levels: identification of the source of energy, evidence of energy, and energy transfer/conversion (Merritt et al., 2019).



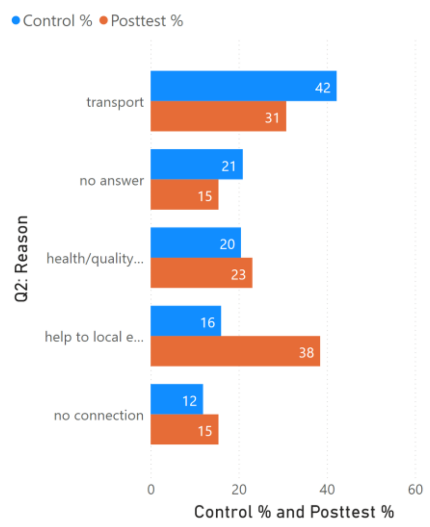
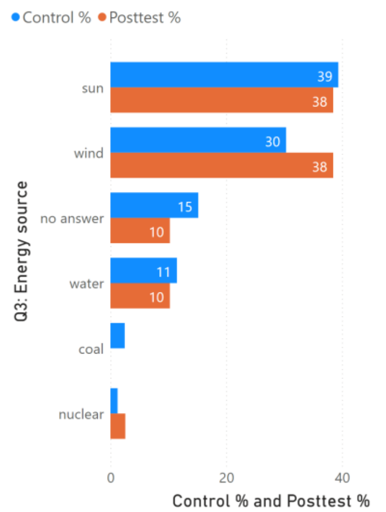


Fig. 3. Q2, agreement with the statement. **Fig. 4. Q2, stated reasons.**

Electricity production (Q3)

As in Q1, the students have chosen predominantly renewable sources such as sun, wind, and water (Figure 5). However, 10 % have skipped this question altogether. Evidence of energy was present mostly in graphical form (sun rays, air flow, water flow) with an additional 5 % of the respondents missing this point (Figure 6, with the experimental group only for clarity). The correct description of energy transfer (solar panels, turbines, generators) was more of a problem, with additional 20 % of students that were unable to suggest the transformation from light or mechanical energy to electricity (Figure 7, also with the experimental group only).

In the control group, 15 % of the students skipped this question, and an additional 7 % and 28 % provided wrong or no answers to evidence of energy and energy transfer/conversion, respectively.



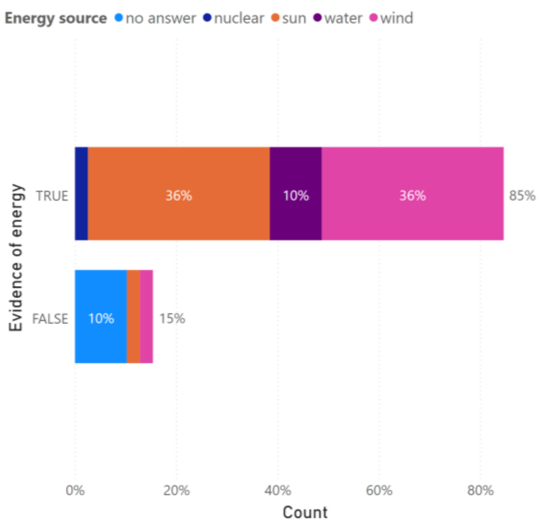


Fig. 5. Q3, selected energy sources. **Fig. 6. Q3, evidence of energy provided**

Fossil fuel externalities (Q4)

Only one student (2 %) did not answer this question, and about half of the students have given more than one answer. Stated problems include air pollution, climate-change related problems, and the problems connected with coal mining as the most important externalities of coal as an energy source. 35 % of the answers cite the non-renewable character of coal and insufficient supply of coal.

In the control group, 22 % of respondents did not answer this question (significant difference). For over 40 % of students, the problem is a limited supply of coal, citing that coal is "non-renewable" or that "there is a lack of coal". Only 3 students (1%) identified the production of CO2 or climate change as one of the answers, while in the experimental group this answer was provided by 31% of the respondents (significant difference).

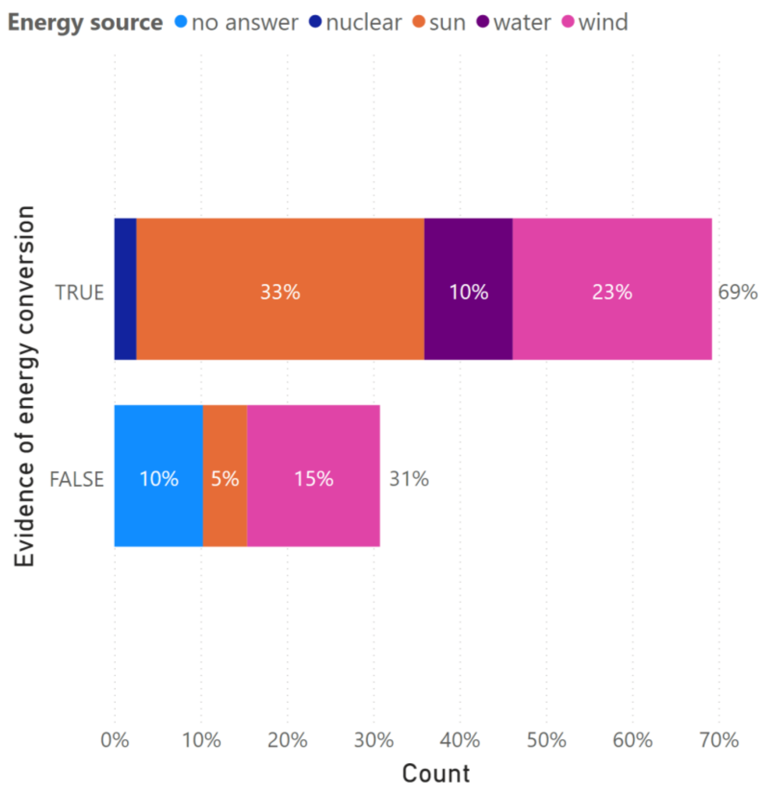


Fig. 7. Q3, energy conversion described.

The results suggest an improvement of orientation in renewable energy sources and their basic operation concepts in the group of students subject to project-based education on energy when compared with other eight-graders (Q1, Q3). The most significant difference is the understanding of the externalities of energy sources as it is demonstrated in answers to Q4. 31% of students were able to identify emissions of greenhouse gases or other climate-change related problems compared to only 1% of students from the control group. No major difference was found for the extended application of the externality concept on life-cycle assessment of food between the experimental and control groups, except for the answer "help to local economy" that was significantly more represented in the experimental group.

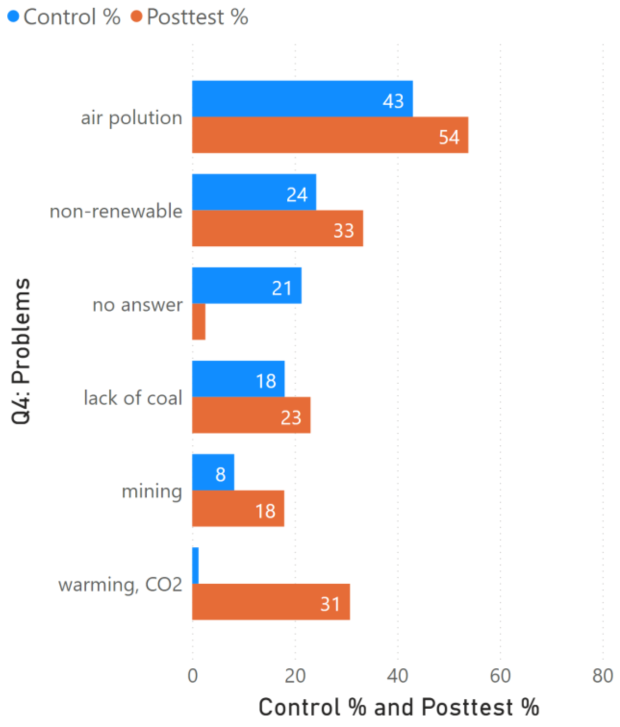


Fig. 8. Q4, problems connected with coal.

Limitations

While the size and variability of the control group (244 respondents from seven schools) allows for safe statistical evaluation, our experimental group (39 respondents from two classes of one school) is an order of magnitude smaller. The reason for this difference is that the research with the control group was undertaken as a separate project with more aims than this study (Šedlbauer et al., 2023). On the other hand, the two groups are otherwise consistent and differ just by the learning intervention (school project on energy).

The inner variability of our experimental group may be tentatively assessed by separate evaluation of the two classes. Table 1 summarizes the ratio of students that have not answered the question(s), presumably due to the lack of appropriate knowledge, separately for the two classes. Only in case of Q3 the difference between the two classes is more prominent and no systematic difference can be observed between the classes. Notably, the answers of the experimental group (= the average of the two classes) are in all cases better (=lower ratio of no-answers) than for the control group.

Tab. 1 Comparison of no-answers between the participating classes and the control group.

Class	Q1 no answer %	Q2 no answer %	Q3 no answer %	Q4 no answer %	Average no answer %
1	0	16	16	0	8
2	0	14	0	7	5
Mean for research group	0	15	10	3	7
Control group	13	21	15	22	18

We have only addressed the cognitive dimension of energy literacy in this study. It may be reasonably assumed that a better and deeper understanding of energy externalities is a factor influencing the willingness of the people to support energy transformation to renewable energy sources. We have not, however, provided justification for this assumption in this study as it would require additional testing and a different research design.

CONCLUSIONS

Interdisciplinary school project on energy resulted in better knowledge of energy-related issues such as renewable energy sources and energy conversion. Most significant is the improvement of understanding the externalities connected with energy sources, namely the impacts on climate change. While these results are promising, the output is not yet quite satisfactory. It is supposed that similar results could be achieved also by other educational interventions, not just project-based education. On the other hand, an interdisciplinary approach to energy education is a must as this issue relates deeply to the environment, economy, and politics.

Addressing all dimensions of energy literacy following novel educational intervention is yet to be tested. There is a room for further research, along with targeting what *type of knowledge* promotes the behavior of the people that is most consistent with the scientific consensus.

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Education Activities in Chemistry with the Support of the Beaker Application

Milada Teplá & Petr Distler

Abstract

The article introduces two educational activities in a form of worksheets with the support of the mobile application Beaker. The first teaching activity focused on the reactivity series of metals (Beketov's metal displacement series) and its consequences. The second teaching task focused on the colour of the flame caused by different metal cations. Nine chemistry teachers and 36 general high school students in year 1/year 2 evaluated the activities. The teachers assessed activities as suitable for students in year 1/year 2, illustrative, having clear instructions, and reasonable in time. The students evaluated the lesson with the support of the Beaker application through the semantic differential; the obtained data showed that students find the activities attractive, comprehensible, and adequately challenging.

Key words

M-learning; mobile applications; Beaker application; active learning methods; chemistry education

INTRODUCTION

Teachers and students use digital technologies on a daily basis since they have become an integral part of our daily lives. A massive increase of its usage is observed in the database of Czech Statistical Office. The current data show that the vast majority of students use mobile phones on a daily basis (Mana, 2021). As mobile phones and other modern technologies are familiar to the students, they have a large potential for being systematically used in the education process. Their wider use is connected with the increasing number of chemistry-related applications, which represent opportunities not only for improving students' knowledge and skills but also for collaborative activities among students and developing ICT literacy (Naik, 2017).

THEORETICAL BACKGROUND

The use of digital technologies in teaching and learning is growing in popularity, which is also reflected in the number of studies dealing with this issue (Bernacki et al., 2019; Crompton & Burke, 2018; Echenique et al., 2015; McKnight et al., 2016). A systematic review of a total of 72 scientific studies showed that the primary mobile device students use in class is the smartphone (Crompton & Burke, 2018). Despite the fact that the development of mobile technologies and applications, including educational ones, has already taken a big step forward, one can still find obstacles that complicate education with the support of mobile phones. One of the key issues is a technological issue (internet connection stability, battery capacity, screen size and resolution of different mobile devices, availability of individual applications for different operating systems) (Crompton & Burke, 2018). The second significant issue is the fact that not all students and teachers have sufficient skills in using different mobile applications. Also, the attitude of some teachers towards the use of mobile devices in education may not always be positive, which may even discourage some students from using mobile technologies in education (Crompton & Burke, 2018; Gikas & Grant, 2013; Sophonhiranrak, 2021). The importance of teachers' attitude towards didactic software is also mentioned in the study by Chroustová et al. (2022) who analyzed the factors influencing chemistry teachers´ acceptance and use of education software in chemistry education. The strongest factors are performance expectancy, facilitating conditions and perceived pedagogical impact.

The incorporation of mobile electronic devices (such as mobile phones, tablets, …) into the education process has great potential for obtaining new skills and knowledge. Furthermore, curricular documents (Jeřábek et al., 2007) and the Strategy for the Education Policy of the Czech Republic (Fryč et al., 2021) support the incorporation of modern technologies in the education process. As mobile electronic devices and WiFi connections are available in most classrooms (Wichová, 2022), m-learning (learning with the support of a mobile electronic device; cf. Herrington et al., 2009) can be more easily implemented in lessons. Moreover, there are other factors enabling the usage of m-learning such as the worldwide increase in the number of smartphones which has brought a major development in mobile applications, the integral parts of each mobile device (Pokorný, 2009). Furthermore, thanks to the frequent usage of smartphones, many educational applications have been developed during the last year.

Mobile educational applications

There are many mobile applications which allow students to visualise complex processes in chemistry at an elementary and high school level. By exploiting the support of mobile phones and suitable applications in the education process, the students can be activated leading to an increase in their effort put into the lessons. Moreover, the subject matter is presented to students using a tool which they are familiar with. As the teachers are the ones who decide whether to exploit the support of modern technologies in the education process, it is essential to familiarise teachers with such technologies and their applications so that they would not avoid m-learning in their lessons (Lambic, 2014).

Beaker application

The Beaker application turns a mobile phone into a virtual lab to experiment with more than 100 different chemicals. It is suitable for teaching inorganic chemistry at the elementary and secondary school level. As the name of the application suggests, the programme changes the smartphone or tablet into a virtual beaker into which students put various chemicals. If the chemicals react with each other, the application shows the process of a chemical reaction and its products. This feature enables the observation of chemical reactions of selected elements, and inorganic (and some organic) compounds. Moreover, connecting multiple devices (smartphones, tablets...) enables having more beakers, the contents of which can be mixed the same way as with real beakers. Additionally, beakers can be heated or closed up by an external lid. Furthermore, finger motion on a touch screen simulates flame allowing the observation of a change in the colour to indicate the presence of selected metals.

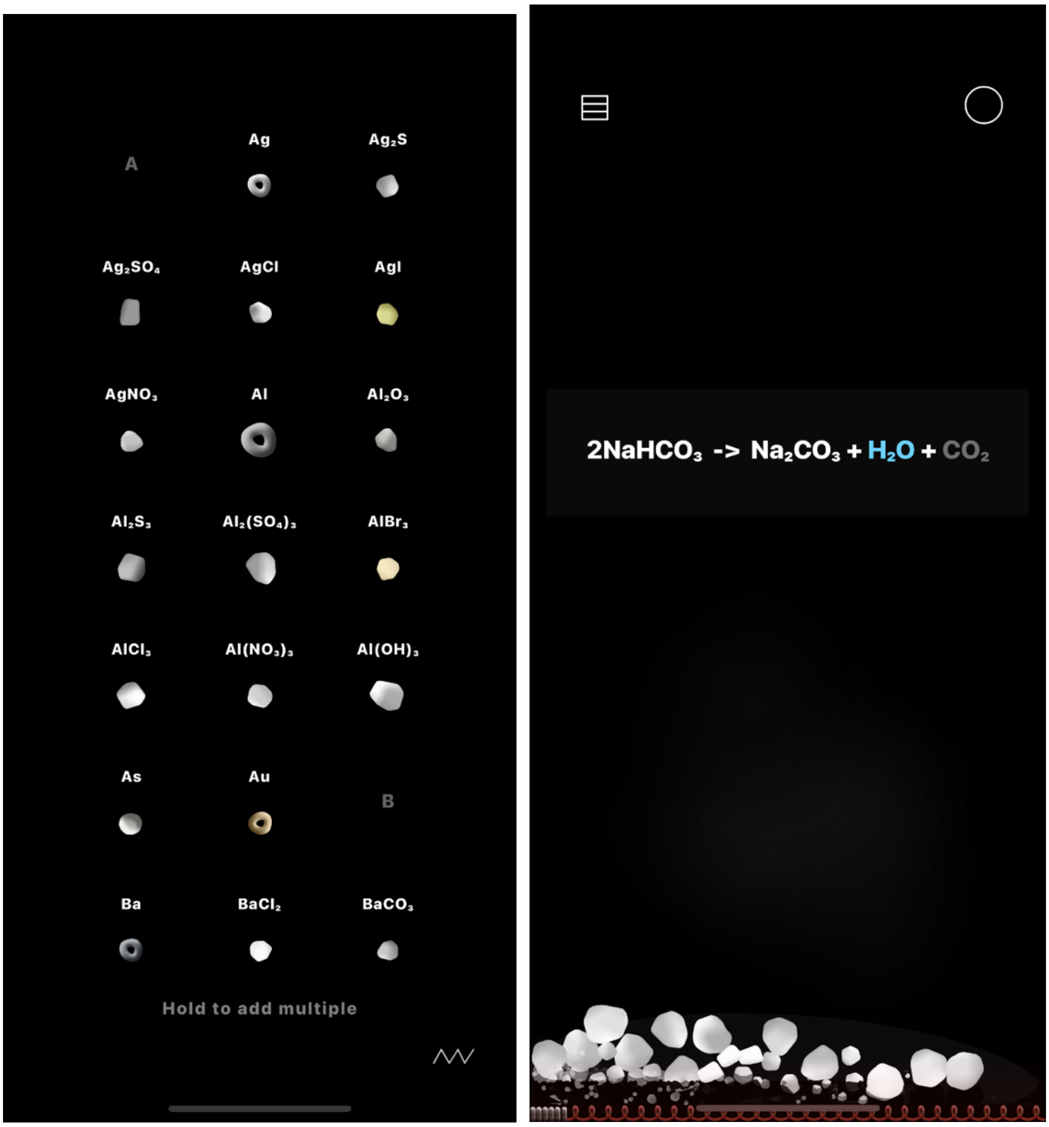

Fig. 1 The Beaker application – screenshots. An example of chemicals (left) and a decomposition of baking soda by an external burner (right).

RESEARCH AIMS AND RESEARCH QUESTIONS

The main aim of the presented research was *to design educational material (i.e. worksheets) for effective usage of the Beaker application in the high school chemistry classes and evaluate their impact from students´ and teachers' points of view.* Based on the goal of this work, the following research questions were settled:

RQ1: How do teachers evaluate the designed educational activities regarding their attractivity, comprehensibility, difficulty and time required for task completion?

RQ2: How do students evaluate the proposed activities?

METHODOLOGY

The first phase of the research was conducted in 2021 and included 9 participating fully-qualified chemistry teachers with various lengths of teaching experience (3 teachers with more than 25 years, 1 teacher with 10 – 15 years, 3 teachers with 5 – 10 years and 2 teachers with less than 5 years). The second phase continued in two classes at a general high school in 2022. Students in Year 1 and Year 2 participated in the research. Students in Year 1 (N = 15) evaluated the first educational activity called **It's Not Metal like Metal**, whereas students in Year 2 (N = 21) evaluated the second educational activity named **Flame Tests in a Mobile Phone**. The age of participants varied from 15 to 17 years. The teacher in both classes was one of the authors of this paper. Educational activities were incorporated into the curriculum when metals and flame tests were taught.

The introduction of educational activities

There were two activities designed for the Beaker application in this project: **It's Not Metal like Metal** and **Flame Tests in a Mobile Phone**. These topics were chosen as conducting these experiments in real life is troublesome (**It's Not Metal like Metal**) or difficult to show (**Flame Tests in a Mobile Phone**). There are worksheets designed for each activity – the instructions and methodological guides for teachers are available at (Teplá, 2022). Both activities imply an inductive way of learning (Pasch et al., 1998) as students generalise statements based on individual chemical reactions and are appropriate in the presenting phase of teaching.

Activity 1: It's Not Metal like Metal is suitable for Year 1 high school students. The aim of this activity is teaching students to recognise noble metals and base metals according to their reaction with sulphuric acid. The metals in this worksheet were chosen so that the application includes the products necessary for the task. The worksheet consists of seven tasks. However, there is also a bonus task in which students try to predict and verify the reaction of given metals with hydrochloric acid.

Activity 2: Flame Tests in a Mobile Phone focuses on the changes in the colour of flames based on the cations contained in a given sample/compound. The activity is designed for high school students in Year 1, or Year 2. The goal of this activity is to teach students which metals change the colour of flames and their possible practical usage. The task is suitable for an inquiry-based method of teaching as students create hypotheses and verify them based on observing chemical reactions in the Beaker application.

Evaluation of activities

Each participating teacher appraised each educational activity in a semi-structured interview**.** Teachers were asked a set of questions followed by additional questions in case their statement needed to be specified. There were a few general questions (length of teaching experience, school and its location, …) at the beginning, followed by questions focusing on teaching methods and also on using mobiles and other electronic devices in the education process. In the second part of the interview, questions aimed at the two proposed educational activities regarding their perceived attractivity of activities for teachers, comprehensibility, ambiguity, activities difficulty and estimated time taken by each proposed activity. Furthermore, teachers were encouraged to name all pros and cons of the activities.

The students' evaluation was processed by using the semantic differential - a method often applied in psychology, marketing, but also in pedagogical research (Vašťátková & Chvál, 2010; Bauer, 2008). Within the field of education, this method is commonly used in the auto-evaluation of school subjects, and study programmes and in measuring the effectiveness of new teaching methods to improve the education process (Kordíková & Brestenská, 2019). In this research, we used a combination of a 7-point scale and 20 bipolar adjectives which were used in previous research (Kubiatko, 2016; Kordíková & Brestenská, 2019). Our research tool was modified by replacing the scale "fear" with "value". Each of the given scales (comprehensibility, value, interest, and emotional satisfaction) was represented by four statements, thus 16 items in total (Tab. 1). Consequently, students evaluated "Chemistry lesson with the support of the Beaker application" by choosing a number 1 to 7 on a scale based on which adjective describes the activity more accurately (the higher value of the chosen number, the more positive approach and vice versa).

Tab. 1 A set of 7-point scales with 16 bipolar adjectives (each belonging to one group: comprehensibility, value, interest, emotional satisfaction) used for the evaluation of the chemistry lesson with the support of the Beaker application.

COMPREHENSIBILITY	1	INCOMPREHENSIBLE	1	2	3	4	5	6	7	COMPREHENSIBLE
VALUE	2	useless	1	2	3	4	5	6	7	useful
INTEREST	3	boring	1	2	3	4	5	6	7	exciting
VALUE	4	insignificant	1	2	3	4	5	6	7	significant
COMPREHENSIBILITY	5	confusing	1	2	3	4	5	6	7	clear
EM. SATISFACTION	6	bad	1	2	3	4	5	6	7	good
EM. SATISFACTION	7	frustrating	1	2	3	4	5	6	7	pleasant
COMPREHENSIBILITY	8	understandable	1	2	3	4	5	6	7	not understandable
COMPREHENSIBILITY	9	unclear	1	2	3	4	5	6	7	clear
EM. SATISFACTION	10	hostile	1	2	3	4	5	6	7	friendly
INTEREST	11	monotonous	1	2	3	4	5	6	7	interesting
INTEREST	12	unattractive	1	2	3	4	5	6	7	attractive
EM. SATISFACTION	13	uncomfortable	1	2	3	4	5	6	7	comfortable
VALUE	14	invaluable	1	2	3	4	5	6	7	valuable
VALUE	15	useless	1	2	3	4	5	6	7	utile
INTEREST	16	unentertaining	1	2	3	4	5	6	7	funny

RESULTS AND DISCUSSIONS

Teachers' evaluation of provided materials

Five of the participating teachers said that they included work with mobile devices as a part of their lessons. In these lessons, students are asked either to find/verify information or to participate in a group task. To complete these tasks, students often use mobile applications such as ChemTube3D, KingDraw, FireworksLab, Beaker, Virtual ChemLab, Atom Builder or Periodic Table to name the most common applications. The other four participating teachers said that they had not used any mobile applications in their lessons, or used them very rarely.

Nevertheless, most of the participating teachers agreed that if they wanted to include an activity using a mobile application in their lesson, they would try to find a worksheet that had already been designed for such a lesson. Teachers claimed that creating new worksheets is time-consuming, especially if they had not been fully familiarised with the mobile applications. At this point, they are not able to exploit the full potential of applications and design the worksheet for students on their own. On the other hand, teachers appreciate worksheets published in an editable format so that they can adjust the task to their pupil´s needs.

The first educational activity **It's Not Metal like Metal** was found to be popular, comprehensive and attractive among teachers (they chose options "mostly positive" and "very positive" regarding the popularity). Most of the teachers would include this activity in the teaching process again although it took up almost the whole lesson (between 35 to 40 out of 45 minutes). Moreover, teachers found the activity adequately difficult and appreciated its visual effects, clarity, extent, and also the way of introducing the topic to the students. However, two teachers suggested shortening the worksheet as it contains information and tasks provoking follow-up discussions with students.

The second educational activity **Flame Tests in a Mobile Phone** was found to be very popular, comprehensive and attractive among teachers (voted mostly as "very positive" regarding its popularity). Most of the teachers would include this activity in the teaching process as it took between 15 to 25 minutes to complete the activity. Moreover, teachers appreciated the adequate difficulty of the task, the length of the task, simple and clear instructions and also the chance of following the principles of inquiry-based education. One of the participating teachers suggested prolonging the time required for task completion as students set their hypothesis incorrectly more than once. This phenomenon was expected to happen if students were not used to formulating hypotheses on their own. Therefore, in such situations, it is crucial for the teacher to be supportive and perhaps brainstorm their ideas with them and help them settle the hypothesis. Moreover, it is vital to prevent students from being afraid of formulating untrue hypotheses.

Both applications were evaluated positively by teachers. This assessment is very important because of the favourable attitude of the teachers towards the educational activities and for their further use in chemistry education. Chroustová et al. (2022) concluded that for using software in chemistry education, teachers should be familiarised with an educational application, provided with materials (activities), and know the methodology and good practice concerning the activity use.

Students' educational activities evaluation

The reliability of the research tool (semantic differential) was evaluated using the method of calculation of estimated internal consistency. We computed Cronbach's alpha for each scale and each activity separately. The calculated results exceed the generally accepted minimum of 0.70 (Nunnally, 1978) in all scales (Tab. 2). Therefore, we can consider the obtained data as sufficiently reliable.

Tab. 2 Observed scales and reliability coefficients.

SCALE	CRONBACH'S ALPHA VALUE	
	Educational activity 1: **It's Not Metal like Metal**	Educational activity 2: **Flame Tests in a Mobile Phone**
COMPREHENSIBILITY	0.771	0.940
VALUE	0.899	0.920
INTEREST	0.823	0.897
EM. SATISFACTION	0.878	0.916

The following graph (Fig. 2) provides the overview of the attitude of respondents towards "Chemistry lesson with the support of the Beaker application" using the arithmetic mean of values of individual scales (arithmetic mean of results of each statement belonging to the scale). The graph shows that both educational activities were perceived positively. Regarding comprehensibility, students evaluated both activities as comprehensible, although they stated that they understand **Flame Tests in a Mobile Phone** better (M1 = 4.6; M2 = 5.6) compared to the other educational activity. On the other hand, the activity **It's Not Metal like Metal** was seen as more valuable for students (M1 = 5.2; M2 = 4.6) which might be caused by more difficult tasks contained in the activity. Nevertheless, the data show that **Flame tests in a mobile phone** reached better results regarding interest and (M1 = 4.6; M2 = 5.1) and emotional satisfaction (M1 = 4.6; M2 = 5.4) compared to another activity. To sum up, all obtained evaluations exceeded the average and therefore "Chemistry lesson with the support of the Beaker application" can be considered comprehensive, valuable, interesting and pleasant.

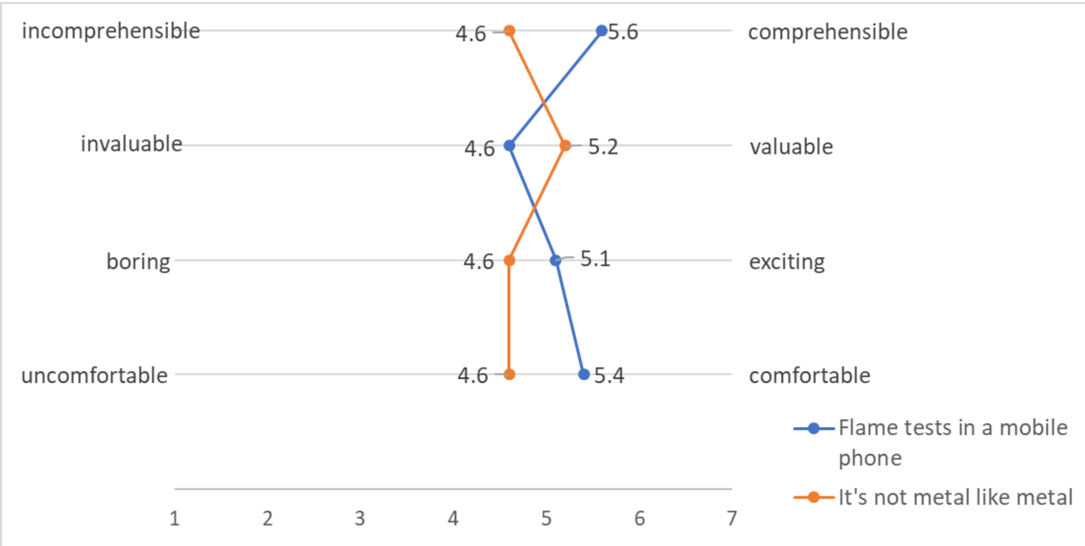

Fig. 2 The obtained average evaluation of observed scales (comprehensibility, value, interest and emotional satisfaction).

The limitation of the study

The research investigations carried out have some limitations. This research presents a case study; the obtained results are valid only for the given sample of students and teachers and cannot be generalised. The teachers and the students involved in the case study were selected from a convenience sample. It is, therefore, the opinion of these individuals.

CONCLUSION

The purpose of this study was to evaluate two learning activities using the Beaker application. The first activity focused on the reactivity series of metals and the principles that follow from it. The second activity focused on the colour of the flame caused by different metal cations. The learning activities were evaluated by nine chemistry teachers, who evaluated them generally positively. They rated them as attractive, sufficiently comprehensible for the age of the students, adequately demanding, illustrative, clear, and reasonable in time. The chemistry lesson with the support of the Beaker application was also evaluated by students through the semantic differential. The students evaluated the lessons as comprehensible, sufficiently interesting, and valuable, and rated the atmosphere as friendly.

Acknowledgement

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Biology subject matter: an analysis of the topic prokaryotic organisms in Czech lower secondary textbooks

Karel Vojíř & Lenka Jarošová

Abstract

Textbooks present a selection of educational content and its transformation to make it as accessible as possible to students. Teachers also use them for their lesson preparation. The research aimed to realize a content analysis of selected chapters of Czech textbooks for lower secondary schools dealing with the issue of prokaryotic organisms. All biology textbooks with approval (N=8) were analysed. Considerable differences were found among textbooks. The topic of prokaryotic organisms is presented mainly from the point of view of their pathogenicity, morphology, and occurrence.

Key words

Textbook analysis; content analysis; biology education; science education; prokaryote

INTRODUCTION

Textbooks have long been a part of human culture. However, they are still a current tool, as evidenced by the growing research interest in this area (Vojíř & Rusek, 2019). As material didactic aids, textbooks fulfil a myriad of functions, containing transformed scientific knowledge and serving as a support for two groups of users – both students and teachers. For teachers, textbooks are not only aids in teaching but also an essential support for lesson preparation (Vojíř & Rusek, 2022). Thus, a textbook defines the scope and structuring of the educational content of specific subjects. As a result, textbooks represent a concrete form of the intended curriculum (cf. Thijs & Akker, 2009).

One of the structural elements of educational content is terms, which play an essential role in explaining and presenting the subject matter. A representation of appropriate terms in textbooks is important for the student's comprehension of the text and, therefore, for an effective educational process (cf. Průcha, 2017). There is an open commercial textbook market in Czechia, and it was found that the choice of textbooks is typically up to individual teachers without their systematic support (Vojíř & Rusek, 2021). For this reason, it is then necessary to examine the content of textbooks to understand the shape of the educational content of each subject.

Several publications were published in recent years focusing on the analysis of selected topics in biology textbooks both in Czechia (see e.g. Dvořáková & Absolonová, 2017; Machová, 2020) and in other countries (e.g. Hoffer et al., 2022; Willinsky, 2020). However, no comparison of Czech textbooks concerning the topic of prokaryotic organisms has been carried out so far. Prokaryotic organisms interfere in our lives almost daily and may fundamentally influence the ecosystems (see Lladó et al., 2017). Bacteria as prokaryotic organisms are also embedded in state-level curriculum documents, together with viruses (see MŠMT, 2021). Therefore, the research conducted focused on this issue.

Research aim and questions

The aim of the research was to analyse the content of the topic of prokaryotic organisms presented in Czech lower-secondary biology textbooks. The analysis was guided by the following research questions:

- How is the topic of prokaryotic organisms treated in the lower-secondary biology textbooks?
- How do the different lower-secondary biology textbooks differ in their treatment of the topic of prokaryotes?

The analysis of textbooks allows an understanding of how the topic of procaryotic organisms is presented to teachers and students in view of the concretization of the intended curriculum. A key role in this context is played by the terms included, which express what is emphasized in the topic subject matter and what students are supposed to learn. A comparison of textbooks shows the variation in the approach to the topic and the different learning opportunities provided to students.

METHODOLOGY

A systematic analysis of textbook chapters dealing with prokaryotic organisms was conducted to answer the research questions. Attention was primarily paid to the terms contained in the chapters as elements constituting the didactic text. The analysis used a quantitative-qualitative approach based on quantifying terms and subsequent open coding.

Research sample

To enable a broader comparison, all Czech lower-secondary biology textbook sets that had the approval clause of the Ministry of Education (MŠMT, 2021) at the time of the research (1-4/2022) were included in the analysis. By obtaining this clause, these textbooks were approved as suitable for teaching in accordance with the currently valid curriculum. They are thus approved concretization of the intended curriculum (cf. Thijs & Akker, 2009). Within each set of textbooks for lower-secondary schools, textbooks covering the topic of prokaryotic organisms were identified. The topic of prokaryotic organisms is included in all textbook sets with the approval clause of the Ministry of Education. The topic is always assigned to only one grade in all textbook sets. This means always only one textbook in the set, except the Fortuna textbooks, where the 7^{th} grade textbook (covering the topic of prokaryotes) is divided into two volumes. Since these are two textbook volumes for the same year, they were evaluated together. The list of textbooks analysed is given in Table 1. Because of the complicated titles, the individually analysed textbooks hereafter are referred to by the name of the publishers.

Table 1 Analysed textbooks

TEXTBOOK TITLE	YEAR OF PUBLICATION	AUTHORS	PUBLISHER	PLACE OF PUBLICATION
Přírodopis 6 pro základní školy	2020	Černík, V., Hamerská, M., Martinec, Z., Vaněk, J.	SPN	Praha
Přírodopis 6, hybridní učebnice pro základní školy a víceletá gymnázia	2021	Pelikánová, I., Čabradová, V., Hasch, F., Sejpka, J.	Fraus	Plzeň
Přírodopis pro 6. ročník základní školy	2010	Dobroruka, L. J., Cílek, V., Hasch, F., Storchová, Z.	Scientia	Praha
Přírodopis, úvod do přírodopisu, učebnice pro 6. ročník základní školy	2019	Vieweghová, T.	Nová škola – DUHA	Brno
Přírodopis 1. díl, úvod do učiva přírodopisu	2018	Musilová, E., Konětopský, A., Vlk, R.	Nová škola	Brno
Ekologický přírodopis pro 7. ročník základní školy, první část Ekologický přírodopis pro 7. Ročník základní školy, druhá část	2019	Kvasničková, D., Pecina, P., Froněk, J., Jeník, J., Cais, J.	Fortuna	Praha
Přírodopis 6, vývoj života na zemi – obecná biologie – biologie hub	2011	Dančák, M., Sedlářová, M.	Prodos	Olomouc
Hravý přírodopis, učebnice pro 6. ročník ZŠ a víceletá gymnázia	2017	Žídková, H., Knůrová, K.	Taktik	Praha

All chapters devoted to prokaryotic organisms were analysed in each textbook, regardless of their placement in the book. The analysis focused on the explanatory text as the primary content component of the textbooks (cf. Prucha, 1985). All parts of the explanatory text in the chapters concerned were analysed, regardless of their subdivision.

Analysis procedure

The selected explanatory texts were analysed in relation to the content and the terms contained in them. All terms were identified in the first step of text analysis (see Průcha, 2017). The terms were quantified and then analysed, targeting their thematic focus. Open coding was used to identify the thematic focus of the terms (Švaříček et al., 2007). To increase reliability, the classification of the terms into the identified categories was verified by the second researcher. In case of disagreement, a consensus decision was made by agreement (cf. Honskusová et al.., 2022).

The observed data were descriptively evaluated. The most frequently occurring themes were identified, and textbook differences were compared.

RESULTS AND DISCUSSION

It was found that bacteria are discussed in all sets of textbooks. All textbook sets thus formally correspond to the national curriculum (cf. MŠMT, 2021). However, the treatment of the topic of procaryotic organisms and the attention paid to subtopics vary significantly between textbooks. In addition to the domain Bacteria, there are also chapters in two textbooks considering the domain Archaea. Only In the textbook Prodos it is elaborated in detail, and the textbook Taktik marginally mentions this domain. On average, four pages are devoted to this topic in the textbook. The textbook Prodos is exceptional in this regard, with eight pages (9,2% of the book, 4,0% of both volumes of textbook for the 6th grade) devoted to the topic of prokaryotic organisms. In contrast, the least attention is paid to the topic in the textbook Scientia, in which only two pages (1,6% of the textbook for the 6th grade) deal with prokaryotic organisms. Significant differences in the topics and their range create different learning opportunities for students (see Haggarty & Pepin, 2002).

A significant difference in the range of topics devoted to prokaryotic organisms is also reflected in the number of terms in individual textbooks. In the explanatory texts on the topic analysed, there are between 82 (textbook SPN) and 191 terms (textbook Prodos), see Figure 1. The second highest number of terms was found in the textbook Fortuna, but it was only 117 terms. The Prodos textbook thus outperforms the runner-up by 39% in the number of terms. Regarding students' learning, these numbers of terms are high. The findings correspond with the previously observed high semantic text difficulty trend in Czech biology textbooks (Hrabí, 2007, 2010). A high load of terms can lead to the incomprehensibility of the text for students and the impossibility for them to learn them. However, as the differences between textbooks and especially comparisons with the elaboration of textbooks in other countries (see Beníčková et al., 2021) show, a high load of terms is not necessary for the elaboration of science textbooks.

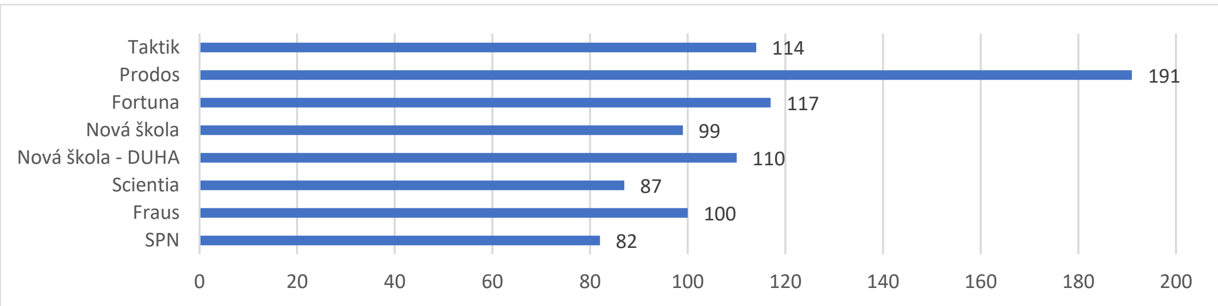

Figure 1 Number of terms in the chapters on prokaryotic organisms in each textbook

Within the chapters, different topics were found to be given different attention in the textbooks in the context of prokaryotic organisms. Generally, most attention is paid to prokaryotic organisms' morphology, occurrence, and pathogenicity, see Figure 2.

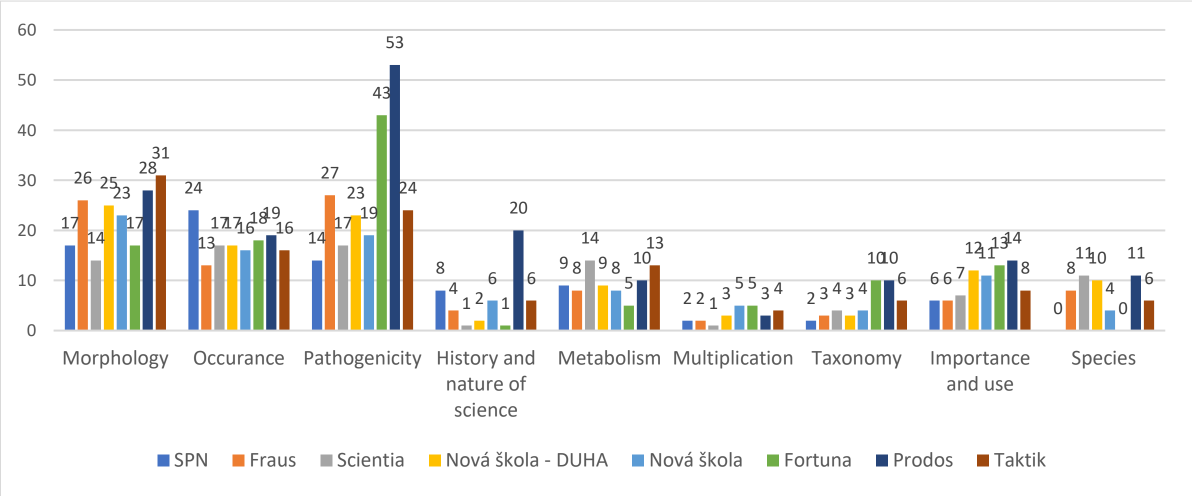

Figure 2 Number of terms by topic in chapters focusing on prokaryotic organisms

There are 14 (textbook Scientia) to 31 terms (textbook Taktik) devoted to the topic of **morphology**. All textbooks cover general morphology (e.g. *unicellular organism*), cell types (e.g. *prokaryotic cell*), cellular parts (e.g. *cell wall*), and cell shape and arrangement (e.g. *coccus*, *bacillus*). Within the last subcategory, the most considerable differences between textbooks were found in the description of morphology. While the textbooks SPN and Scientia mention this topic marginally (1 to 2 terms), the textbooks Taktik and Nová Škola include 10 terms, and the textbook Prodos even 14 terms describing the different types of shapes and arrangement of bacterial cells.

The topic of the **occurrence** of prokaryotic organisms is covered in textbooks with 13 (textbook Fraus) to 24 concepts (textbook SPN). In the textbook SPN, this topic represents more than 29% of all terms, giving the topic significant emphasis. In contrast, in the textbook, Prodos, terms related to this topic represent less than 10% of the concepts. Typically, terms such as *digestive tract* or *algal bloom* are mentioned.

The most considerable differences in the number of terms within a category were found about the **pathogenicity** of prokaryotic organisms. Between 14 (textbook SPN) and 54 (textbook Prodos), terms from this category were found in the textbooks. Terms of this focus represent 27% of the terms in the textbook Fraus, 28% in the textbook Prodos and even 37% in the textbook Fortuna. In all textbooks, there are terms related to the course and symptoms of diseases (e.g. *enteritis*, *incubation period*, *infection*), treatment and prevention (e.g. *vaccination*, *antibiotics*), and specific diseases (e.g. *cholera*, *tuberculosis*). The latter subcategory is the most abundantly represented in all textbooks within pathogenicity. In the textbook Fortuna there are 27 and in the textbook Prodos even 32 terms expressing specific diseases. The explanatory text thus has considerable features of an enumerative list. Except the textbook Taktik, terms relating to transmission and hosts (e.g. *sexual intercourse*) were also found.

Considerable differences in the number of terms in the various textbooks were also found in relation to the **history and nature of science**. The greatest attention is paid to this topic in the textbook Prodos, in which 20 terms were found. In the other textbooks there are only 1 to 8 terms. The terms relate primarily to scientific methods and procedures, which are reflected by at least one term in all textbooks (e.g. *pasteurization*, *microscope*). The textbook SPN deals with this most (6 terms). In the textbooks SPN, Nová škola - DUHA, Nová škola, Prodos, and Taktik, attention is also paid to concrete scientists. Most scientific personalities are mentioned in the textbook Prodos, in which 9 names are mentioned (e.g. Alexander Fleming, Ignaz Philipp Semmelweis).

Regarding the number of terms, prokaryotic **metabolism** receives relatively balanced attention in textbooks, ranging from 5 (textbook Fortuna) to 14 terms (textbook Scientia). Only terms from the subcategory of specific metabolites (e.g. *sugar*, *oxygen*) are present in all textbooks analysed. In the other subcategories, a maximum of 2 terms were always found in the textbooks, with no clear trend between textbooks. The textbook Scientia is then exceptional for its greater attention to the trophy of prokaryotic organisms (e.g. *parasitic*).

Multiplication of prokaryotic organisms is included in all textbooks. In all textbooks, the general term *division* is included. The topic receives the most attention in the textbooks Nová Škola and Taktik (5 terms identically). Terms related to **taxonomy** were also found in all textbooks. However, the approach in this area varies considerably between textbooks. From 2 (textbook SPN) to 10 terms (textbooks Fortuna and Prodos) are included, but these are very different terms. For example, while the textbook Fortuna contains terms such as *algae* and *protozoa* to define other groups having a unicellular structure, the textbook Taktik includes terms such as *archaebacteria* or *Cyanophyta*.

The textbooks are relatively uniform regarding the frequency of representation of terms related to the importance and use of prokaryotic organisms. There are from 6 (textbooks SPN and Fraus) to 14 terms (textbook Prodos) and all textbooks include terms related to both human use (e.g. *biogas*) and importance in the ecosystem (e.g. *decomposers*) in a roughly analogous focus. While in the case of ecosystem relevance, the concepts are practically the same thematically, in the case of human use, different sectors are mentioned in particular textbooks. Differences in the selection of core curriculum appear in a similar way in the category of **species**. This category was the only one not represented in all textbooks, and so while it is completely absent in the textbooks SPN and Fortuna, 11 particular prokaryotic organisms (e.g. *Mycobacterium*, *Yersinnia*, *Thermococcus gammatolerans*) are listed in the textbooks Scientia and Prodos. In the case of the use of different textbooks, students are thus presented with significantly different educational content.

As found in the textbooks, within the topic of prokaryotic organisms, in addition to aspects that are easy for students to understand (occurrence), there is also a strong emphasis on specialised terminology (morphology) and abstract concepts (metabolism). Abstract science concepts are difficult for students to understand and learn (cf. Johnstone, 1991). Emphasis on disciplinary terminology without broader understanding and application as well as giving the Latin names of organisms without introducing them to the students also reduces the relevance of learning content for students (see Stuckey, 2013). This causes biological topics with abstract concepts to be difficult for students to master (see Çimer, 2011).

The emphasis on the pathogenicity of prokaryotic organisms over their importance in ecosystems and their positive impact and use by humans also appears to be a significant trend in textbooks. Explanations that focus primarily on the negative effects of organisms on humans may amplify the problem of alienation from nature (see Jančaříková et al., 2020). The high focus on theoretical concepts and terminology without concrete students' ideas and the emphasis on negative manifestations of procaryotic organisms may influence students' attitudes not only towards this topic but towards science in general.

CONCLUSION

A total number of terms varies by up to more than two times between textbooks. These differences point to the different emphasis given to prokaryotic organisms in particular textbooks, which may also affect students' views of biodiversity. The greatest attention in the textbooks is paid to prokaryotic organisms' morphology, occurrence, and pathogenicity. Despite differences between textbooks, this focus appears to be the pattern in which prokaryotic organisms are represented. Emphasis on abstract concepts, terminology, and negative perceptions of prokaryotes can have a negative impact on students' conceptions of science. It therefore needs further attention.

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Discourse of primary pupils about scientific work in relation to science education

Žaneta Staníková & Kristína Žoldošová

Abstract

The aim of this paper is to analyse the sense of competence in science, pupils' ideas about the work of a scientist with an emphasis on their aspirations for a scientific profession. We found that the way science is taught is also reflected in the activities in which pupils feel competent and self-confident. Pupils seem to lack confidence in their own scientific abilities, which probably occurs when science as a discourse of identity encounters a contradiction of the idea of the scientist as a thoughtful person, with the feeling of the pupil alone not feeling competent enough to pursue a profession of which he has not experienced the basic elements during his science education.

Key words

Primary education; sense of competence; science education; aspirations to science

INTRODUCTION

For several decades, the educational community has been addressing the issue of a constant decline of interest in science and technology fields. Recently, several research studies have focused on finding out whether the lack of interest in these areas of professional activity is due to an underdeveloped idea of what science is, what the job content is, and so on (Scholes & Stahl, 2022). However, there is relatively little research that qualitatively clarify pupils' views on science and scientific work. A significant number of evidence suggests that compared to other school subjects, those in science are reflected minimally into pupils' career aspirations (Archer et al., 2020). In Slovakia, low attractiveness of science subjects and low interest in science subjects are cited as reasons for pupils' lack of interest in science as a career (Sláviková et al., 2012). This argument is supported by the well-known low level of science literacy of our pupils in PISA measurements. In the UK, pupils' low aspirations to become a scientist are justified by the low level of scientific capital, which also includes the above mentioned science literacy (DeWitt et al., 2016). According to Science Capital Teaching Approach (Archer et al., 2016), pupils who are never placed in a position of discoverer feel insufficiently competent to pursue science in the future, they perceive science as something unattainable and as something that relates only to a selected group of people (Staníková, 2020). It seems that the exclusion of pupils from the science profession cannot be specified in terms of pupils' disinterest in science alone but needs to be looked at in terms of a complex range of factors (Moote et al., 2020). Recent research on pupils' interest in science education suggests that the perception of oneself as 'good at science' and competent to follow a scientific path plays a key role (in addition to family support) in the choice of future studies or profession (Vedder-Weiss, 2018). Pupils' science aspirations have also been found to be related to school science engagement (Majtuba et al., 2018). Nowadays, research is one of the most commonly used terms in science especially when the pupils are actively engaged in scientific experiments that stimulate their curiosity, encourage them to ask questions, investigate things and use supporting evidence to explain phenomena (Gillies, 2020). This implies that the very sense of competence is related to what happens in science education (Staníková, 2021).

RESEARCH GOALS AND METHODOLOGY

Our intention was to find out the situation in selected schools in Slovakia – whether our pupils feel competent enough to devote themselves to science and find out connection between this sense of (in)competence and by in which activities of science education they feel confident. We focused on the following variables: *pupils' aspirations towards science (1), the way pupils perceive school science (2), pupils' opinions on science education (3), pupils' ideas about science and the work of scientists (4), the pupils' sense of competence in science (5).*

Our study is guided by the following research questions:

In which situations in science classes do primary pupils feel most competent?

How are pupils' ideas about science education, science and scientific work related to pupils' sense of competence in science and their scientific aspirations?

Participant´s selection

There were 6 schools involved in our research and a total of 104 pupils took part, of which 46 were girls and 58 were boys (Tab 1). The research sample was made by available selection.

Tab.1: Information about the research sample

Name of the school	PS* Olešná	PS* Turzovka	PS* Staškov (2 classes)	Private PS* Félix Žilina	Private PS* Žilina (2 classes)	PS* anonymous	**n**
Number of pupils in class	10	12	16/16	13	15/12	10	10
Number of pupils in the focus groups	5/5	7/5	8,8/8,8	7/6	7,8/6,6	5/5	4

Primary school

Research design and data processing

The qualitative approach in data collection of our research was represented by methods of spontaneous content drawing by which, in the first step, we tried to understand the way pupils perceive school science (2) in connection with the pupils' sense of competence in science (5). On the basis of the data obtained from the qualitative part of the research, in the second step we created a questionnaire, representing a quantitative approach to data collection, with which we monitored pupils' opinion on science education (3) and pupils' sense of competence in science (5) in connection with pupils' aspirations towards science (1). In the third step, we used the focus group method to find out more detailed information about the pupils' drawings, being particularly interested in whether pupils identified the activities carried out in class - pupils' views on science education (3) with the activities carried out by scientists in their work - pupils' ideas about science and scientists' work (4) in relation to pupils' sense of competence in science (5). Research instruments were based on the knowledge of the theory of science literacy development and inductively oriented educational practices.

Drawing method

In compiling and also analysing the drawings, we were inspired by Katz (2017). We took inspiration from the use of DASTT and DESTIN methods mentioned in this publication to explore how science education is implemented. The Drawing-Science-Teacher-Ideal-Not (DESTIN) method is a strategy used to explore pupils' perceptions of science subjects, science teachers and science teaching. The Draw-A-Scientist-Test (DAST) is the most common method of assessing pupils' drawings of scientists. However, we focused in the present study on how pupils see themselves in science lessons and, in particular, in which situations they feel most confident. There are considerably fewer studies with this focus, so we relied on our own instruction for pupils after reviewing the methods presented above.

Questionnaire method

We used a questionnaire designed to allow pupils express their agreement or disagreement with statements on a Likert scale. When constructing the questionnaire, we relied on existing research instruments, while all constructs used in the original version had a verified theoretical or empirical basis that contributed to the validity of the instrument. In order to enhance the validity of the measurement instrument, we incorporated revised items from long-term studies of the ASPIRES project, which focuses directly on pupils' aspirations in science and factors that are related to their aspirations in accordance with the concept of science capital (Archer et al., 2010).The initial version of the research instrument was pilot tested, during which we conducted an internal consistency analysis, i.e., internal consistency reliability using Cronbach's alpha ($\alpha = 0.75$). Content validity of the questionnaire was ensured by reviewing and adjusting questions by two experts in the field of science didactics involved in IBSE (Inquiry-Based Science Education), while the same research instrument was used in the pilot measurement. Questions used in the questionnaire are presented in Fig. 1 and Fig. 2.

Focus group methods

We completed our research with a focus group method, through which we found out whether pupils identify activities carried out in the classroom with those carried out by the scientist in his/her work. When constructing questions, we relied on existing research instruments, and all the constructs used in the original version had a verified theoretical or empirical basis that contributed to the validity of those instruments. The main source of inspiration when creating questions for focus groups was the study by Archer et al. (2010). The study offers a new perspective on the way pupils construct ideas about science and scientists. We created a set of six questions that formed an open-ended discussion between pupils and the researcher. First two questions were aimed at identifying a variable *pupils' opinions about science education (3)* (e.g., What qualities make someone a good science student?); other two questions were aimed at finding out the variable of the *pupils' ideas about science and the work of scientists (4)* (e.g., What qualities make someone a good science student? What kind of people can become a good scientist?), and the last two questions were aimed at identifying the variable of *pupils' sense of competence in science (5)* (e.g. Do you think that in the future you would be able to work the way scientists work?).

Research process and data analysis

After receiving positive feedback from schools that were interested in participating in our research, we have contacted particular science teachers who taught children of the 4th grade. This research took place within the formal education framework of the school where children usually are. Due to the current legislation of data protection, only those children whose legal guardians had agreed in writing to their children's participation in the research took part in the research and were informed about the purpose of the research investigation and also about the possible processing of other personal data provided. Throughout the research, we have followed the principles of the GDPR. Based on the methodology we developed, we began data gathering in September 2022. Similar levels of ability and knowledge in the groups formed in the classrooms (Table 1) were identified before the actual research began by comparing the average grades of pupils in science subjects at the end of the school year (June 2022). Each group we worked with, had a similar number of students, while we divided them into groups randomly, i.e., by drawing lots.

The first step was to use the drawing method, while pupils were asked to draw on A4 paper a picture of themselves implementing science learning. The exact instruction for the pupils was as follows: *"Try to draw a situation from a science lesson that you have experienced in the past and that made you feel confident, understand the lesson, feel good about yourself during the lesson and enjoy learning."* Pupils were encouraged to draw in as much detail as possible, adding small written descriptions to their drawings. During the process of making drawings, researcher attempted to find out as much detailed information about the drawings as possible by making individual inquiries about details of drawings. When analysing their drawings, we were particularly interested in the elements of scientific practices applied to the educational process in contrast to the elements of traditional educational practice.

In the second step of the investigation, we used a questionnaire that was constructed in such a way that pupils could express their agreement or disagreement with the statements on Likert scale. We surveyed *pupils' opinions on science education (3)* in relation to their *sense of competence in science (5).* The data obtained through the questionnaire in paper form were coded and further processed in electronic form using MS Excel for the purpose of evaluation using descriptive statistics.

In the third step, by using the focus groups method, we explored *pupils' ideas about science and the work of scientists*, and their *sense of competence in science (5)* in relation to the drawings they had made. Interviews were recorded on a mobile phone and then transcribed. Average duration of the interviews was 15 minutes. Transcripts were coded according to the investigated variables through Foucauldian-informed discourse analysis (also known as post-structuralist discourse analysis) (Archer et al., 2010). Through this analysis, it is possible to identify reasons why respondents rate themselves as they do, whereby certain constructions of identity can be developed.

RESULTS AND DISCUSSION

Results of the investigation will be presented in sub-chapters as answers to the research questions.

I feel confident when…

Pupils mentioned a range of characteristics that contributed to their own sense of competence in science. Based on the analysis of pupils' drawings and statements during the focus group method, we identified elements of the category and classified pupils' drawings and statements according to similarity by using open coding (Tab. 2). We tried to characterize these categories in more detail, starting with the most frequent category of drawings and ending with the least frequent category of drawings.

Tab. 2: Frequency of created categories and their characteristics

Categories	Elements of drawings	The number of pupils
I feel confident when we explore	Practical activity, observation, demonstration	32
I don't feel confident when I sit in the desk and listen to	Elements of traditional teaching, arrangement of desk in the classroom	29
I don´t feel confident at science lessons	No drawing, drawing not related to science	21
I feel confident in a topic I like	Favourite subject matter, preference of particular issue, interest reflected from everyday life	18
I feel confident when my efforts are appreciated	Oral response in front of the blackboard, evaluation by the teacher, appreciation of classmates	4
		∑ = 104

Category 1: I feel confident when we explore

These drawings (31%) were characterized by the fact that the pupils through them expressed a certain practical activity. Pupils characterized the research activity in their drawings most often by depicting observation or manipulation of objects (e. g., detecting the strength of a magnet). We found out about what pupils realized through further questions. Pupils of the research sample who had experienced practical activities during which they could participate in the investigation also depicted them in their drawings and identified themselves with the work of a scientist to a greater extent than pupils who had not experienced practical activities: *"Yes, we work like scientists, for example when we were investigating water."*, *"We tried to find out in which conditions a plant will germinate, we planted seeds in different environments and that's when I felt so scientific, because I guess even scientists have to try and experiment to find out something new."*. On the other hand, pupils who illustrated in their drawings the observation of an activity carried out by the teacher did not identify such work as scientific work. Pupils especially emphasized relationship between the implementation of experiments and the factor of self-reliance: *"The teacher does it on her own and we can't try it.". Pupils* also highlighting self-reliance as one of the most important aspects of scientific work: *"Scientists are more likely to experiment on their own. They do more challenging things than we do at school."* and "*When the whole class made one experiment it wasn't very good, I didn't have a chance to find out by myself how the sinking and floating of the object works*". Pupils also defined a number of conditions under which they could feel like scientists during science lessons. Words 'explore' and 'discover' were frequently repeated in pupils' answers as activities needed to approach scientific work. *"To feel that way, we would have to explore, to pour over, inventing elixirs, exploring new things. We should do something. Now we are doing not enough. I would like to mix chemicals, explore new things."*.

From pupils' descriptions, it seems that it was mostly about demonstration experiments carried out by the teacher. According to the pupils, it was mainly an observation connected with the teacher's explanation, and when asked how often they made such observations, pupils answered that they only observed once during the whole school year, or only occasionally. These findings are in agreement with the findings of Rusek et al. (2020) who, by examining older age groups of pupils, found that practical activities are carried out with pupils sporadically, i.e. pupils are not sufficiently confronted with science and scientific work. From the pupils' point of view, pupils seem to have limited contact with research and practical activities, as we identified very few such situations in their drawings. It is still interesting to note that pupils in the first category feel confident especially in situations related to practical activities, despite the fact that they were probably not activities conducted in an inductive way of learning using elements of scientific investigation. Pupils seem to consider science to be similar to the work of a scientist, especially when they carry out activities based on their investigative and own work. Self-participation is therefore one of the most important factors in increasing interest in science and scientific work.

Category 2: I don´t feel confident when I sit in the desk and listen to

In this category 28% pupils depicted a typical classroom ordering in drawings, sketching themselves sitting in a desk and listening to the teacher explaining the material in front of the blackboard. In this category, pupils' drawings included typical elements of traditional teaching, where the teacher is the active participant and, on the contrary, the pupil is a passive receiver of information. In a deeper analysis of the drawings by using the method of complementary interview, we found that pupils did not draw a situation in which they feel competent, but rather drew a situation in science class that is typical for them and to which they are accustomed, or when they know what their role is in a given situation. Pupils commented on the drawings in terms that are typical for the transmission instructional model**,** which is often characterized by memorization: *"The teacher gives us an enormous amount to learn, we have to memorize it."*. It seems that elements of the he transmission instructional model, such as explanations have little educational value for pupils and a negative impact on their attitudes towards science education. Similar findings were also shown in a study by Gillies (2020).

Pupils have a quite good idea of what science is, what happens in science, but they don't put it in the context of what happens directly during science education. It's probably because they don't really experience what is typical for science there.

Category 3: I don't feel confident at science lessons

Up to 21% drawings were typical in the way that they expressed pupils' disinterest in science, either not being able to draw any situation in which they felt confident during science lessons and handing in a blank sheet of paper, or pupils choosing to draw what they felt really competent in, regardless of whether it fell under science or not (e.g. playing mobile games, playing football). Or it could have been pupils who didn't understand the instruction we gave them.

Category 4: I feel confident in a topic I like

In the fourth category we included 17% drawings. By asking additional questions, we found that the drawings reflected mainly pupils' personal interests in the subject matter, such as the universe, plants or particular species of animals. Pupils are naturally driven by their curiosity and interests and they try to use their previous knowledge to understand new ideas or solve problems. It is interesting that in these drawings pupils presented the contents as they and the teacher had learned them from the textbook, i. e., besides expressing a certain preference for science issues, they also indicated the way in which they had acquired information about the issue. Some of them drew their favourite lesson in the form of a picture from the textbook and others, after asking the researcher additional questions, added that the teacher had told them about the lesson they had drawn. Pupils in this category seem to feel competent mainly in situations that correlate with their personal interests and preferences, whereas they indicated a way of realizing science most often in a traditional way of teaching related to the interpretation of the material and the use of a textbook. Pupils' interests in selected science topics also seem to play a role in their feelings of competence in science, as has been shown in other studies (Fančovičová & Kubiatko, 2015).

Category 5: I feel confident when my efforts are appreciated

Drawings of pupils in this category (4%) depicted a typical classroom ordering most often in a situation of a pupil's oral response in front of the blackboard. Using pupils' written descriptions in drawings, we found out that they feel most competent when their efforts are rewarded with a good evaluation from the teacher or a compliment from their classmates.

Science is important and interesting, but only for the smartest

Pupils unanimously agreed that knowledge from natural science is applicable in everyday life, i.e., they feel the importance and practicality of science education. The above-mentioned opinion of the pupils from the research sample about science is in contrast with the results of some domestic and foreign studies (Veselský & Hrubišková, 2009; Kubiatko, 2007; Pavelková et al., 2010), which point out rather to the pupils' disinterest in science subjects, considering them to be distant from everyday life. On the other hand, we find a discrepancy between the fact that pupils from the research sample find science useful, interesting and, to a lesser extent, fun, but they would not like to take science as a subject more often. The results for *pupils' opinions on science education (3)* are further specified in Fig. 1.

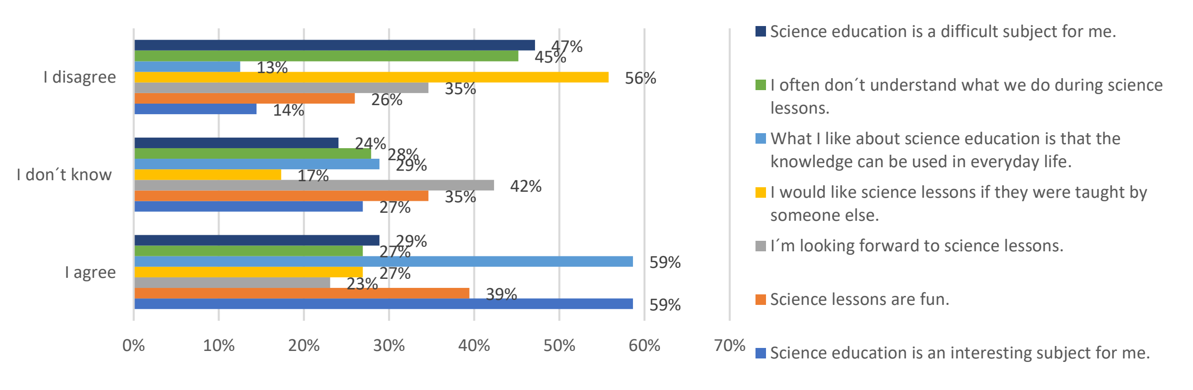

Fig.1 Research results of pupils' attitudes towards science education

We found out that pupils from the research sample, despite considering the work of a scientist as attractive and desirable, do not show aspirations in science and scientific work themselves, which has been confirmed in several implemented studies, e.g., Scholes & Stahl, 2022. Pupils from the research sample mostly agreed that they do not have sufficient qualities to become a scientist, emphasizing mainly intellectual abilities: *"We are not wise enough to be scientists."*. Suggestions of who could be a scientist were also added to the statements: *"Our teacher is wise, she could be a scientist."* and *"Scientists work like our teacher, always demonstrating something, explaining."*. As other qualities typical for scientists, pupils mentioned ingenuity, wisdom, skilfulness and they should also have a good memory. It is interesting to note that scientists were not just associated with good grades in school, but rather with natural intelligence: *"Scientists have to get only good grades, especially in chemistry, but good grades alone are not enough."*. It seems that the reason for the pupils' low aspirations for science is not low attractiveness in scientific work. It could be low sense of competence to pursue science in the future. We claim this mainly because up to 82% of the pupils said that they would not be a good scientist or were unable to comment on the question. The results for the pupils' science aspiration variable are further specified in Fig. 2.

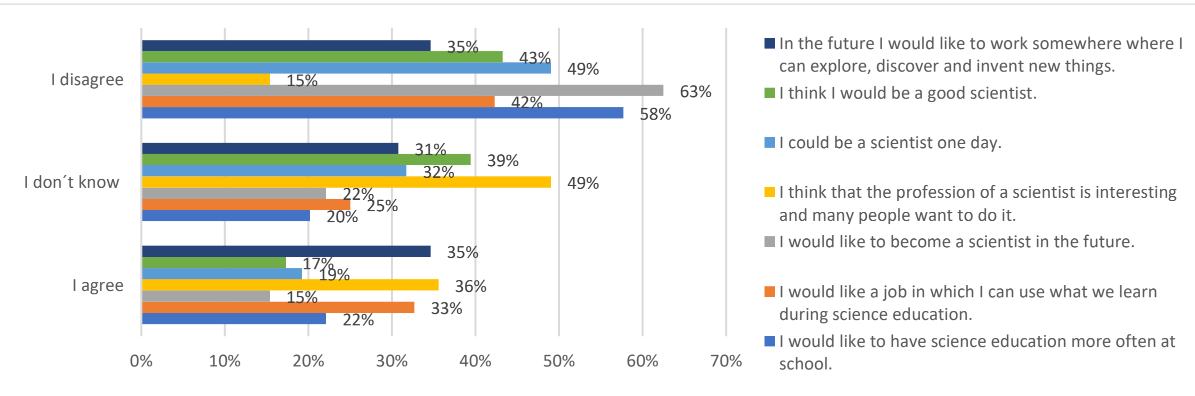

Fig. 2 Research results of pupils' aspirations to science

Findings of the sample of pupils studied above are in agreement with the results of Archer et al. (2020), who state that one of the most important factors for choosing a scientific career is whether the pupil feels competent enough to do the work of a scientist. Similar results were reached by Moote et al. (2020) who found that the exclusion of pupils from the scientific profession cannot be specified only in terms of pupil's lack of interest in science, but it is a problem from the complex point of view of various factors including whether pupils consider themselves "good at science".

Typical traits that specify a good science learner as characterized by our sample of pupils were features of traditional teaching. Pupils who were good at science were mainly described by pupils as obedient, wise, clever: *“They have to know everything, they are so obedient, they pay attention in class, they listen and don't disturb.”.* Others also stressed the importance of getting excellent grades in school: “*They have only good grades.”* Among the respondents' statements there were also those that assumed intensive preparation for lessons from pupils who are excelling in science: *“They are preparing for every lesson, they are definitely always studying at home and they know the material in advance.”*.

Stereotypical perception of scientific work as a diminishing factor in pupils' aspirations in science

Among responses to the question of why pupils thought they did not work as scientists during science lessons, there were often those that stressed the importance of dressing as scientists as well as special equipment: *“We don't work like scientists, they have to be in special white suits, and they have to wear glasses. Scientists use test tubes, microscope.”.* They also talked about the difficulty of their profession compared to what pupils do in the classroom: *“They do harder experiments, we only do the easy ones with the magnet. We don't do any chemical experiments.”.* Pupils do not seem to associate the school environment with the scientific environment: *“They have their laboratory, they need things other than desks.”*. It is interesting to note that pupils would not feel like scientists even if the items listed above were available to them: *“No, it's not just about what they have, it's about what qualities they have. They are wise and skillful.”.* When scientists are considered in a positive light (e.g., as intelligent or able to “save the world”), these images often place scientists in the position of being “different”, which prevents young people from seeing them as 'like me' or as someone they could become. These findings are in agreement with the research of Archer and others (2016). It seems that there are multiple reasons why young people perceive science as “not for me”, indicating the multifaceted nature of this issue. Substantial research suggests that young people have limited and often stereotypical views on scientists and their work. These findings were also reflected in our sample of respondents. For example, several decades of studies using the DAST-test reflect that children continue to have a very limited, highly stereotyped view of what a scientist is or is doing, as Katz (2017) does in another of his studies.

CONCLUSION

Our intention was to find out whether our pupils feel competent to do science in the future, and to find out the link between this sense of (in)competence and the activities they feel they are confident in during science education.

We have found that the way in which science is taught is also reflected in the activities in which pupils feel competent and confident. Pupils who have experienced science lessons with elements of practical activity seem to feel most competent in situations that reflect the work of the scientist through the implementation of practical activities such as observation. Based on the analysis of the interviews, pupils seem to lack confidence in their own scientific abilities. Our understanding of the reasons why the enjoyment of 'doing science' may not be reflected in a desire to 'be a scientist' is an argument that this disjunction occurs particularly when science as a discourse of identity encounters a contradiction of the idea of the scientist as a good, wise and very thoughtful person, with the feeling of the pupil himself not feeling competent enough to pursue a profession of which he has not experienced the basic elements (such as the competences of scientific work) during his science education.

Scientific cognition is the natural cognition of the environment and therefore if we want pupils to acquire the basics of scientific cognition, we should orient them towards acquiring knowledge in a scientific way. We found out which science learning activities pupils consider they feel competent in (only considering what children actually experience in school). Pupils who have also experienced practical activities during science lessons consider them to be the ones in which they feel more confident. The problem is that if the groups of pupils had not experienced any scientific methods during their science education, then they could not reflect them in their drawings. The presented study has limitations such as the size of the examined sample and the use of a 3-stage Likert scale. For these reasons, it is not possible to generalize findings to the entire population of pupils. Anyway, it is likely that a larger sample of pupils could show similar results.

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Data Literacy in Science Education: Research Studies Review

Jana Urbanová & Katarína Kotuľáková

Abstract

The present paper reviewed research studies about data literacy in science education among students at each level of education. For this purpose, the Web of Science database was consulted and relevant studies from 2008 to 2022 were selected. A rather limited number of research studies (n=53) were found based on relevant keywords. We focused on identifying the elements of data literacy described in the research papers, determining the frequency of work with selected age groups of students, and also on characterizing the formality of the included studies. Thus, we can conclude that we reviewed a relatively new area of research in science education that has been represented in research studies mainly in the last six years. The studies have mainly focused on the field of biology and undergraduate students, with most of the work coming from the data evaluation area and less from the data management or application. A general conclusion based on the reviewed research studies is the considerable potential of work with data in making science education more effective in terms of knowledge, skills and attitudes.

Key words:

Science education; data literacy; research studies review

INTRODUCTION

The process of collecting and analysing data is essential in the practice of science. Data literacy is becoming increasingly important as science and society rely on information based on large data sets (Noble, 2018). Consequently, students need to be able to understand and use data to make informed decisions (Gould, 2017; Wolff et al., 2017; Rafaghelli, 2018; Mandinach & Gummer, 2013). In the educational context of developing literacies, Kjelvik and Schultheis (2019) characterise data literacy as an interconnection of data science – developing and/or using digital tools to work with data, authentic context – understanding of content knowledge from the field, and quantitative reasoning – the ability to use mathematical principals, critical thinking and sound logic in authentic context (also in Mayes et al., 2014; Vacher, 2014). Ridsdale et al. (2015) frame it as a set of skills containing statistical readiness, collecting, processing, and deployment of data as evidence. Natural science curricula as well as international comparative student assessments focus on practices that align with described comprehension of data literacy avoiding the tendency to limit it to technical and instrumental approach (Bridle, 2018; Erickson, 2018) or mere computational thinking (Berikan & Özdemir, 2019).

Data in science classroom

Researches indicates that students and adults lack data literacy (Hernandez et al., 2012; Manyika et al., 2011). A potential solution seems to be the usage of authentic or big authentic data in education, qualitative or quantitative, collected from real life phenomena (first-hand or second-hand data) contradicting collection of inauthentic data that can be gathered in order to demonstrate patterns, correlation, or any other expected results (Kjelvik & Schultheis, 2019). Big data is most often defined as very heterogeneous, high-volume information that is often collected very quickly thanks to technology (Williamson, 2017). However, in our primary or lower and upper secondary school context, we also understand big data as working sets of real data whose quantity exceeds the cognitive capacity of the students. Working with big authentic data requires scaffolding, sequencing and gradual complexity as they can be diverse and messy (Kjelvik & Schultheis, 2019). Studies prove that secondary-level students can understand the data concept and improve their thinking skills (Browning & Channell, 1992; Phipps, 1994). The real context often offers benefits that enable students to deal with situations when the hypothesis is not supported, when they must analyse error in their measurements, formulate another research question or they just get really interested and engaged in the topic (Gould et al., 2014).

The presented research studies review offers the findings from studies conducted in the context of using authentic data in science education in order to develop data literacy as described earlier. The findings have implications for science teachers and students and present the direction of further research.

Purpose of the study

The study aims to determine the scope of data in real research context usage in science education by answering the following questions:

- What fields in science education are the most likely open to working with data?
- What is the target age group of students when working with data?
- What kind of data is used in the science education context?
- What skills are investigated when working with data?
- What is the potential when working with data?

METHOD

The study uses the systematic review methodology addressing the purpose, inclusion, and exclusion review criteria, coding system, and transparency in analysing the data, and communicating the results (Zawacki-Richter et al., 2019).

Research studies selection process – data collection

The aim of the research is to examine and synthesise academic publications from the Web of Science database published from 2008 to 2022 as analysed skills depend upon the advancement of technology. The study uses the systematic literature review methodology and content analysis process. Keywords were selected for the search (Table 1). In the process of critical appraisal, the inclusion criteria were set to include only research peer-reviewed studies in the science education context excluding conference papers, idea papers, or reports. Additional criteria (2nd round exclusion criteria) were applied during the screening of the papers in order to analyse the appropriateness of the study design, its relevance a quality in the context of the review questions (Tab. 1, Fig. 1) (Gough, 2007; Petticrew & Roberts, 2005). The selection process resulted in 53 research studies.

Tab. 1 Inclusion and exclusion criteria for publication selection

KEY WORDS	INCLUSION CRITERIA	EXCLUSION CRITERIA
"Science Education", "Data Literacy", "Big Data", "Authentic Data", "Messy Data", "Real Data", "Data Science Education", "Data-Driven", "Data Repository", "Data Management", "Data Representations", "Quantitative Literacy"	science education context, peer-reviewed studies, students involved working with data in real research context	1st round exclusion criteria: conference, workshop and symposium papers, idea presenting papers, reports, curricula proposals, 2nd round exclusion criteria: no relevance to natural science education or the field not stated, overall statistics or computing context, Introducing data systems and platforms, librarian support to data usage

Data extraction and analysis

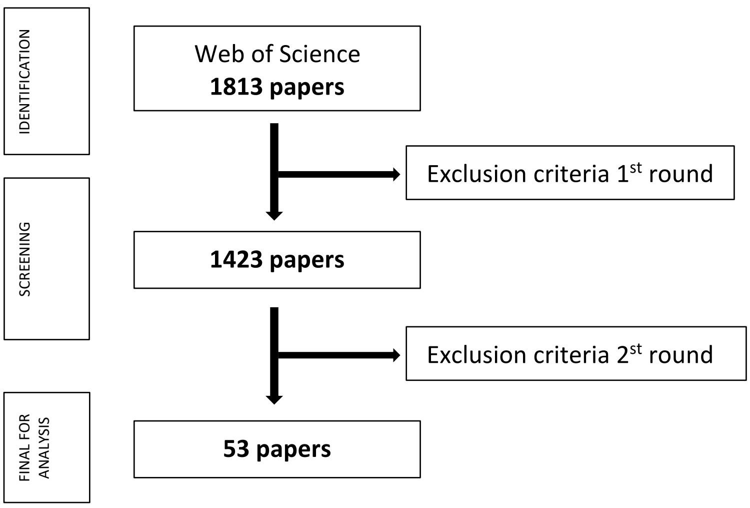

Fig. 1 Workflow - selection of studies for analysis

To answer the research questions the selected studies were coded for:

- publishing information (year, journal),
- context of the research (science field / area / school subject),
- levels of education,
- elements of data literacy described in reviewed literature,
- results of the research papers,
- implications of the findings.

We engaged in multiple rounds of coding. The codebook was piloted by extracting data from a random 10 studies. Both researchers coded data extracted from the studies independently to ensure reliability of the review. The percentage of codes on which the two authors agreed was calculated. Ambiguities were discussed until a joint decision was reached. For the questions with fixed response options, we calculated the sum of the responses (quantitative data analysis). We used thematic analysis for open-ended questions (qualitative data analysis) (Hatch, 2002).

Validity of the review was addressed by stating clear and non-overlapping criteria for studies selection in the 1st and 2nd round to avoid reviewers' bias. Also, the above specified design features of the studies had to be present if findings were to be treated as valid.

RESULTS

Characteristics of included research studies

Analysed research studies were published in 37 different journals, 6 of which do not have an educational topic in their scope. Due to the paper length limitation, a complete list of included and excluded studies is available by request from the corresponding author. Most studies were published in BioScience (n=4) and the International Journal of Science and Mathematics Education (n=4). Three studies were published by CBE—Life Sciences Education, International Journal of Science Education, Journal of Biological Education and British Journal of Educational Technology. Other journals published two or fewer related studies.

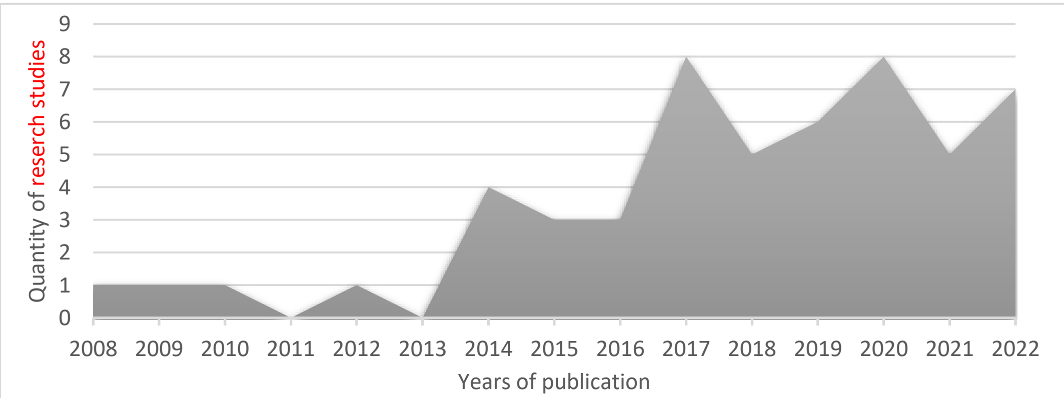

Fig. 2 Quantity of studies published between 2008 and 2022

Figure 2 shows the quantitative increase in the number of studies published after 2016. Most of the studies have been published in the last six years, with the highest number of studies published in 2017 and 2020 (n=8 in both years). No related studies were published in 2011 and 2013 and no more than one study per year was published until 2014.

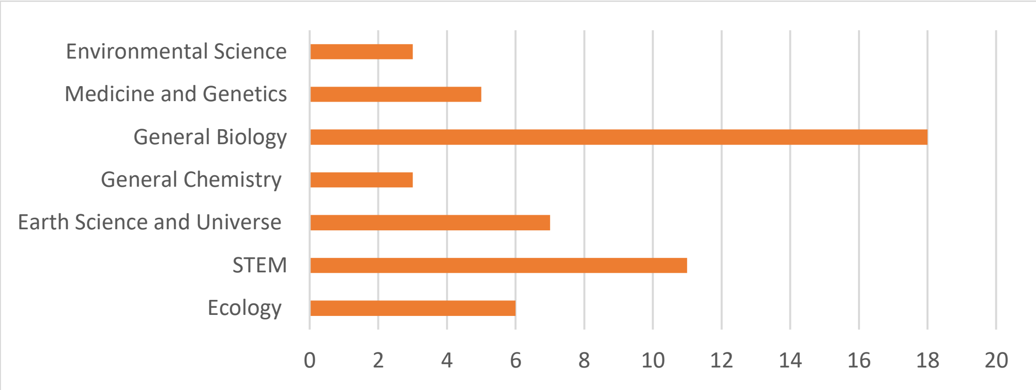

Fig. 3 Number of related research studies in different fields of natural sciences

Specific areas which also are falling into the group in the Fig. 3: Medicine and Genetics – Biomolecules, Bioinformatics, Genomics, Immunology and Biomedical Engineering; General Biology – Molecular Biology; Earth Science and Universe – Astronomy, Geography, Geoscience and Meteorology.

Based on the analysed studies, it is evident that working with data is most commonly used in the biological sciences (n=18). Quite a lot (n=11) of work on data literacy has also been done in STEM or Earth Science and Universe (n=7). In other science fields, no more than 6 related studies have been published, with the least amount of work with data in Chemistry and Environmental Science (n=3 in both cases) (Fig. 3).

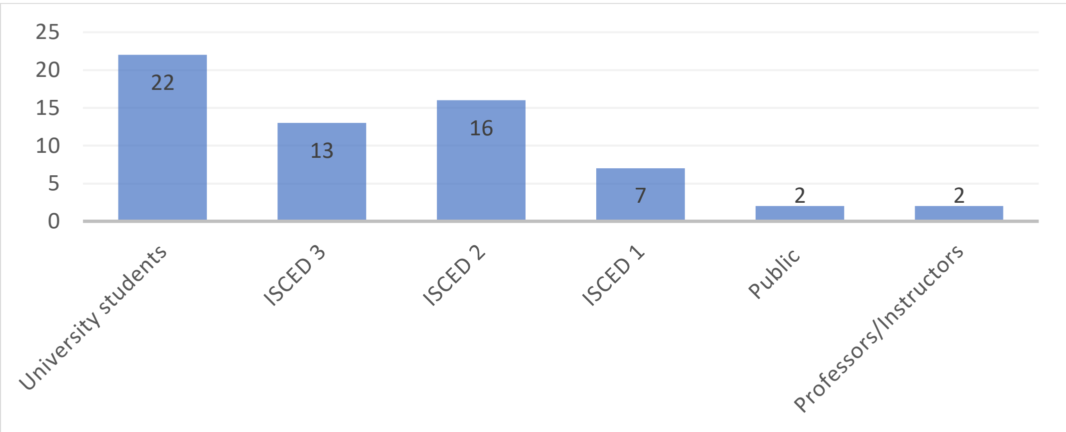

Fig. 4 Age distribution of participants working with data in the analysed research studies

Definition of the groups in the Fig. 4, with respect to the different designations of levels of education in English-speaking countries: University students – undergraduate, graduate, higher education, master; ISCED 3 – high school, upper secondary school, K-12, K-14, 11 – 12 grades; ISCED 2 – lower secondary school, middle school, 5 – 10 grades; ISCED 1 – primary school, grade, 1 – 4 grades.

The included studies spanned the age range of students working with data from primary education through university education (Fig. 4). Two studies included professors or instructors as a sample, for the sake of comparing skills with students in working with data and two another examined the data literacy of the public in order to find out how and with what data adults work and to apply these findings to work with students. Some studies (n=5) included students from multiple age groups. We added these to all relevant age groups and therefore the Figure 4 quantifies a larger number of studies than were actually analysed. The largest number of studies focused on the data literacy of university students (n=22). The group of students in ISCED 2 and ISCED 3, was represented in smaller numbers (n=13, n=16).

Type of data used and skills developed

In the included studies, we have defined the core competencies and skills that comprise data literacy (Tab. 2). The studies covered a range of key abilities areas from conceptual framework to data application.

The most represented competences were in the data evaluation area - data analysis (n=26), data interpretation (n=21) and data visualization (n=18), what represents 49%, 40% and 34% of the reviewed research studies. Data discovery, and collection was represented in 32% (n=17) of the studies. Objectively, competences in the field of application and data management with four or fewer studies were the least represented in the reviewed research studies. We identified an exception in data manipulation (n=7) that was more abundantly represented than others within the area of data collection (Tab. 2). This competency is characterised by cleaning data and identifying anomalies. Studies in category Identifying Problems Using Data (n=8) worked with authentic data focused on actual issues such as earthquakes, coral bleaching, environmental change, HIV, or COVID-19. In some papers students also worked with big data (n=16). Studies that focused on testing the proposed project, module, or course (n=28), noted more effective work with information and understanding of the issues at the end of the proposed activity. In 17 of these studies, they also focused on developing and acquiring attitudes towards working with data or science. They also tracked changes in their self-assessment or motivation. In all cases, there was a positive change.

Tab. 2 Data literacy competencies represented in the analysed studies (inspired by Ridsdale et al., 2015)

KEY ABILITY AREA	COMPETENCY	QUANTITY OF STUDIES
CONCEPTUAL FRAMEWORK	Introduction to Data	9
DATA COLLECTION	Data Discovery and Collection	17
	Evaluating and Ensuring Quality of Data and Sources	2
DATA MANAGEMENT	Data Organization	4
	Data Manipulation	7
	Data Conversion	1
	Metadata Creation and Use	2
	Data Curation, Security, Re-Use	3
DATA EVALUATION	Data Tools	5
	Basic Data Analysis	26
	Data Interpretation	21
	Identifying Problems Using Data	8
	Data Visualization	18
	Presenting Data (Verbally)	5
	Data Driven Decisions	10
DATA APPLICATION	Critical Thinking	3
	Data Culture	1
	Data Sharing	1
	Evaluating Decisions Based on Data	3

DISCUSSION

It is clear from our results that the issue of data literacy in science education is a relatively new topic. This is indicated by the number of studies published each year, where a significant increase is visible only in the last six years. This is also evidenced by the relatively small final sample of analysed studies (n=53). The trend of increased publications on data issues in education in recent years is also confirmed by other authors (Baig et al., 2020; Li & Jiang., 2021). An explanation for this phenomenon is suggested, for example, by Marx (2013), who points to the explosion of data production in bioinformatics since 2008 and the gradual beginning of the era of "big data". Another factor that has influenced and expanded data work in recent years is the advancing and freely available technology (Zeide, 2017). Also evident is the significant preponderance of papers related to working with data in biology and, conversely, a minimum of papers in chemistry or environmental science. The authors' focus on working with undergraduate students is also distinct. This trend was also pointed out by Olson (2021), who therefore focused on the development of data literacy in students aged 8 to 10. From her work, we found out that, with the correct correction of the design of the proposed tasks, it is possible to work with data also with pupils from 8 years of age. The focus on university students in particular is linked to their further progression often straight into research. Therefore, there is a need to educate data literate graduates (Schultheis et al., 2022; Olimpo et al., 2018).

In a significant number of studies, we have identified work with data analysis and data interpretation. Most often, however, these skills were developed or tested using only graphs, charts, or tables. In this form, the data is already partially processed and sometimes does not allow working with a large sample of data. We see the same conclusion in the smaller number of papers that used big data work or low student participation in data collection and data management. In this context, Medová et al. (2022) emphasizes that students have problems during the data collection phase due to their lack of measuring knowledge. At the same time, some studies (Wolff et al., 2017; Peters-Burton et al., 2022) show that it can be useful to act in the role of a data collector. Students have a better understanding of large data sets, know how to work with them and are more responsible and sceptical when processing those (Peters-Burton et al., 2022). However, it should be noted that in most studies, the authors found out that pupils already had great difficulty in reading graphs, and including any work with data in the teaching process improved pupils' knowledge, attitudes and confidence in working with data. We also noticed that the fewest studies were focused on the application of data when working with students. Yet, this skill set is mainly built on critical thinking, which according to Ridsdale et al. (2015) is an essential 21st century skill and its use is essential when working with data in any industry.

Implications

Based on our research, we recommend more focus on working with primary and lower and upper secondary school students and working with big data in future studies. This would explore or develop complex data literacy from data collection to different forms of data presentation. Equally, further research should continue and make even greater use of working with real data and with the wide range of computer programs available. To achieve this, new collaborations between researchers, science teachers, and data visualisation inventors will be needed (Mirel et al., 2016). Appropriately prepared activities could provide better data visualization and skill acquisition in working with more complex data, technology, and related software.

CONCLUSION

In our analysis we focused on examining research studies with elements of introducing different components of data literacy into science education. We selected 53 relevant studies from the WOS database over the time span 2008-2022. Our results suggest an increased interest in this topic in the last six years only. We also observed a strong orientation of study authors towards undergraduate students and biological content. Of all the competencies comprising data literacy, we identified competencies from the key area of data evaluation most frequently and the least from the area of data management and application. Therefore, authors of future research could focus on engaging all data literacy competencies when working with data in science education. Research confirms improvement of work with information and deeper understanding of studied issues. Potential of working with data represents also developing positive attitude toward working with data and science generally as well as improving students' self-assessment and motivation.

LITERATURE

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Teaching photosynthesis in the digital age: STEM inquiry-based learning activity

Tereza Brčáková, Renata Ryplová & Jan Pokorný

Abstract

This contribution brings results of a pilot study aimed on the impact of STEM inquiry-based learning activity supported by the use of digital measuring device with optical oxygen sensor in students experiments on understanding photosynthesis. Several misconceptions in students' understanding of photosynthesis were discovered in pre-tests. The pilot study was conducted among 71 lower secondary school students of 9th grade. The tested learning activity improved the students' understanding of photosynthesis and helped overcome misconceptions in the field of plant nutrition and biomass development. Based on the analysis of student preferences for different ways of learning photosynthesis we assume that learning photosynthesis via experiments using modern measuring devices is positively accepted by students.

Key words

Inquiry-based education; Photosynthesis; STEM

INTRODUCTION

Photosynthesis is considered one of the most difficult topics in biology. Among the reasons of difficulties especially high level of abstraction of this topic is frequently considered (Vagnerova et al., 2019; Yenilmez & Tekkaya, 2006). According to Svandova (2014), many students do not understand the basic principles of photosynthesis and respiration and are often unaware that these are physiologically linked processes. The abstract context of photosynthesis leads to many misconceptions (Cipkova et al., 2017; Svandova, 2014; Hershey, 2003).

Among these misconceptions, especially the connections between plant nutrition, photosynthesis, and plant growth (Marmaroti & Galanopoulou, 2006; Hershey, 2003; Cañal, 1999) and the misconception of inverse respiration (Svandova, 2014; Marmaroti & Galanopoulou, 2006; Cañal, 1999) are considered to be the most common. Students have difficulty understanding that plants use the same nutrients as animals to develop their body. They do not consider the autotrophy of plants and do not understand the energy transfer from solar energy to biomass (Marmaroti & Galanopoulou, 2006; Eldridge, 2004; Hershey, 2003). Another reason for the low level of students understanding of photosynthesis seems to be low student interest in plants in general. This is related to the overall spread phenomenon of plant blindness (Wandersee & Schussler, 1999), which expresses humans' ignorance of plants.

Students are not attracted to botany topics and find them boring. The attractiveness of botany even decreases with higher education (Prokop et al., 2010).

Previous research reports that traditional explanatory methods cannot eliminate the emergence of misconceptions (Yenilmez & Tekkaya, 2006; Cañal, 1999). Therefore, innovative approaches are necessary to improve students' understanding of photosynthesis, avoid misconceptions and enhance attractiveness of learning. Among these innovative approaches, inquiry education supported by the use of digital devices by students seems to be one possibility. Inquiry education is widely recommended and used to enhance attractiveness of science education (Rocard et al., 2007; Bilek & Machkova, 2014), improve student engagement and knowledge in the field of botany (Ryplova, 2017) and the frequency of the use of this approach among activating strategies in science education has increased during last years (Rusek & Vojir, 2018). The positive impact of inquiry-based teaching activity on students' understanding of photosynthesis was already reported by Kuncova & Rusek (2019).

Photosynthesis is interdisciplinary topic based on interconnection among several disciplines, especially biology, chemistry, physics, and mathematics. Due to biomass and oxygen production is photosynthesis tightly related to human environment. The topic of photosynthesis fits well with the idea of STEM learning. STEM uses the combination of Science, Technology, Engineering, and Mathematics for practically orientated way of engineering problem solving in context of real-life experiences (Bybee, 2010). STEM offers the possibility to use digital technology in student hands on activities, which could increase the visuality of photosynthesis for the learners. The use of digital tools in teaching was found to be effective in simplifying the learning of abstract and complex processes (Vagnerova et al., 2019; Keleş and Kefeli, 2010).

For the measurement of photosynthesis in student experiments, aquatic plants can be used with an advantage because the measurement of their photosynthesis is highly illustrative (Eldridge, 2004). Under light exposition they release bubbles of oxygen. Counting bubbles has been a traditional method for quantifying photosynthesis of aquatic plants since the development of this easy method in 1779 by Jan Ingen-Housz until the latter part of the 20th century (Bowes, 1989).

Aquatic plants in broad sense include both phytoplankton and macrophytes. Photosynthetic biomass production is linked to the uptake of carbon dioxide and the release of oxygen. Solubility of oxygen in water is weak. At 20^{o} C air-equilibrated water contains over thirty times less oxygen than the same volume of air (9 mg versus 285 mg). Diffusion of gases is also slower in water than in air. Therefore, oxygen produced via photosynthesis often forms bubbles and concentration of oxygen in water increases during day light and declines night due to respiration (Pokorny & Kvet, 2004). The oxygen yield of aquatic plants can be measured by different types of sensors. Until recently, the most common one was the Clark – type of electrode (Gansert & Blossfeld, 2008) requiring time-consuming maintenance. Therefore, experiments using these types of sensors were considered as difficult for teachers' preparation and use in school practice (Eldridge, 2004). Hence students' experiments on photosynthesis of aquatic plants were mostly limited just to counting air bubbles (Iancu & Chilom, 2016). But in recent time, due to technology development optical sensors for the measurement of dissolved oxygen in water are available, offering fast and accurate measurement without any maintenance. Hence, besides traditional bubble counting experiments more sophisticated methods for the school experiments using these types of sensors are available.

From these reasons, inquiry- based STEM learning activity on photosynthesis was developed which uses modern measuring instrument with optical oxygen sensor for student experiments. This activity was pilot tested at education with an aim to find an answer on the research question: Can newly developed teaching activity improve students' understanding of photosynthesis and help to overcome common misconceptions?

METHODOLOGY

Developed teaching activity is based on a well-known dark and light bottle experiment (Pratt & Berkson, 1959), but innovated by incorporation of STEM practices and inquiry approach including measuring of oxygen and pH in water by digital measuring device with optical oxygen sensor (MFD 790PTO, INSA, CZ) for student hands-on experiment. The whole worksheet supported activity (with teacher as a tutor) took 90 minutes and is designed for both indoor and outdoor environments.

The activity starts with an introductory motivation question combined with a demonstration of two bottles, one of them with aquatic plants (algae), both exposed to sunlight. Students were asked where the bubbles in the bottle with algae comes from. They tried to formulate their own hypothesis which was later corrected by discussion with a teacher. Students were then divided into the groups and asked to design an experiment using pre-prepared tools including measuring device for the measurement of pH and dissolved oxygen in water. Proposed experiments were discussed with the teacher again. Students then worked on their hands-on activities and measurement and filled in the results into their worksheets. Further STEM based tasks of the worksheet led them to realize the connection between photosynthesis oxygen production and biomass production. After the measuring, students count the amount of biomass that was built by photosynthesis during the time of the lesson. Calculation was based on the equation of photosynthesis and measured amount of oxygen measured in their own experiments. Ecological significance of water plants was then introduced further via the task asking the students to count the energy content of the amount of biomass developed during the experiment (based on energy content of molecule of glucose; 2800 $kJ.mol^{-1}$). By this way the release of oxygen was visualised and connection among the self-measured amount of developed oxygen, photosynthesis and biomass production was explained. Connection with real life was ensured via tasks aimed on the importance of aquatic plants as primary producers influencing chemical balances in aquatic ecosystem.

This activity was pilot tested at 3 different lower secondary schools in June 2022. The teaching was always led by the same teacher (the first author). Together 71 participants of 9th grade took a part in this survey. They all already possessed some conceptions on photosynthesis due to education at 6th or 7th grade. Their prior knowledge was studied by using the pre-test a week before the intervention, post-test followed just after the teaching. The pre- and post-tests were based on the same questionnaire containing both open as well as closed questions aimed in particular on previously known common misconceptions. Because of the limited space of this article, it is not possible to introduce all the questions, therefore just overall mean score of the test together with some examples of the questions and their analysis are presented. Students could get maximum amount of 15 points, one point for each question answered correctly. In addition, at the end of post-test, students' preferences for different ways of learning photosynthesis were studied. The students were asked to evaluate different ways of learning on the 5 grade Likert scale. Data were analysed using the STATISTICA 12 PC package (StatSoft Inc.), the differences among the pre-and post-tests were compared by the Student T-test.

RESULTS AND DISCUSSION

Detected misconceptions and impact of the learning activity

Pre-tests revealed that our respondents possessed several misconceptions on photosynthesis. Based on the results of post-test, we can assume, that absolved education helped to overcome these misconceptions.

Common "nutrient misconception" ("Plant use different nutrition than animals") was detected in case of 88.23 % respondents. Students had problems to realize that plants use the same nutrients as animals, they can just make them in the process of photosynthesis. The students do not assume that plants are autotrophic organisms and believed that increase of weight of the plants is due to the uptake of water with minerals from the soil. They have problem to understand the difference between nutrient and nourishment. The same misconception has been observed among students of all levels by other studies (Cipková et al. 2017; Keleşe and Kefeli 2010). In post-test this misconception was detected just in 39.44 % cases ($t = - 7,20791$; $p < 10^{-6}$). As expected, based on the previous international results (Cipkova et al., 2017; Svandova, 2014; Keleşe and Kefeli 2010) our respondents also confused photosynthesis and respiration. This misconception was detected in 67.61 % cases in pre-test, but just in 33.99 % cases in post-test ($t = - 5,63454$; $p < 10^{-6}$).

Beside these two most common misconceptions also some further were detected by pre-test: Students believed, that the only one product of photosynthesis is oxygen. They usually know that plants produce oxygen during photosynthesis, but they don´t know that the product of photosynthesis which is the most important for plant is sugar. Students also assumed that just gases are exchanged during photosynthesis. They don´t consider the biomass production as a result of photosynthesis.

Based on the comparison of the results of knowledge pre- and post- tests we assume, that focused teaching activity contributed to the significant improvement of student knowledge of photosynthesis (Fig.1) and helped to overcome the misconceptions mentioned above. Statistically significant increase of the overall mean score of the pre-test (5,7 ± 2,6 SD) compared to post-test (10,3 ± 2,8 SD) was proved by Student T-test ($t = -13,3173$; $p < 10^{-7}$).

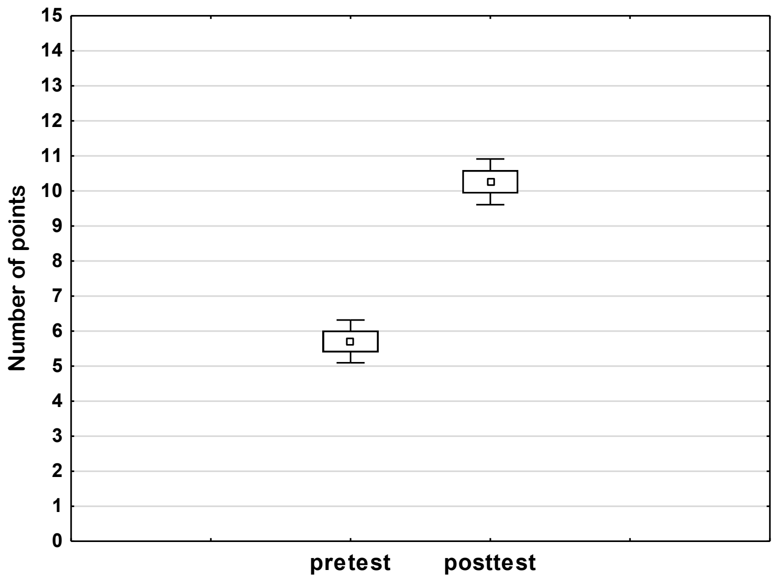

Fig. 1 Comparison of the general results of pre- and post-test (small squares represent mean values, boxes mean value ± std. dev., line segments mean value ± 1,96*std. dev.)

Here we bring some examples of individual questions:

- "What substances are formed during photosynthesis?". Oxygen and sugar were considered right answer. The most frequent wrong answers were carbon dioxide, carbon, nutrients, chloroplast, and chlorophyll. Statistically significant improvement appeared after the intervention (mean score ± SD: pre-tests 0,97 ± 0,63; post-tests 1,48 ± 0,60; maximum number of points = 2, $t = 5,25498$; $p = 10^{-6}$).
- "What is the name of the process causing plant growth and creation of plant biomass?" Students know that photosynthesis produce oxygen but were not able to connect photosynthesis to biomass formation. In our research, we find these wrong answers: flowering, respiration, or growth. From this reason we have included the task aimed on counting increasing biomass in the worksheet into our teaching activity. The mean pre-tests

score was 0,21 ± 0,41 SD, mean post-test score was 0,69 ± 0,46 SD, ($t = -6{,}93197$; $p < 10^{-6}$). Maximum score int this question was 1 point.

Students' preference for different ways of learning photosynthesis

Based on the analysis of the answers to the question: "How would you like to learn photosynthesis?" (Fig. 2) we can assume, that all the ways of learning photosynthesis which are based on using technology are welcome by students. Slightly worse were assessed just traditional transmissive method of learning, field/laboratory tasks without any instrument and learning via educational videos.

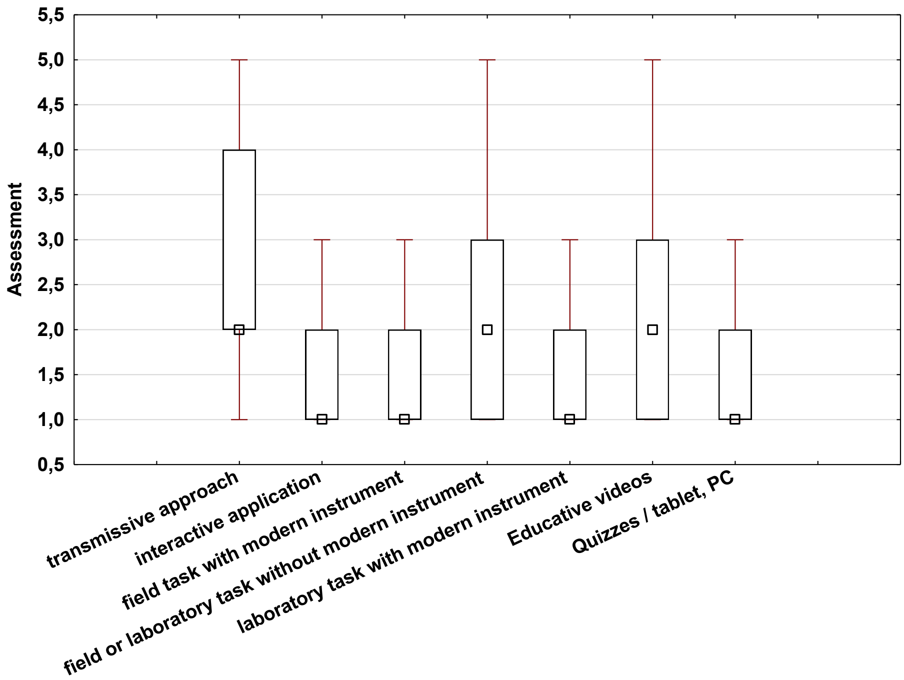

Fig. 2 Analysis of the answer to the question "How would you like to learn photosynthesis" (5 grade Likert scale, 1 = I like this approach very much, 5 = I do not like this approach at all). Small squares represent median values, boxes quantiles 25 – 75 %, line segments min-max values, N = 71).

CONCLUSION

Based on the results of pilot testing, we can conclude, that developed STEM and inquiry-based teaching activity using modern measuring equipment with optical oxygen sensor in student hands on activities could improve students' understanding of photosynthesis and help to overcome common misconceptions. To prove the conclusion of this pilot study, further research using higher number of respondents and comparison with the control group is necessary.

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Testing techniques pH and their attractiveness in chemical education

Małgorzata Nodzyńska-Moroń, Paweł Cieśla, Vladimír Sirotek, Jitka Štrofová & Paulina Zimak-Piekarczyk

Abstract

Currently, in everyday life, the term pH appears frequently in advertisements or on the packages for various products. The definition of pH has changed since the beginning of the 17th century. Currently, the Sørensen definition for pH from the beginning of the 20th century is most often used. However, many students and teachers find the mathematical notation very difficult to understand. Therefore, in education, teachers use various activities to introduce the concept of pH without having to introduce logaritmus and additionally to keep the classes interesting for students.

Studies on the attractiveness of pH measurement laboratory classes were carried out. Five different activities of pH testing were investigated among pupils (8-10 years), university students and teachers.

Key words

Methods of measuring pH; attractiveness of classes; motivation

INTRODUCTION

The pH of solution X in which a standard IUPAC-defined galvanic cell is immersed and for which the value of the first electromotive force E_X has been measured equals:

$$\mathrm{pH(X)} = \mathrm{pH(S)} + \frac{(E_S - E_X)F}{RT \ln 10}$$

where: F – Faraday constant, R – universal gas constant, T – temperature on the Kelvin scale, S - standard reference solution (Covington et al., 1985).

The concept defined (according to IUPAC recommendations) this way is very difficult and is used in practice at the tertiary level and possibly in secondary schools with an extended chemistry curriculum. It is used to calculate, measure and calibrate pH meters. In practice, both in secondary and primary school, the Sørensen's (1909) definition is used, in which pH is defined as the negative logarithm of the concentration of hydrogen ions. For example, Hawkes (1994) criticizes defining pH by concentration and suggests the use of ionic activity. In eight sets of Polish textbooks for high school chemistry published in 2017-2022, only Sørensen's definition from 1909 is provided. Similar results were obtained by Burton, (2007), they concern 24 English-language textbooks for general chemistry and biochemistry, published in 1981–2002. Of course, the activity of ions is not included in the curricula of Polish high schools, as in most countries and international high schools, but chemistry textbooks (especially for classes with extended chemistry) contain a lot of content extending the core curriculum. Therefore, the lack of a modern definition of pH in so many textbooks is astonishing.

PURPOSE AND SUBJECT OF RESEARCH

Many students find even such a simplified definition of pH very difficult (Burton, 2007). It is also sometimes difficult for students - future teachers (Rusek et al., 2021). Various researches were carried out to help pupils/students understand the concept at this level. For example, Eskinazi and Macero (1972) developed software to teach students logarithms and pH calculations, and computational programs were introduced to explain pH measurements in teaching laboratories (Ibáñez et al., 1990; Scholz et al. 2005). However, many students will not need even such a simplified definition of pH in their adult life. It is common practice in secondary and primary school to test the pH of substances with general-purpose indicating paper or using natural plant indicators that contain anthocyanins (Kim, 2008; Kanda et al., 1995).

So perhaps one should treat pH as a number on a practical acid-base scale (Bates, 1973) or consider pH simply "a reading on a conventionally calibrated pH meter" (Burton, 2007). Simplifying further, we can assume that pH can be read from a coloured scale, e.g. universal indicator papers.

pH experiments, due to spectacular colour changes, are one of the most frequently performed experiments during shows in non-formal and informal education (Kim, 2008; Kopek-Putała, & Nodzyńska, 2019; Lazarowitz, & Witenoff, 1990). Therefore, we believe that pH tests based on colour changes do not exceed the intellectual capabilities of students.

Such simplifications allow us to introduce the concept of pH at various levels of education - even the lowest, through the selection of appropriately designed classes.

Based on the research described above, it has been found that there are different methods to familiarize students with the concept of pH. Some researchers focused on simplifying, clarifying pH calculations. However, some researchers have omitted the computational aspect, simplified this concept and treating pH as a scale number, pH reading, or reading from a coloured pH scale. Therefore, it was decided to examine whether the second approach to the concept of pH is correct. And is it possible to introduce the concept of pH without mathematical notation and calculations. Techniques for pH measurement based on a pH meter reading or a colour scale have been developed. It was also decided to examine whether the selected techniques are attractive to the surveyed people.

When preparing chemistry laboratory classes, teachers must take into account both the chemical content and the students' perceptual abilities. But they should also consider the motivating factor. Based on the literature analysis, the following research questions were posed: Is each of the pH measurement techniques equally attractive to students? Does the attractiveness of a given method depend on the age, sex or chemical experience of the respondents? Are the choices of teachers of the most interesting pH measurement techniques analogous to those of their students?

The aim of the research was to determine the preferences of the participants of the classes regarding pH, as well as to compare the preferences of pupils and students in this regard.

MATERIALS, METHODS, AND RESEARCH GROUP

There were three research groups:

1. Primary school pupils - 54 primary school pupils (aged 7-10) who had not yet studied chemistry.
2. University students - 60 university students of non-science studies - those students finished their chemical education at secondary school.
3. Chemistry teachers - 9 experienced chemistry teachers at primary and secondary school (from 30 to 70 years).

All respondents gave their consent to the research, additionally, in the case of underage students, their parents also gave their consent.

Five pH measurement techniques were selected. The assumption was that they would show different possibilities of reading the pH value without calculation. One of the elements of choosing the method was the accuracy of the measurement. In the computer simulation and soil pH measurement, students used a pH-meter - where they read the exact pH value of the tested substances. Using universal papers, they could, using a color scale, determine roughly the pH. However, using indicators (natural and synthetic) they could only determine whether the tested substance was acidic or alkaline. Another distinguishing element was whether the experiments take place in a real laboratory or in a virtual one (computer simulation). The third element was the scale of the experiment (microscale in the case of synthetic indicators and macroscale in the case of other indicators). The whole class took about 120 minutes and consisted of 5 different activities, which took approximately 20 minutes each. Each group took part in every activity. The description of the activities is presented below.

Activity 1. Computer simulation

Classes based on the polish version simulation: pH scale - the basics (Phet Interactive Simulations).

By modifying the simulation parameters, students were expected to:

- examine the pH of solutions of various substances,

- determine the pH and check whether the change in the volume of the solutions affects the pH,
- study how the dilution of the solution affects the pH.

Students worked individually on a computer, tablet or mobile phone. The results of the above-described measurements were summarized in a table and then discussed.

Activity 2. pH testing soil

Students had several potted plants at their disposal, the growth of which depends on the pH of the soil in which they grow. The students' task was to transfer the plants to larger pots, into a soil with a properly selected pH. Students had to take samples of the soil in which the plants were growing, as well as the soil samples that would be used to replant the plants, and then test the pH of these soils with a soil pH meter. In the next step, the students chose the right soil for a specific plant, and then replanted it.

Activity 3. Natural dyes, macroscale

The students' task was to prepare decoctions or extracts of selected plants, and then to test how those substances behave in solutions of known pH - acidic, alkaline and neutral solutions. On the basis of the conducted research, students then determined which of the tested substances can be used as acid-base indicators.

Activity 4. Synthetic indicators, microscale

The students' task was to investigate how the colours of synthetic dye solutions change in solutions of known pH. In other words, they investigated whether different dyes acted as pH indicators. The students used micropipettes and a research sheet prepared on the foil. They put drops of solutions of known pH with a pipette to the appropriate places on the foil, and then added drops of solutions of tested dyes and observed the colour changes.

Activity 5. Universal paper indicators

The task was based on the measurement of the pH of the solutions of various substances present in everyday life with the use of universal indicator papers. The students' task was to prepare, in test tubes or beakers, solutions of various cleaning agents, as well as food products, and then determine the pH, and investigate how the dilution of solutions affects pH.

They summarized the results in a table and then discussed in a context of application of those substances.

Studying the preferences of pupils, students and teachers

Due to the age of the youngest respondents, the study of students' and teachers' interest in particular pH measurement techniques was carried out using a drawing test.

The test contained two questions. In the first question, next to the drawing of each of the five activities, the respondents were supposed to circle as many hearts as they assessed the given activities (1 heart - boring activities, 10 hearts - very interesting activities). In the second question, they had to choose one - the most interesting classes. The same test examined the preferences of pupils, students and teachers.

RESULTS

The results of individual statistical surveys are presented in tables.

Tab. 1 The results of testing the hypothesis that the compared populations: school pupils (n=54) vs university students (n=63) have the same median, significance level α = 0,05. (Abbreviations: df -degrees of freedom, p - test probability, techniques: 1 - PhetColorado computer simulation; 2 - Soil pH test; 3 - natural dyes, macroscale, 4 - synthetic indicators, microscale, 5 - Universal paper indicators). Results were calculated by Statistica StatSoft 13.1.

VARIABLE	GROUP WITH MEDIAN VALUES [ME]	KRUSKAL-WALLIS TEST	DF	P	STATISTICAL CONCLUSION
THE MOST INTERESTING TECHNIQUE (1-5)	students vs pupils Me = 2 Me = 3	1,261	116	0,2615	population has a same median
ASSESSMENT OF THE 1 TECHNIQUE	students vs pupils Me = 6 Me = 9	14,463	117	*0,0001	* population has a different median
ASSESSMENT OF THE 2 TECHNIQUE	students vs pupils Me = 5 Me = 9	26,668	117	*0,0000	* population has a different median
ASSESSMENT OF THE 3 TECHNIQUE	students vs pupils Me = 9 Me = 10	1,333	117	0,2482	population has a same median
ASSESSMENT OF THE 4 TECHNIQUE	students vs pupils Me = 8 Me = 8	2,032	117	0,1540	population has a same median
ASSESSMENT OF THE 5 TECHNIQUE	students vs pupils Me = 5 Me = 9	39,116	117	*0,0000	* population has a different median

The distributions in some samples were not normal distributions, therefore the Kruskal-Wallis test was used, as it does not require the assumption of normality and homogeneity of variance to be met. It is a non-parametric test for $m \geq 2$ populations with any distributions, the examined feature is continuous on an ordinal scale - assessment of classes from 1-10 (Wołek, 2006).

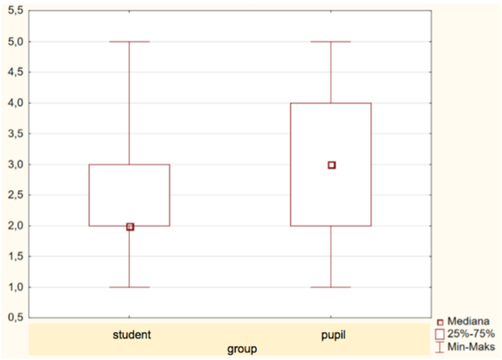
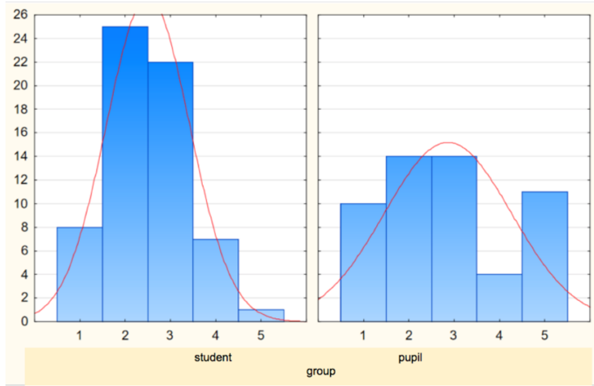
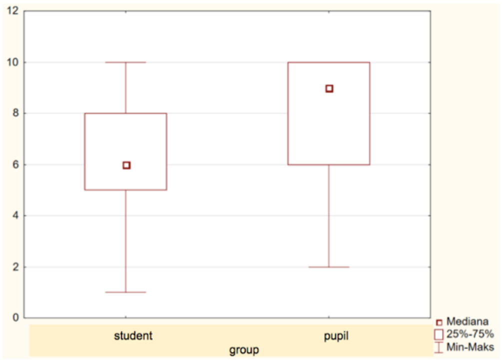
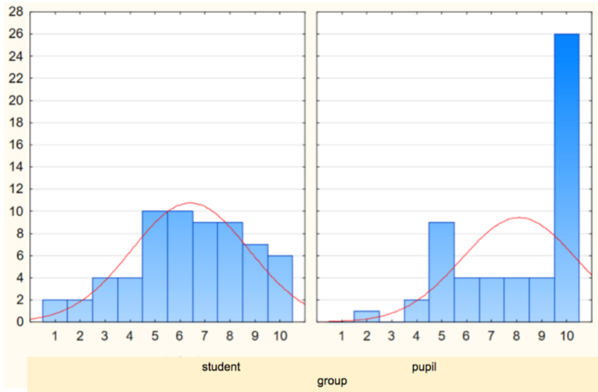
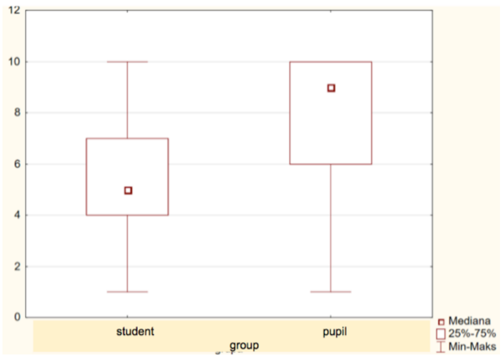
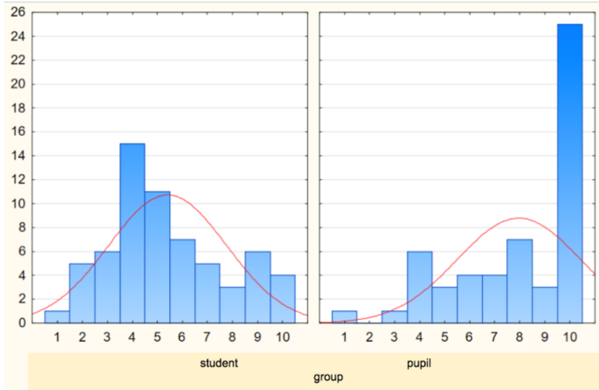
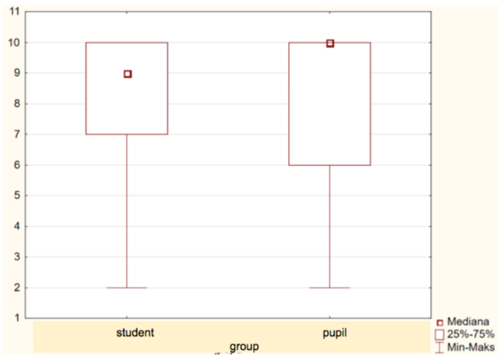
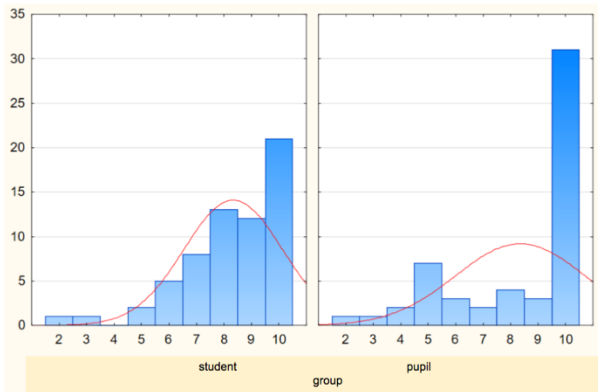
The most interesting		

Fig. 1. Kruskal-Wallis test results, comparison of groups of pupils and students. A question about the most interesting techniques. Results were calculated by Statistica StatSoft 13.1.

*1		
*2		
3		

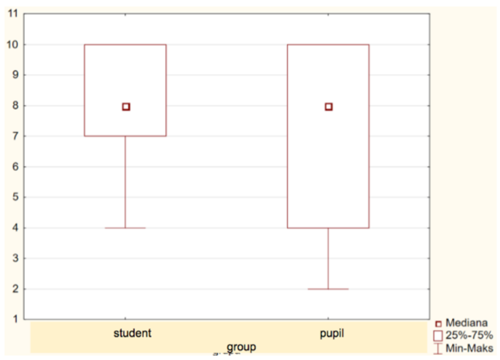
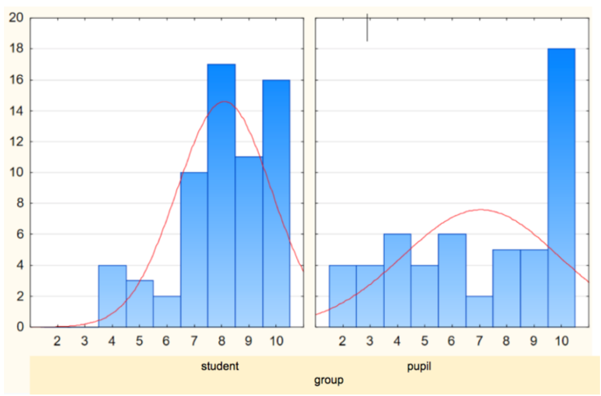
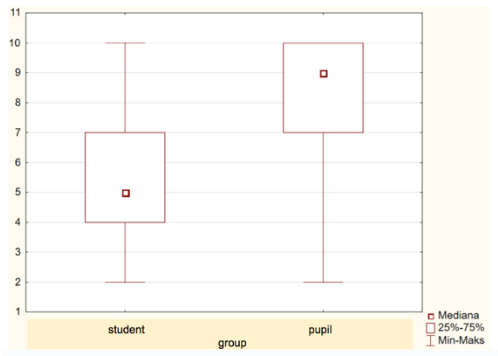
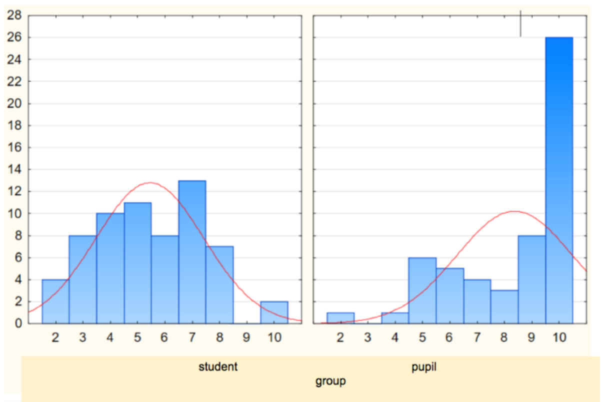
4		
*5		

Fig. 2. Kruskal-Wallis test results, comparison of groups of pupils and students. Ask for an assessment (on a scale of 1 to 10) of individual techniques: 1 - PhetColorado computer simulation; 2 - Soil pH test; 3 - natural dyes, macroscale, 4 - synthetic indicators, microscale, 5 - Universal paper indicators. Results were calculated by Statistica StatSoft 13.1.

The research results show that there is no correlation between the gender and age of the surveyed pupils and students and their choice of the attractiveness of the classes.

DISCUSSION

Primary school pupils

The obtained results show that when evaluating individual classes, the primary school pupils rated activity 3. (Natural dyes, macroscale) the highest. Activitys 1 (Computer simulation), 2 (pH test of soil) and 5 (Universal paper indicators) received a similar level of interest. They considered activity 4 (Synthetic indicators, microscale) the least interesting. Similar results were obtained in the pupils' answers regarding the selection of the most interesting classes. In this case, pupils considered activities 2 and 3 to be the most interesting. And activities 4 were considered the least interesting. Taking into account the results from both questions, the order of activities was established from the most interesting to the least interesting (Table 2).

Tab. 2. Sequence of activities from the most interesting to the least interesting in particular age groups.

	PRIMARY SCHOOL PUPILS	**UNIVERSITY STUDENTS**	**TEACHERS**
MOST INTERESTING ACTIVITIES	Natural dyes, macroscale	Natural dyes, macroscale	Synthetic indicators, microscale
	pH test of soil	pH test of soil	Computer simulation
	Computer simulation & Universal paper indicators	Synthetic indicators, microscale	Universal paper indicators
		Computer simulation	pH test of soil
LEAST INTERESTING ACTIVITIES	Synthetic indicators, microscale	Universal paper indicators	Natural dyes, macroscale

University students

The obtained results show that when evaluating individual activities, students rated activity 3 (Natural dyes, macroscale) the highest, followed by activity 4 (Synthetic indicators, microscale). However, students' interest in activities 1 (Computer simulation), 2 (pH test of soil) and 5 (Universal paper indicators) was at a comparable level.

The obtained results differ from the students' answers regarding the selection of the most interesting activities. In this case, the students considered activities 2 and 3, similarly to primary school pupils, to be the most interesting activities. Activities 1 and 4 were assessed much lower. They found activity 5 to be the least interesting. Taking into account the results from both questions, the order of activities was established from the most interesting to the least interesting (Table 4).

Primary school pupils vs. University students

Comparing the results obtained by pupils and students, we can see that, in general, regardless of the activity, pupils rate their interest in a given activity higher than students. Comparing the answers to the first and second questions, we can see that the answers are less consistent among students. (For example, students assessing the attractiveness of individual activities rated activity 2 quite low, while many of them indicated this activity as the most interesting.) Activities 2 and 3 are considered the most interesting by both groups.

Teachers

The survey was also conducted for 9 teachers. Due to their small number (incomparable to the size of groups of pupils and students), statistical calculations were abandoned. Taking into account the results from both questions, the order of activities was established from the most interesting to the least interesting (Table 4).

The teachers, similarly to the university students, found the classes that are known from the school's curriculum to be the least interesting.

The most interesting activities they chose were:

- cheap (we use only drops of reagents, instead of larger amounts & foiled sheets that can be reused)
- safe small amount of reagent,
- quick and easy to prepare and clean up.

This proves their teachers' practical approach to the issue. But it lacks concern for students' interests.

The obtained results show that the introduction of concepts related to pH at this early stage of education is possible as long as it is contextual teaching without relying on mathematical apparatus. Similar results were obtained (Burton, 2007; Kim, 2008; Pereira, & Fernandes, 2021). It also seems that our research confirms the validity of treating pH as a number on a practical acid-base scale (cf. Bates, 1973; Kopek-Putała, & Nodzyńska, 2019) or reading on a pH meter (Burton, 2007; Kopek-Putała, & Nodzyńska, 2019).

Both primary school pupils and university students considered pH testing with macroscale natural indicators to be the most interesting activities (Bates, 1973; Kopek-Putała, & Nodzyńska, 2019), however, they found the reading on a pH-meter, whether in a computer simulation or during soil testing, to be less interesting (Burton, 2007; Kopek-Putała, & Nodzyńska, 2019).

So far, the perceptions of students and their teachers as to the attractiveness of particular pH measurement techniques have not been compared. Due to the large discrepancies and the small group of teachers, further research is being conducted.

CONCLUSION

Every research group chose a different activity as the most attractive to them. For primary school pupils every activity was interesting; however, the least interesting was not directly connected with everyday life – synthetic indicators and microscale - where in fact it, from young pupils' point of view, was just dripping drops on laminated paper. In contrast, for teachers, the most interesting were activities which pupils liked the least; however, results in the teachers group should be confirmed in the larger group of teachers. University students didn't like activities, which were well known to them.

The results confirmed the hypothesis that the reception of pH classes by participants depends on their educational level, in particular on their knowledge of chemistry and previous experience; however, the previous experience of respondents can play a crucial role.

The obtained results show that the attractiveness of particular pH measurement techniques does not depend on the age of the subjects but on their "chemical" experience. Experiences known to the subjects are less interesting for them. In the era of widely available non-formal and informal education, this is a challenge for teachers. Because many shows or science festivals show spectacular experiments - students are familiar with them before they start formal chemical education.

Research also shows that teachers do not know their students' preferences as to the attractiveness of particular pH measurement techniques. It seems that in the process of teacher education, more attention should be paid to the analysis of the attractiveness of chemical experiments. Due to the small number of teachers, wider research on this topic is planned.

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The Use of an Online Escape Room in the High School Chemistry Teaching

Irena Chlebounová

Abstract

Escape rooms are popular among young people. Teachers recognized their motivational potential and tried to transfer them into an online environment. They learned how to prepare them during a lockdown and used them in their subjects. The author of this contribution was one of them. She did 4 digital games, three of them in chemistry subject. The online chemical game "Found Diary" was intended for 17 (18) years old students in the last months of the second year or at the beginning of the third year of high school. It was tested with two classes, improved, and tested again with another two classes. Students saw it as a motivational tool for effective repeating and for fixing their knowledge.

Keywords

Escape room; Didactic game; Remote learning

INTRODUCTION

Young people like to do things in their way, together with their friends in a safe environment. They enjoy adventure and having fun. Well prepared escape room has the potential to fulfil those needs even in school. It can stimulate motivation for the subject and also the willingness to learn (Borrego et al., 2017). It is trendy and it could cause a "flow" feeling (Sárközi et al., 2019; Gilbert et al. 2020). Gaming is engaging and stimulates curiosity compared to the number of facts accepted very often by the transmissive teaching in high school, which turns out to be boring for many listeners (Vörös & Sárközi, 2017). The real escape room is preferred by students before the digital one because of the possibility to do real experiments and because of an immersive environment presence (Wei Jie Jang et al., 2020).

Teachers of subjects like chemistry, which are often seen as difficult and are not well appreciated by students, are open to using escape rooms as a tool for helping students to associate the basics concepts, playfully discover scientific concepts, and be more active than in traditional teaching (Dietrich, 2018). When the difficulty of an educational game is high and at the same time, the game offers many hints, it could satisfy every player, the one who has low efficacy and also the hardcore player with high efficacy in the subject of the game (Nicholson, 2015).

Escape rooms are attractive for both genders and their appropriate use can motivate students to review the curriculum in an effective way and with engagement (López-Pernas et al., 2019). The consistent narrative and well-balanced difficulty of the game create an atmosphere for fostering soft skills like problem-solving, teamwork, and collaborative learning even in a remote environment (Gordillo et al., 2020). It is an innovative activity that encourages critical thinking (Plakogiannis et al., 2020).

The last years of repeated lockdowns in the Czech Republic due to Covid-19 showed the importance of communication skills and the active role of students in their learning (Alonso and Schroeder, 2020). The author of this article created 4 remote escape rooms during that time for her high school students and tested them first during the lockdown and afterwards in present teaching. One of them will be explained in this contribution.

This qualitative research aimed to see the influence of such a game on the willingness of high school students to spend at least 40 minutes of active work with the chemistry tasks. The research question was: "How will students take the challenge of the game and complete all tasks from a wide range of chemistry knowledge?" The hypothesis was that participation in the game as a member of one group will help everybody with motivation to finish all tasks on time and not give up.

METHODOLOGY

Chemical Escape Room "Found Diary"

The game was intended for the end of 2nd year or the beginning of the 3rd year at high school. The chemical content of the game was hydrocarbon derivatives. The 17 years old students of the 2nd year got the game to foster new knowledge. The 18 years old students in the 3rd year had the game as a repetition of the previous year's knowledge. The main chemical aim was to recognize representatives of each group of chosen derivatives and match them with their formulas. Some questions were asked about the use of the chemicals or their properties. Another aim was to actively cooperate with others in small groups of four, which means effectively dividing roles and work to finish in proper time.

The escape room contained 10 websites with hidden paths among them. There was one slide of Google presentation on each website with a real nature photograph as a background of the presentation. There were also mostly 3 embedded pictures with hidden internet links to the application Flippity Scavenger Hunt and Wordwall Matching pairs. After clicking on the picture, the players saw the application with tasks to open the hunt and got the password, and link to the next website. Players could ask for a hint or search for the right answer on the internet whenever they were stuck or needed help to prevent their frustrations. This was done according to the recommendation of Nicholson (2015). The hint was in Flippity Scavenger Hunt under the light bulb symbol.

The story of the Escape room was written as the diary of an unknown person. Every group followed the journey that was the escape of this kidnapped man from his prisoners. The unknown person was under the influence of some chemical because he saw strange things while running away as is seen in Fig. 1.

Fig. 1 The strange creature is seen by the escaping man in the game. It corresponds with the topic of alcohol or other organic drugs. It demonstrates the difficulty to connect the story with the chemical content.

The duration of the game was planned for 90 minutes lesson. There had to be time for the evocation phase before and the reflection phase after the game. So, the maximum time for own game was 60 minutes according to the recommendation of Veldkamp et al. (2020).

The nature of the tasks

The main aim of this game was to strengthen the knowledge of recognise different types of derivatives according to their functional groups in their formulas. There were the following topics: halogen derivatives, nitrogen derivatives and oxygen derivatives. As the area of needy knowledge was so wide, the tasks had to be easily understandable and quickly answered. The form of such a game has some limitations in the difficulty of questions because it needs a very precisely specified word (or group of words) as the answer. It is impossible to create a question with more correct answers because the computer recognises just the same one which was written by the teacher. Complicated problems can be given as a task in the form of a series of successive steps.

The observation of the students during the game

The whole time the teacher was present to support her students. She went around the classroom and spoke with groups during the game all the time. She also observed the behaviour of all groups and made comments in her notes about the activity and strategy of all players. She asked them about their feeling and their needs during the game and also after the game was over.

Reflective questionnaire

The reflective questionnaire was prepared for the feedback response of students. It was done through Google Forms. Every player had to answer all questions alone after finishing the game. There was also planned space for discussion about the game and the feeling of students.

Below is the list of questions in the questionnaire:

1. What was the number of people in your group?
2. How long did it take you to get to the end of the story?
3. How often did you use the help?
4. How often have you looked for an answer on the Internet?
5. Was it easy for you to understand the principle of the game?
6. Do you find the escape game a useful tool to review chemistry?
7. How difficult did you find the tasks?
8. Did you like the game?
9. Did you have previous experience with the Escape room?
10. If you had such an experience, choose where it was:
    - In a real environment outside the school
    - In a real environment inside the school (in another subject)
    - In an online environment in another subject
    - In an online environment outside the school

The sample of students

The first version of Escape Room played 2 classes, the reflective questionnaire was sent by 38 people. The improved version played the other 2 classes. There were another 42 students. These classes led a discussion about possibilities of other improvements to the game and the feelings of students according to the written questionnaire.

Data analysis

The main data analysis was done qualitatively because of the small size of the sample. Just one question was analysed quantitatively. The reason was to recognize influence of the group size on the evaluation of tasks difficulty.

Let p_1 (p_2) be the probability that a member of Group A (Group B) considers the subject matter easy. The null hypothesis: $p_1 = p_2$ and its alternative $p_1 < p_2$. Two tests were performed, namely the asymptotical test (p-value equal to 0.00253) and the exact Fisher factorial test (p-value equal to 0.00233), see, for instance, pages 328 – 331 of Hátle and Likeš (1974). The effect size (ES) calculated according to Cohen (1992), Table 1 (test No. 6). The four-fold Contingency table was used as is seen in the chapter "Results and Discussion".

RESULTS AND DISCUSSION

The first version of the escape room was played as remote learning, and the reflective questionnaire was sent back by 38 students. Players were divided into groups of four through breakout rooms. Some of them faced different technical problems with internet connection and the teacher did not know how to help them. It means, that in reality there played 29 % (11 people) of them alone and others in groups of at least 2 (13% = 5 people) and a maximum of 5 members (45% = 17 people). There were not seen any problems during playing the game in classroom. All students seemed to be involved into the game. They were trying hard to be the first group who will come to the end. They enjoyed funny atmosphere and were much more active than in usual chemistry lesson.

There was one misunderstanding between the teacher and students during the first game. Some students refused to use the help of the hint and felt bad if they needed it. But the teacher did not expect that they will everything know without any external help. She explained this properly to the next two classes before their game started. As is in the recommendations of López-Pernas et al. (2019), a very important is strong initial guidance and help for students in the form of hints. Borrego et al. (2017) speak about the limitation of the number of difficult riddles. They are warning that the right way is to combine them with easier ones because students need the hope that they will finally succeed.

For those, who played alone or in a group of 2, was the game too long and difficult (29 % = 11 people). For groups with 3 – 5 people was mostly a game of appropriate difficulty (71% = 27 people) and took them from 40 to 60 minutes. The duration of 60 minutes was the same as in some Escape Rooms described in articles about them (Dietrich, 2018; Peleg et al., 2019; Sánchez-Martín et al., 2020; Yayon et al., 2020). The results from question 1 (What was the number of people in your group?) and 5 (How difficult did you find the tasks?) form the following four-fold contingency table as seen in Tab. 1.

Tab. 1 Four-fold Contingency Table. Group A contained all players who played in groups less than 3 members, group B contained all players who played in groups from 3 to 5 members. Chleboun 2023

THE GAME WAS	EASY	DIFFICULT	∑
GROUP A (1-2 PEOPLE)	7	9	16
GROUP B (3-5 PEOPLE)	20	2	22
∑	27	11	38

On the basis of the results obtained in both tests (asymptotical test and the exact Fisher factorial test), a joint conclusion is made that the null hypothesis can be rejected in favor of the alternative hypothesis at any significance level $\alpha \geq 0.00256$. The effect size in Table 1 according to Cohen (1992) is equal to 0.513, that is, effect size is large, which supports the rejection of the null hypothesis. It means, that the size of the group influenced the feeling of students about the difficulty of tasks in the game. Members of small group evaluated the game as more difficult than members of bigger group.

The teacher tried to avoid the frustration of some students during playing the game through breakout rooms and gave clear instructions at the beginning of the game at school. The most important thing was the explanation that is expected to search for the right answer with the help of textbook, internet or game hint. This precaution led to the increased activity of all students and the division of the roles in one group. Every group had its strategy for how to succeed. The most successful groups divided tasks among all members and everybody searched for another answer.

Most of the students liked the game (90% = 34 people). Just 4 students did not like it and saw it as wasting of time. It could be connected with their frustration during the game as Nicholson points out (2015). Some of them spoke about some functional problems. These problems were removed before the second version of the game started. Some students missed a stronger connection between the story and chemical tasks. The teacher understood these requests but did not have enough invention to improve according to them the game.

All students finished the game. It was incredible that all students gave continuously full concentration on chemical tasks for at least 40 minutes (some of them for more than 60 minutes!) and they seemed to be in good spirits. Even weak students were interested and actively looking for answers. This hardly happens in a common lesson. The such strong motivation was surprising and gives the hope that there is a good reason for gaming as a way of learning. It is impossible to say how effective the learning itself and there is a need to do another research to get the answer to such a question.

About 55% (21 people) did not play in any escape room before. Other 29% (11 people) experienced escape rooms in the real environment. Students of the two first classes needed a very precise explanation of what to do and how to do it compared to the next two classes, who in the meantime played another remote escape room and were more experienced. The experienced class needed less time to finish the game. The atmosphere was more relaxed and all students enjoyed the game.

Most students saw the escape room as a funny, interesting, and effective tool for the repetition of chemistry (34 people). Two students have written, that it is funny or interesting but not effective. Two others did not see it as effective. It corresponds with the claim of Yayon et al. (2020) that the Escape Room with the student-directed approach is a motivating activity that increases the self-efficacy of students and can be an effective activity for reviewing topics for the exam.

The playing of the improved version with the other two classes was done in the real classroom. Students played in groups of four in a sequential puzzle path and the teacher was near them in case they need any help as recommended by Veldkamp et al. (2020). The atmosphere was nice and students were strongly engaged. It corresponds with the study of Gordillo et al. (2020). Many students were seen with their heroic feeling as described by Nicholson (2015). The time varied from 40 to 60 minutes, and everybody came to the finishing slide at the proper time. Students had previous experience with another online escape room from the same teacher. It helped them to be independent of the teacher and it saved time for play. The higher autonomy of students improved their creativity, decision-making, and teamwork as mentioned by Ferreiro-Gonzáles et al. (2019).

The difficulty with the chemistry knowledge of all derivatives including carboxylic acids took groups as a challenge and everybody in the group searched for the answer to some question. The members of every group divided tasks to save time and be at the finish line as soon as possible. The first group at the finish line got a mark of one for the activity during the lesson. There was a discussion about the game instead of a questionnaire afterwards according to the recommendation of Veldkamp et al. (2020). Students showed satisfaction with the game, nobody had any serious problems with it and nobody saw it as a waste of time or an ineffective tool for repetition. The activity encouraged communicative skills and cooperative learning between team members. This effect was also observed by Plakogiannis et al. (2020). Some of them expressed a wish to play such a game more often.

Constructing the digital escape room took the teacher a lot of time (one week) but there is the possibility to use it every year again and again which will save time with preparation in the future. The same opinion had Vörös & Sárközi (2017). This is the link to the digital escape room "Found Diary": https://sites.google.com/natur.cuni.cz/nalezendenk/domovsk%C3%A1-str%C3%A1nka

CONCLUSION

The escape room prepared by the author for her high school students aimed at repeating knowledge about derivatives of hydrocarbons and fostering soft skills like teamwork or communication. The effectiveness of chemical knowledge was not tested. Communication and teamwork improved according to the teacher's observations during the game, reflective questionnaire, and discussion after the game. The hypothesis that it will be motivating and nobody gives up was confirmed.

Students enjoyed playing in the escape room and asked for doing such activities more often than before during the school year. They saw it as a fun engaging experience and an effective way how to foster their chemical knowledge. The hardcore players enjoyed the challenge of the game, and the anxious students used many hints. Even quiet students expressed enthusiasm and sometimes even leadership according to Peleg et al. (2019). Gaming is an activation tool even for difficult topics and weak students.

The 10 websites are a lot, 5 to 7 would be enough. The challenge for the teacher is to prepare a combination of a digital and real escape room. The disadvantage of the game is too much time to prepare such an activity but once it is prepared it could be reused with new classes. Comparing the knowledge before and after the game would be useful. The aim of the research was fulfilled. The limitations of the research are the small number of tested pupils and just one teacher in one class. Quantitative research with more classes would be needed to prove the effectiveness of such learning.

Acknowledgement

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There is a link to the digital Escape Room "Found Diary" made by Irena Chlebounová:

https://sites.google.com/natur.cuni.cz/nalezendenk/domovsk%C3%A1-str%C3%A1nka

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How do secondary school students use the periodic table of elements: Preliminary eye tracking study

Pavel Teplý, Petr Šmejkal, Milada Teplá & Svatava Janoušková

Abstract

This research aimed to study the ability to use the periodic table of elements (PTE) of university freshmen admitted to chemistry and non-chemistry science study programmes and reveal possible underlying factors. Students of chemistry-related programmes were comparably successful to students of chemistry-unrelated programmes. Eye tracking and retrospective think aloud (RTA) us to identify four groups based on their success and strategy. The results revealed major gaps in knowledge and understanding the basic principles of the PTE. We recommend emphasising the symbolism in the PTE, the periodic law and the laws it implies in upper secondary school teaching.

Keywords

Eye tracking; periodic table of elements; upper-secondary school; undergraduate students; problem solving; chemistry education

INTRODUCTION

The Periodic Table of Elements (PTE) is one of the cornerstones of chemistry education. It is a sophisticated representation of the well-known periodic law published by D. I. Mendeleev in 1869 (Bierenstiel & Snow, 2019). Since PTE is based on the periodicity of chemical properties, it inherently harbours many patterns, trends and connections. It is the understanding of these principles and relationships that enable us to understand the bigger picture and make predictions (like Mendeleev did) about the physical or chemical properties of unfamiliar elements and their compounds) (Brush, 2007).

Although PTE has long been used in chemistry education, we still know very little about how students work with it, whether they understand the principles of its construction and whether they can adequately use it.

Periodic table

In 1869 D. I. Mendeleev postulated his version of the periodic law, and we all use it (in a slightly changed version) ever since. His main goal was to understand the relations among chemical elements and be able to explain them to his students. After more than 150 years, we still struggle to teach our students the very same principles and trends (Hargittai & Hargittai, 2019).

The fundamental trends that can be traced in the periodic system are periodically changing chemical and physical properties such as density, ionization energy, atomic size, electronegativity and many others. Other relationships and properties can then be derived from the position of an individual element within a particular group, such as reactivity or stability of oxidation states.

One of the most important goals of teaching chemistry should be to explain those principles to students so that they understand and are able to use them. This of course should be preceded by the knowledge about the basic arrangement of elements in the PTE (groups, periods), their symbols, names and, last but not least, the numerical data accompanying the element symbol, such as the proton number (Franco-Mariscal et al., 2015; Selco et al., 2013).

Representations, knowledge and problem-solving

The PTE and the periodic law are good examples of how a graphical representation could help students understand difficult phenomena assuming their active engagement. Science representations help us memorize basic facts and understand the nature of complex phenomena (Tytler et al., 2013).

In order to solve any problem we need to have some knowledge to work with (Hartman & Nelson, 2015). Furthermore, knowledge should be accommodated and associated with our previous knowledge in order to be able to effectively use it. Representations enable us to create associations and thus incorporate new knowledge into our long-term memory (Anderson, 2009).

Memorization is an essential part of science learning (Hartman & Nelson, 2015) but it must be tightly interconnected with comprehension. Since the problem-solving process is a collaboration of working memory (thought) and long-term memory (knowledge) we usually need some memorized fundamentals prior to solving any problem (Anderson, 2009).

Eye tracking (ET) in (chemistry) education

Eye tracking is already an established research method that enables objective data acquisition in social sciences. It has been used in psychology, marketing, linguistics, computer sciences etc. (Chandon et al., 2009; Conklin & Pellicer-Sánchez, 2016; Rahal & Fiedler, 2019; Zhang et al., 2017).

In recent years, the importance of this method has also been growing in didactic research, including chemistry education (Lai et al., 2013; Topczewski et al., 2017; Tsai et al., 2012; VandenPlas et al., 2018). Eye tracking can be used for exploring student-teacher interaction (Huangfu et al., 2022), designing and assessing the effectiveness of teaching aids (Clark & Lyons, 2010) or discovering strategies for problem-solving (Škrabánková et al., 2018), including comparing approaches of groups with different level of expertise (Dogusoy-Taylan & Cagiltay, 2014).

Even the periodic table of elements has been subjected to ET research methodology. Tóthová et al. (2021) explored the „students' ability to use the periodic table of elements to solve problem tasks". Their findings were rather disturbing since they concluded that students have low reading, problem-solving skills and lack of fundamental knowledge. In addition, they even lack the motivation to solve more demanding tasks. „*Students' ability to use the periodic table was proved insufficient to the corresponding curricular objective*".

RESEARCH METHODOLOGY

We have formulated research questions (RQ) as follows:

RQ1: What predictors influence the effective use of PTE?

RQ2: Are there similar groups of students in terms of coping strategies?

Twenty-four participants (first-year students of the Faculty of Science Charles University study programmes) voluntarily took part in the experiment. We intentionally call the sample "secondary school students" because their knowledge and skills, as first-year students not yet exposed to university teaching, are still based solely on their secondary school chemistry training. All the participants had normal or corrected to normal vision and normal colour vision. Due to data quality concerns and missing data, two participants' eye movement data were excluded from the analysis. Analysis was performed on the final sample of 22 respondents (8 men and 14 women) at the very beginning of the first year of their pregradual study (M_{age} = 19,2; SD = 0,5; q_{age} (1/2) = 19,0). Prior to beginning the experiment, demographic data pertaining to age, sex, study programme (they enrolled), interest in chemistry and whether they have passed the final exam in chemistry (in upper secondary school) were collected via questionnaire.

Apparatus

Eye movements were recorded with the SMI RED250m eye-tracker mounted on a 15,6" notebook screen with a resolution of 1920x1080px. The temporal resolution was set up at 250Hz using iView X 4.2.1.1 software. Above that, we used a web camera to record participants' behaviour and responses during the session. To ensure the measurement validity, there was a five-point calibration and subsequent validation prior to the session with an acceptable eye deviation in the range [0,0 - 1,0°].

Research design and objectives

Participants were presented with 14 tasks in four sets. The first set of tasks was based on locating p-block and individual chemical elements (P, Ba, Co, Kr) in the blinded periodic table. Participants were given the name of one chemical element (or the whole p-block) at a time and were asked to find its most precise position in the blinded PTE (see Fig. 1) possible and confirm it by left-mouse button clicking. The areas of interest (AOIs) are marked in the figures below.

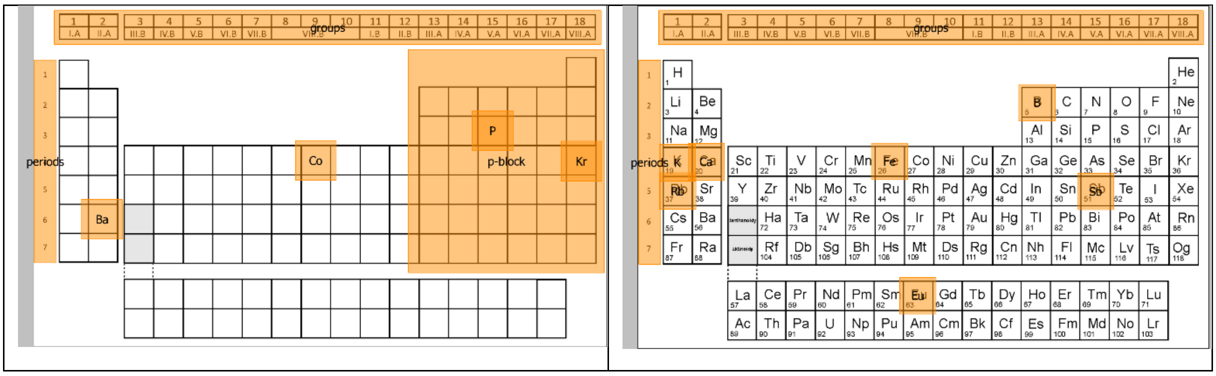
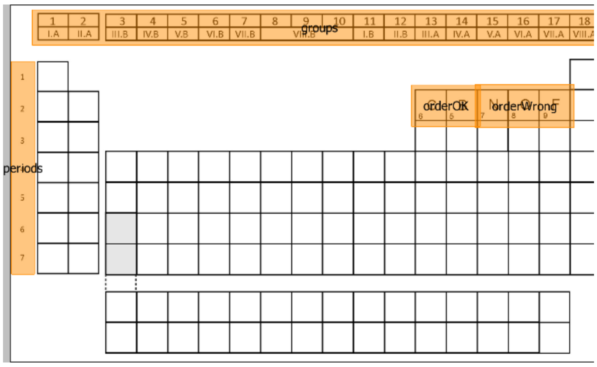


Fig. 1 Blinded PTE with highlighted AOIs (Tasks 1-5) and Fig. 2 Full version of PTE with highlighted AOIs (Tasks 7-10, 12-14)

The second set of tasks was to search for an error in a semi-blinded and in the group of halogens in the full version of PTE (see Fig. 3 and 4).



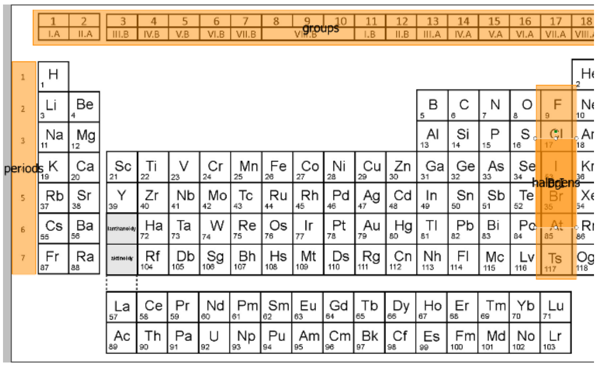


Fig. 3 Partially blinded (Task 6) **Fig. 4 Full version of PTE (Task 11) with highlighted AOIs**

Third, the participants searched the full version of PTE for particular element symbols (Rb, Eu, Sb, Ca). And in the last set of tasks, participants were supposed to calculate the exact number of neutrons when given an element symbol along with the atomic mass (see Fig. 2).

All the stimuli were designed and presented using Experiment Centre 3.7 software. All the eye tracking data were processed with BeGaze 3.7 software, fixation detection parameters being set to 80ms (minimum duration) and 50px (maximum dispersion) (Popelka, 2018). The raw data was exported to IMB SPSS Statistics and analysed. The ScanGraph application (Levensthein String-edit distance method) was used to analyse and compare Scanpath data (Doležalová & Popelka, 2016). This enabled us to divide participants into two groups, effective and ineffective regarding to effective work with PTE.

Students took as much time as they needed to solve individual tasks. This resulted in overall processing time for all tasks ranged from 20 to 52 min. In the next phase a retrospective think-aloud (RTA) was video-recorded for each participant. The RTA interviews were transcribed, coded and analysed (Prokop et al., 2020) with respect to success and the means used to achieve the goals (problem-solving approach). For this purpose we defined success and effective work with the PTE as the ability of effective navigation through it with comprehension to basic principles of the PTE construction.

RESULTS AND DISCUSSION

All tasks in all sets varied in cognitive difficulty. The sets were designed to gradually increase the difficulty of the tasks. Participants varied greatly in their overall results, from the least successful (participants 19 and 25 scored only 14%) to excellent results (participants 4 and 8 scored 93%). From the tasks' point of view, the easiest were tasks 8 and 10 (searching the full version PTE for Ca and Eu) with a 95% success rate, whilst the most difficult was task 3 (searching the blinded PTE for Ba) with only 14% success rate.

The RTA analysis provided useful information about understanding the assignment and eventual knowledge application. Furthermore, the RTA analysis helped to sort participants into groups according to their problem-solving approach. We divided them into three groups: 1) no problem (G_1), 2) problems with understanding (G_2) and 3) lack of effort (G_3). The G_2 and G_3 often overlap.

Figure 5 visualizes the Trial Duration of individual tasks (for all participants). There is a visible discrepancy in the overall solution duration, particularly tasks 5 and 10 differ from others by their quick average time. The reasons are nonetheless not the same. Task 10 was focused on searching for calcium in the full version of PTE (with 95% correctness), so we can say with confidence it was an easy task to do because calcium (as RTA confirmed: G_1 = 95%, G_3 = 5%,) is a commonly known chemical element even among non-chemists. Whereas in task 5, participants searched for krypton in the blinded version of PTE, and more than 60% of them did not solve it correctly often because they quickly gave up, as many of them did not even know where to place it in the PTE (RTA: G_1 = 36%, G_2 = 16%, G_3 = 62%). From the RTA point of view Tasks 6 and 11 are quite interesting since they report the biggest ratio of understanding problems (RTA Task 6: G_2 = 54%, G_3 = 23%; Task 11: G_2 = 25%, G_3 = 11%). Still, most of the participants chose at least to guess the answer (see G_3 values above).

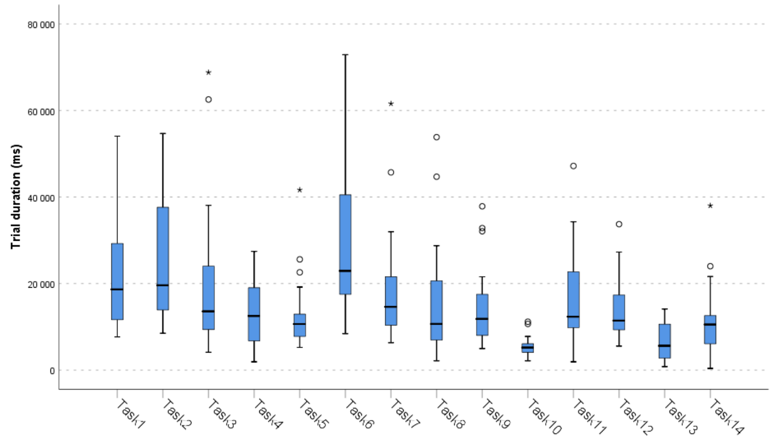
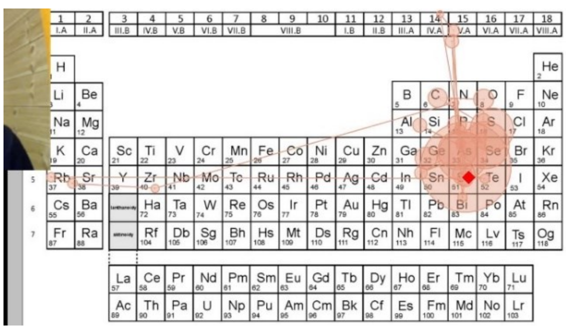


Fig. 5 The trial duration for individual tasks (for all participants)

A very wide range in trial duration exhibits task 6, a partially blinded periodic table (see Figure 3) with only 5 elements in the p-block displayed and the rest of the table blinded for clarity's sake. Participants were supposed to find an error in the order of those elements. Only 40% were able to connect the correct order of elements with their atomic number and reveal that carbon and boron switched places.

The RTA showed that the wide range in this task's trial duration is related to a seemingly straightforward assignment that made participants feel obliged to solve it. "…at first it seemed very simple, but after a while I found that I do not know how to solve it…"

The Scanpath comparison proved very well in discriminating participants who understand the principles of construction and functioning of PTE and very well corresponded with GR_{ch} and GR_{Nch} distribution. They intentionally used legend such as periods and group numbering to navigate the PTE (see Figure 6) unlike the rest of the group (see Figure 7). The RTA confirmed the findings from Scanpath comparison (participants' statements are in italics): *"…I was just searching PTE and looking for the chemical symbol by letters…"* (see Fig. 7) "…I made sure I was in the right group…" (see Fig. 6)



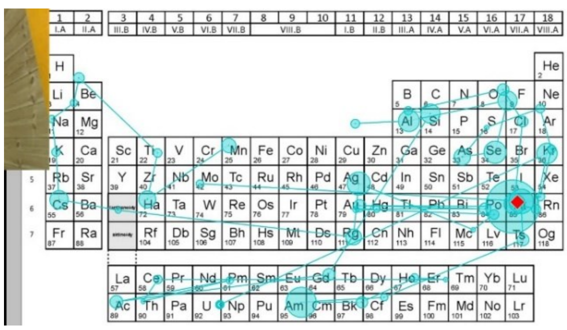


Fig. 6 (left) and Fig. 7 (right) The Scanpath comparison (from RTA) of two participants solving task 9. On the left is a well-oriented participant familiar with PTE (from GR_{ch}) on the right is a typical participant from GR_{Nch}.

As you can observe in Figure 7, some participants knew neither the approximate position of the element (in the task) nor the element symbol and wandered aimlessly through the entire PTE (this was confirmed by the RTA). Figure 6, on the other side illustrates participants who navigated throughout the PTE very well, showing at least a basic understanding of how the PTE is assembled. You can notice using the group and period numbers for that purpose (again confirmed by RTA).

We have investigated predictors that influenced successful task solving (and effective use of PTE). We analysed eye tracking metrics primarily based on AOIs (namely Fixation Count (in predefined AOIs, see Figures 1 to 4 above) and Fixation Duration). To discover relevant predictors influencing effective PTE using (and thus correctly solving given tasks), we correlated those metrics and correct solutions to participants' gender, study programme and secondary school graduation exam (with chemistry = GRCh vs GRNch = no chemistry). Since our data indicated non-normal distribution, we utilised non-parametric tests (particularly Kruskal-Wallis *H* test and Spearman's rho).

We confirmed that there is no evidence of significant differences between genders or among students of different (investigated) study programmes. Still the RTA provided evidence that females reported guessing to a higher extent (29%): *"…I didn't know the right solution, so I guessed…"* than males (15%) which is in agreement with Stenlund et al. (2016). A significant difference was between the group of GR_{Ch} performing significantly better than the rest of their peers (see Fig. 8). Regarding to the effective use of PTE the final exam in chemistry is clearly a good predictor. Additionally, the RTA and Scanpath analysis revealed that GR_{Ch} used group and period numbers to navigate through PTE more often than GR_{Nch}. Moreover, Spearman's rho has shown that the group GR_{Ch} overlap with Scanpath effective group ($r = 0.68$, $p = 0.023$).

GR_{Ch} spend significantly more time in these AOIs (groups end periods) with longer average fixation duration and higher fixation count. Even though the *p*-value was smaller than 0.01, the effect size (*Cohen's d*) was relatively small in all cases, ranging between 0.18-0.22.

In order to unravel and understand solving strategies of individual participants, we have performed a hierarchical cluster analysis (between group linkage with squared euclidean distance). This resulted into 4 clusters (groups – see Table 1) of participants who differed in "solving proficiency". Solving proficiency was defined as a combination of the overall Correctness (percent of correct solution), the Sum of the Time spent solving all tasks, the Overall Fixation Count in the relevant AOIs and the total time spent in the relevant AOIs.

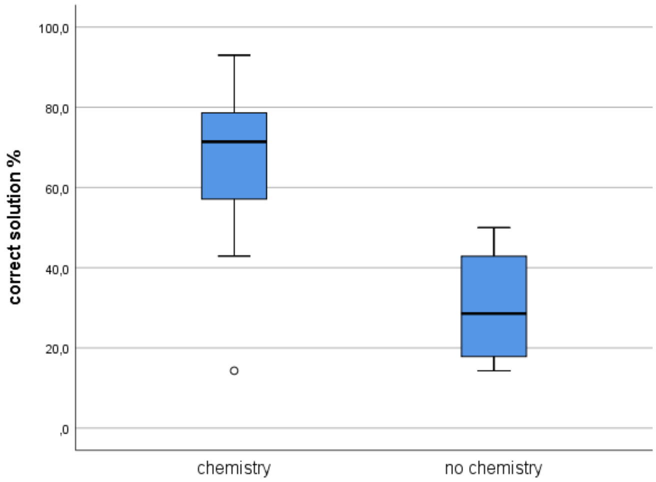


Fig. 8 Difference in performance between groups according to the final exam in secondary school (with chemistry = GR_{Ch} vs GR_{NCh} = no chemistry).

Table 1 Participants split into groups by their "solving proficiency".

GROUP NUMBER	GROUP CHARACTERISTICS
GROUP 1	Participants scored high on the test and also solved the test in a relatively short time.
GROUP 2	Participants scored high on the test, but solved the test in a relatively long time.
GROUP 3	Participants scored low on the test and solved the test in a relatively short time.
GROUP 4	Participants scored low on the test and solved the test in a relatively long time.

Thus we were able to discriminate that more successful solvers in groups 1 and 2 (both slow and fast) spent significantly more time in AOIs, and their fixation count was smaller compared to the groups of less successful respondents (compare to Epelboim & Suppes, 2001; Topczewski et al., 2017). The Kruskal-Wallis *H* test (H = 9.31, df = 3, $N_{as.}$ = 0.25, η^2 = 0.351) revealed that there were significant differences with a large effect between the group 1 and groups 3, 4 as well as between group 2 and groups 3, 4. This concerned mainly the time spent in the relevant AOIs when participants from groups 1 and 2 stayed in the relevant AOIs significantly longer than their peers from groups 3 and 4. Similarly to Tai et al. (2006), we can conclude that different participants need a various Number of Fixations to attain the same or similar result (see Table 2).

Table 2 Group description based on median values of variables.

GROUP NUMBER	N (%)	CORRECTNESS (%)	SUM OF TIME (MIN.)	OVERALL AOI FIXATION COUNT	OVERALL AOI FIXATION TIME (S)
GROUP 1	54	70.9	33.1	135.5	408.6
GROUP 2	18	75.0	48.6	147.5	348.2
GROUP 3	14	28.6	26.6	50.0	148.5
GROUP 4	14	30.9	50.3	80.0	128.4

Furthermore, we analysed the common characteristics of individual group members (see Tables 1 and 2) using RTA and found some common characteristics for each group. The RTA analysis showed that students from the group 3 often briefly skimmed through the task assignment or even skipped it because they were reluctant to read, which is in agreement with Tóthová et al. (2021). *"I didn't know how to handle it, so I skipped it."* This occurred mostly in the last set of tasks, where participants were supposed to calculate the exact number of neutrons when given an element symbol along with the atomic mass.

Especially groups 2 and 4 did not pay enough attention and must have returned (some of them several times), again especially in the last set of tasks. *"I didn't remember the assignment, so I went back."*

RTA also revealed that many of them neither really understand the meaning of the PTE legend (groups and periods and how to use them), nor did they know any mnemonic tools and thus failed to navigate through the PTE. Yet one skill or the other was crucial to solve the first and second sets of tasks successfully.

RTA also pointed out that some participants did not remember relations between variables (atomic number, atomic mass number and number of neutrons) which was apparent in their reactions at the very last set of tasks assignment and led to quickly giving up any attempt to solve it.

Moreover, the RTA clarified an interesting artefact occurring often in the group of GR_{Ch}. Participants often lost eye contact with the eye tracker at the end of the assignment reading (or at the very beginning of solving the task). While going through the footage, the participants explained this loss of connection as them thinking or visualizing the PTE. *"…this is where I was just thinking…"* or *"I visualized the approximate position of the element in the PTE…"* This phenomenon freely extends the knowledge published by Hollander & Huette (2022) and Uzzaman & Joordens (2011).

The following process of task solving was usually quicker than if this artefact was missing. This is consistent with the group mentioned above of more successful solvers who need less time and fewer fixations to solve the task.

LIMITATIONS

There are some general limitations regarding sample size and eye tracking. We have taken measures to compensate for known ET limitations. We have triangulated the gaze point interpretation subjectivity with RTA, supplemented raw data analysis to the foveal vision and tried to formulate the assignment since the eye movements are task-dependent clearly.

Still, it is difficult to generalize the results since the number of participants was relatively small. The participants applied to different study programmes of the Faculty of Science at Charles University. To address this limitation, it would be useful to enlarge the sample in respect of the study programme and look more profoundly into the participants' background (especially previous chemistry education).

CONCLUSION

The results suggest that secondary school students lack a basic understanding of the PTE concept (the exception was GR_{Ch}). Participants failed to navigate through the periodic table while solving given tasks which was apparent in how ignored using the groups and periods to get to the right area of the PTE. They often guessed or skipped tasks because they did not understand the meaning of terms related to PTE such as the atomic number, its relation to the atomic mass number, or terms nuclide and isotope.

Based on the research results, we would recommend that more emphasis be placed on the symbolism in the PTP, the periodic law and the regularities resulting from it in secondary school teaching (especially in preparation for graduation). Similarly, the general and inorganic chemistry undergraduate curriculum should reflect the statistical uniformity of freshmen and include a repetition of the basic concepts and laws related to the PTE.

This study has shown that students who have at least a general idea of the principles underlying the periodic table (understand the nature of the PTE) can better navigate around it when searching through it or solving problems. This understanding in turn leads to good estimation of chemical and physical properties of elements or at least its skilled comparison with those found in the surrounding. And that should be one of the main goals apart from remembering and recalling the particular knowledge without understanding.

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A Digital Collaborative Learning Environment to Support First-Year Students in Learning Molecular Orbital Theory

David Johannes Hauck, Andreas Steffen & Insa Melle

Abstract

In natural sciences, students struggle when abstract and non-intuitive concepts have to be applied to explain phenomena, such as molecular orbital (MO) theory for the description of bonding and electronic properties of molecules.

To address this challenge, we have developed and evaluated digital collaborative learning unit, where students were familiarised with MO theory through interactive learning videos, and subsequently created concept maps in order to foster their understanding of chemical bonding.

In this paper, we describe the interactive videos in detail. In addition, the students' assessment of the different phases is described and discussed.

Key words

Tertiary education; molecular orbital theory; Computer-Supported Collaborative Learning; digital learning environment; concept maps

INTRODUCTION

Abstract and non-intuitive concepts pose great challenges to university students, especially in the first semesters of science subjects such as chemistry (Eurostat, 2018; Heublein, 2014). In addition to demanding subsidiary courses such as physics and mathematics as well as an insufficient level of fundamental knowledge, students have difficulties understanding complex new topics like quantum chemistry. An immediate consequence is a decline in motivation to continue their studies, especially if the curriculum deviates from prior expectations. This can even become a crucial reason for dropping out of studies. Not least because of these factors, high drop-out rates prevail worldwide (OECD, 2020).

This emphasises the need to support chemistry students, particularly at the beginning of their studies, not only in refreshing necessary fundamentals, but also in learning difficult new content. At universities that follow an atoms-first approach (Chitiyo et al., 2018; Esterling & Bartels, 2013; Zumdahl & Zumdahl, 2016), quantum physical theories of chemical bonding such as molecular orbital (MO) theory are among the most challenging contents at entry-level due to their mathematical requirements and abstract nature (Taber, 2005; Tsaparlis, 1997).

In recent years, various studies have shown the potential of digitally supported collaborative approaches for learning challenging scientific content (Kyndt et al., 2013). From a socio-constructivist perspective, learning occurs as students build on their own ideas by engaging in conversations with other students and integrating multiple perspectives into the learning process through co-construction (Heeg et al., 2020). Although such approaches are theoretically well suited for learning quantum physics or chemistry, there are only few studies so far in which students engage with these contents collaboratively (Bungum et al., 2018; Partanen, 2018).

The exceptional situation caused by the COVID-19 pandemic also led to an acute need for innovative forms of learning, both to support students in the exclusively digital semesters, and to promote networking amongst students who no longer met on campus or in the lecture hall (Werner et al., 2021).

Consequently, a central aim of our study was to develop and evaluate a digital collaborative learning unit that enables students to engage with difficult quantum chemical contents, specifically MO theory. To facilitate the transition to standard university practices, the intervention consisted of an introductory chemistry course. The content of our digital learning environment was aligned to that of the lecture, so the students already had the opportunity to acquire basic knowledge.

DESIGN

Building on the ideas of the Computer-Supported Collaborative Learning (CSCL) framework (Zurita & Nussbaum, 2004), we developed a two-part intervention on the quantum physical basics of chemical bonding in general and MO theory in particular, which we conducted for the first time in January 2021 (Hauck et al., 2021) and revised for a second implementation in January and February 2022 based on the results obtained. Subsequently, results from the second study in 2022 (N = 115) will be presented along with the final design. The intervention consisted of a total of five two-hour seminar sessions which took place after the topics were presented to the students in their introductory chemistry lecture. The professor who held this lecture is co-author of this paper.

The seminar structure is summarised in Figure 1. Because of the COVID-19 pandemic, all courses at our university were held digitally via Zoom. We used Moodle to coordinate the intervention and to distribute the learning materials, i. e. the digital learning environment ('DLE' phase in Figure 1), the questionnaires, and templates for supplementary tasks such as the glossary that the students had to fill out with central concepts of MO theory ('CMP II' phase in Figure 1).

After a brief introduction and pre-testing of content knowledge, the students partook in team building activities. As most classes were conducted online due to the ongoing COVID-19 pandemic, many students did not have sufficient opportunity to connect with fellow students and thus felt isolated

(Werner et al., 2021). Therefore, this team building phase was especially important (Staggers et al., 2008).

Following up on that, the students worked with interactive learning videos (Digital Learning Environment, phase 'DLE' in Figure 1) in the second seminar, which they assessed in terms of perceived cognitive load, attractiveness and usability ('Mid-Test I', see Tables 2 to 4). Afterwards, the students' subject knowledge was tested once again ('Mid-Test II'). In seminar sessions three to five, the students created concept maps (Concept Mapping Process, 'CMP') using the external software *CmapTools*. Since this method is very challenging (Ghani et al., 2017), the students practised the method by creating a training map in session three ('CMP I'). Additionally, students were instructed to clarify essential concepts of MO theory in the form of a glossary ('CMP II'). Building on this glossary, students wepposed to create concept maps on MO theory in session four ('CMP III'), which they presented to fellow students in session five ('CMP IV' and 'CMP V'). The intervention concluded with an assessment of the creation of the glossaries and concept maps in terms of attractiveness and usability ('Mid-Test III'), a final subject knowledge test, and open-ended feedback questions ('Post-Tests').

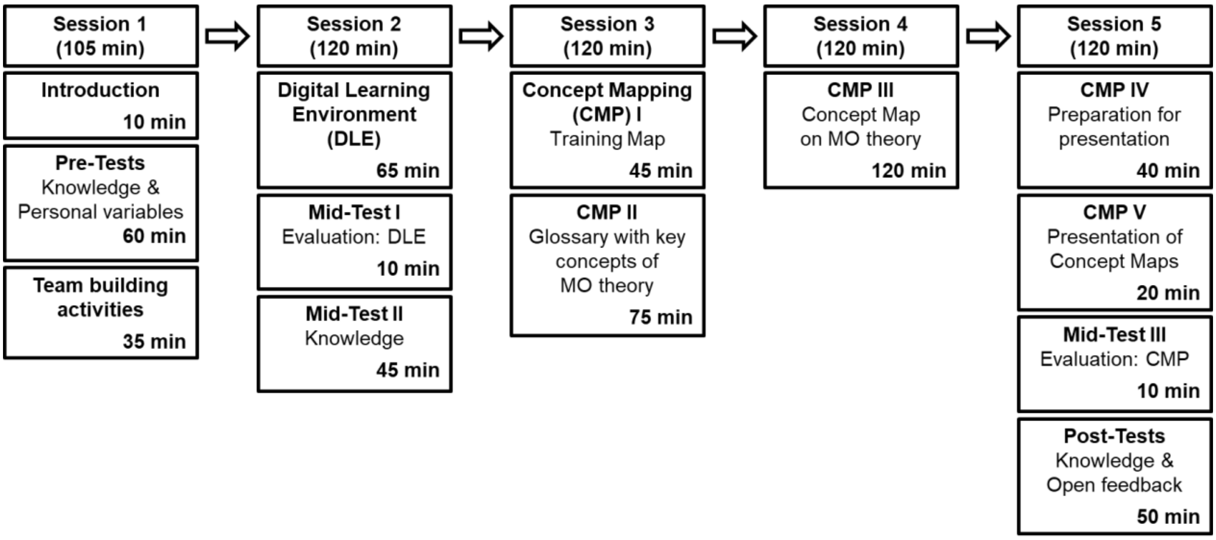

Fig. 1 Structure of the Digital-Collaborative Intervention.

In order to evaluate the intervention, we investigate (a) the students' content knowledge before, throughout and after the intervention; (b) the collaborative processes; (c) the students' evaluation of the learning unit; and (d) the students' (mis-)conceptions regarding quantum chemistry in general and MO theory in particular.

In the following, we present the digital learning environment in detail and give insight into the students' assessment thereof in comparison to the creation of glossaries and concept maps.

THE DIGITAL LEARNING ENVIRONMENT (DLE)

The DLE comprises a total of four videos: (1) General Introduction to the intervention; (2) Fundamental aspects of MO theory; (3) Application of MO theory to homonuclear compounds from boron to neon and to (4) heteronuclear compounds.

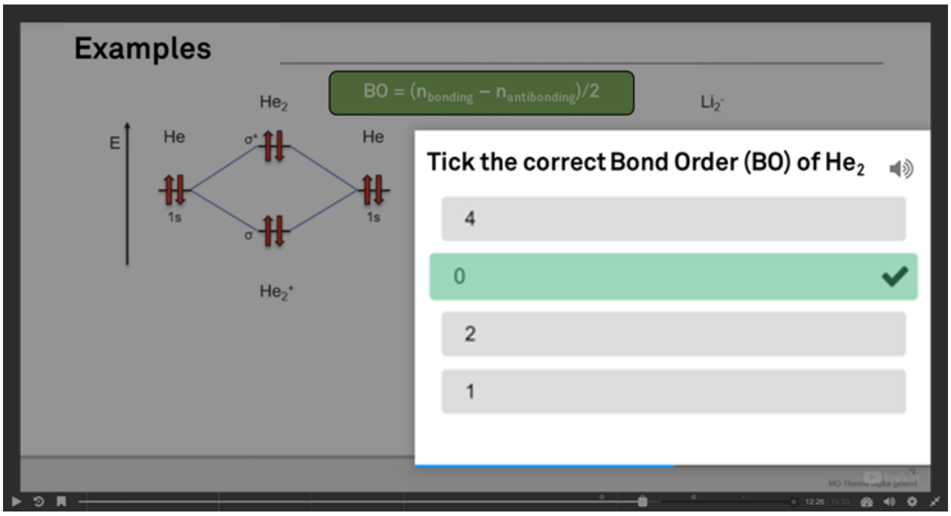

Fig. 2 Example of a mandatory task embedded in the second interactive learning video (H5P). The video is paused until the students answer correctly.

The videos cover, as an introduction, fundamentals of quantum chemistry that are important for molecular bonding in general and for MO theory in particular. This allows the students to repeat the topics in order to participate in the following work phases, similar to pre-lecture assignments in a flipped classroom scenario. Following the principles and guidelines for "Effective Educational Videos" outlined by Brame (2016), the videos were enriched with interactive elements, in our case via H5P, a framework to create HTML5 content and applications (cf. https://h5p.org/interactive-video). Interactive learning videos are already generally considered to be among the most, if not the most, effective media for digital learning (Hattie, 2010). H5P-based approaches in particular have proven to be effective in STEM learning on a secondary (Richtberg & Girwidz, 2019) and university education level (Mutawa et al., 2023). Part of these elements are mandatory single-choice tasks which students have to answer while watching the video (see Figure 2). Only if they answer correctly, the video continues. Otherwise, the students have to rewatch the last segment and try again.

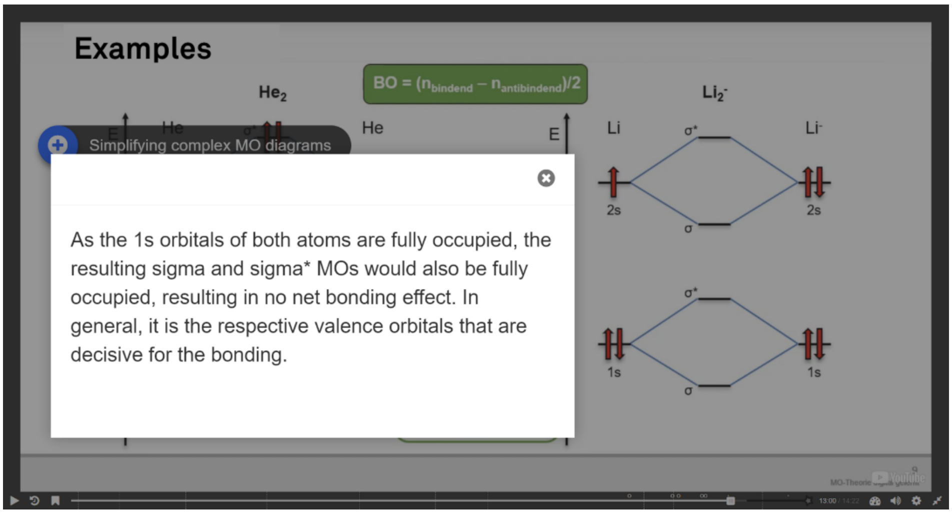

Fig. 3 Example of an optional textbox embedded via H5P, explaining how to simplify MO diagrams. The text box can be opened and closed at any time by clicking the blue button.

The tasks in the DLE serve as activators, but also enable learners to self-monitor their individual learning progress. In recent research, such question-embedded videos have proven to be superior to "passive" videos or simple textbook readings (Pulukuri & Abrams, 2021).

The other part of the interactive elements are text boxes with supplementary information. These boxes help students remember prior knowledge required to understand the video content, e.g. a definition of the Pauli exclusion principle, as well as some tips and tricks, e.g. a rule to simplify MO diagrams. All of these text boxes can be opened and closed by clicking an overlay button (see Figure 3).

Video 1: General Introduction to the intervention

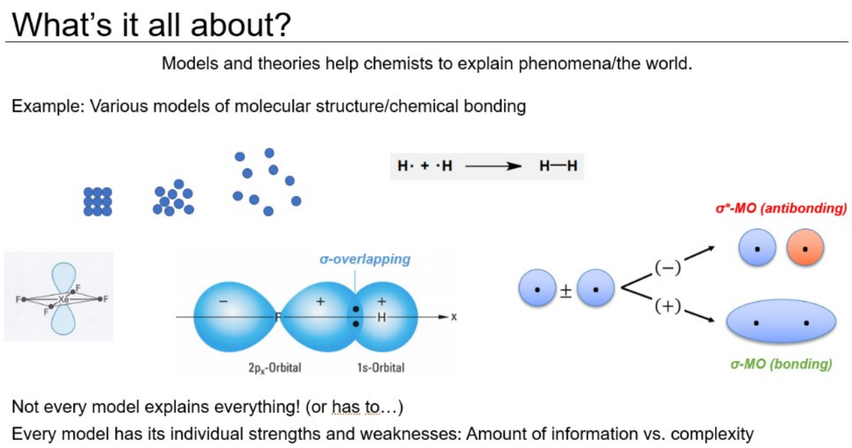

Fig. 4 Screenshot from the first video ('General Introduction'). Images adopted and translated from German (Riedel & Janiak, 2011).

The students watch the first video together in a plenary session. The general introduction explains the importance of MO theory for modern chemistry and why the students need to learn about the theory. Furthermore, special features of the learning environment such as the interactive elements or the option to speed up/slow down the videos are demonstrated to the entire seminar. Questions regarding the organisation of the following individual work phase are also clarified at this point. The students work with all subsequent videos individually.

Video 2: Fundamental aspects of MO theory

In the second video, the basic premises of classical valence bond (VB) theory and MO theory are contrasted (see Figure 5). Limitations of VB theory are demonstrated, e.g. when trying to describe the paramagnetic behaviour of molecular oxygen or the measurement of different bond energies in methane. The Linear Combination of Atomic Orbitals (LCAO) method is described as a means of calculating molecular orbitals from atomic orbitals. MO diagrams for simple diatomic homonuclear hydrogen, helium, lithium and beryllium molecules and ions are used to visualise the LCAO method. Using these diagrams, bond order is introduced as a measure for describing chemical bonds (energy, length, …) and calculated for some examples (see Figure 2).

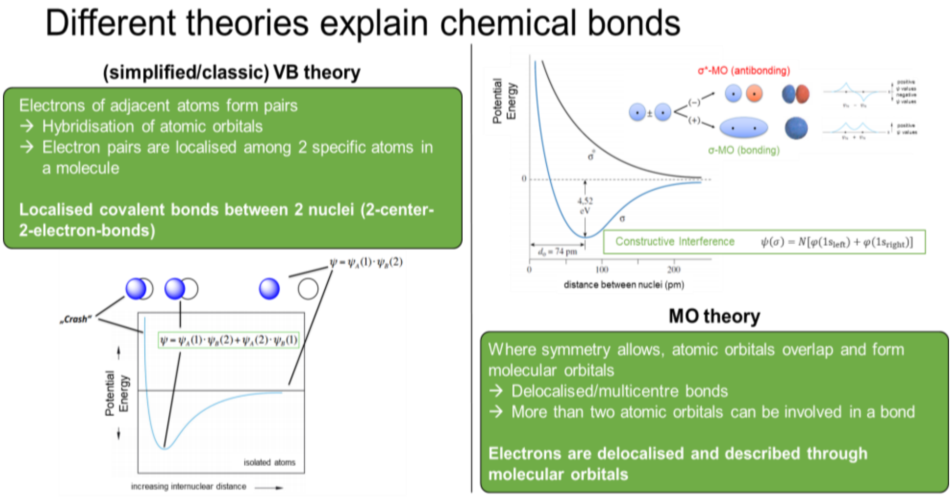

Fig. 5 Screenshot from the second video ('Basics of MO theory'). The basic premises of Valence Bond (VB) and MO theory are contrasted on this slide. Images adopted and translated from German (Riedel & Janiak, 2011).

Video 3: Application of MO theory to homonuclear compounds from boron to neon

The third video builds on the content of video two. Diagrams for other elements of the second period (boron, carbon, nitrogen, oxygen, fluorine and neon) are introduced and extend the simple diagrams for elements where only s-orbitals are occupied (Figure 6). The students learn about possible overlaps between s- and p-orbitals and practice filling in the corresponding MO diagrams. In doing so, they also consider 2s-2p-mixing for the elements lithium to nitrogen.

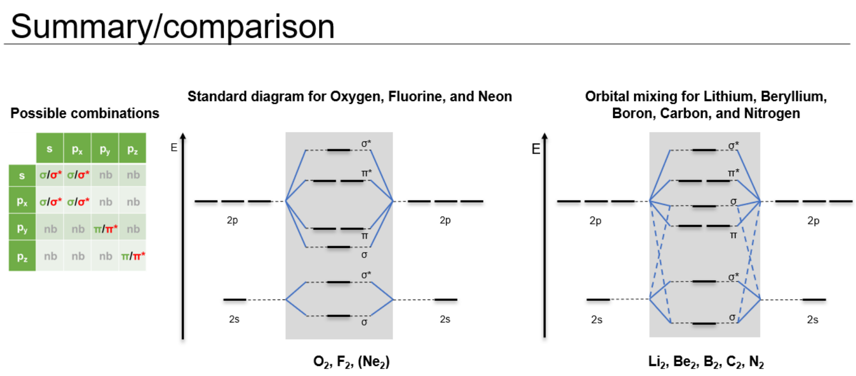

Fig. 6 Screenshot from the third video ('Homonuclear compounds from boron to neon').

Video 4: Application of MO theory to heteronuclear compounds

The fourth video concludes the DLE by explaining bonding in diatomic heteronuclear compounds of elements from the first two periods. Structural differences between the MO diagrams of these heteronuclear compounds and their homonuclear counterparts from the second and third video are explained and attributed to electronegativity differences between the two species (see Figure 7). Furthermore, non-bonding molecular orbitals are introduced to the students using the hydroxide anion as an example.

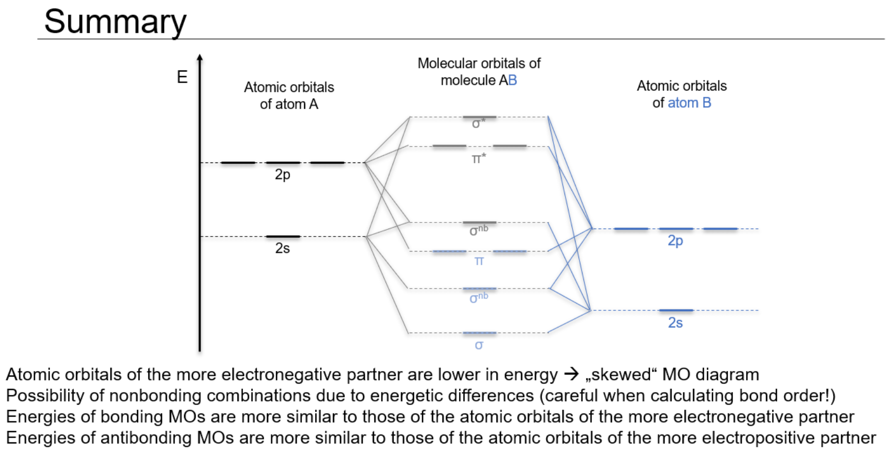

Fig. 7 Screenshot from video 4. The structure of the 'skewed' MO diagram for diatomic heteronuclear compounds is explained by differences in electronegativity between the two species.

RESULTS: STUDENTS' ASSESSMENT OF THE DLE AND CMP

With a view to future implementations of the intervention or a transfer to other locations, we were interested in how well the intervention or the work phases were received by the students. For this reason, the students assessed the intervention in terms of the following variables (see attached Tables 2 to 4 for the detailed questionnaires):

- Cognitive Load (13 items; Likert scale from 1 (low) to 6 (high); translated and adapted from Leppink et al. (2013); α = .872);

- Attractiveness (10 items; Likert scale from 1 (low) to 6 (high); adapted from Greitemann (2022) and Kieserling & Melle (2019), starting from Tepner et al., (2009); α = .872);
- Usability (10 items, Likert scale from 1 (low) to 5 (high), translated and adapted from Brooke (1995); α = .883).

Tab. 1 Students' assessment of the Digital Learning Environment (DLE), the Creation of a Glossary in Moodle (CMP II in Figure 1) and the Creation of a Concept Map in CmapTools (CMP III in Figure 1). Mean values.

PHASE	ATTRACTIVENESS (6-POINT LIKERT SCALE)	USABILITY (5-POINT LIKERT SCALE)
DLE	4.92	4.36
CMP II	4.49	4.18
CMP III	4.54	3.83

As Table 1 shows, both the DLE and the two evaluated sub-phases of the CMP are rated as attractive with high usability. The cognitive load of the DLE is also rated as low by the students (M = 1.83). This suggests that all three phases are well received by the students, which is an important prerequisite for future implementations of the intervention as well as for a possible transfer to other universities.

Nonetheless, a one-factor Welch ANOVA (non-homogeneous variances) indicates small differences in the students' assessment of attractiveness ($p < .001$, $\eta^2_{part.} = .052$) between the phases. A post-hoc analysis (Games-Howell test) confirms that the students evaluate the DLE significantly better than the creation of the glossaries or concept maps.

Furthermore, medium differences ($p < .001$, $\eta^2_{part.} = .100$) can be found regarding usability by a one-factor ANOVA (homogeneous variances). An investigation of post-hoc effects (Tukey-HSD test) shows that the digital learning environment and the creation of glossaries in Moodle are described with significantly higher usability than concept mapping with the *CmapTools* software.

RESULTS: STUDENTS' OPEN-ENDED FEEDBACK

In addition to the closed-ended questionnaires described above, the students were asked to answer four open-ended questions, giving general feedback about what they liked, disliked, and where they encountered technical difficulties within each phase. Their answers were categorised via structuring content analysis (Mayring, 2014). With regards to the DLE phase, more than half of the students answered that they really enjoyed the interactive video elements which kept them engaged, concentrated and motivated. About one fifth highlighted that they could understand the explanations in the videos well and gained a more profound understanding of the topic. The possibility to watch the videos at their own pace was also appreciated by the students. Additionally, more than half of the students wrote that here was either nothing they disliked or left that question unanswered. The only negative aspect that several students mentioned was a lack of time when working with the DLE. On the technical side, only 10 students reported minor issues such as slow connection speed or long loading times between videos. In the general feedback, several students asked for similar environments for other topics such as acid-base chemistry or stoichiometry.

Regarding the CMP phases, the students' feedback was overall positive, but more heterogeneous than for the DLE: Students enjoyed working in small groups, finding connections between different contents, and told us that the creation of glossaries and concept maps helped them gain a better understanding of MO theory and discover content areas in which they still lacked knowledge. On the negative side, there were about ten students who were not convinced by the method or even framed the creation of concept maps as "useless" – especially given the amount of time required to do so. One tenth of students particularly disliked the *CmapTools* software, which they found to be too complicated and confusing. Beyond that, no major technical difficulties were reported by more than one or two students.

DISCUSSION

The findings from our investigation align with other recent studies: Working with learning videos is not only potentially very learning effective, but also very popular among learners and educators (Kohler & Dietrich, 2021). According to the recent Top 100 Tools for Learning survey (Hart, 2022), YouTube has been the most popular learning tool for personal learning, workplace learning or education for the seventh year in a row. In the open-ended questions, students also clearly highlighted which video element they found to be most attractive for them: The questions which kept them engaged throughout the process. Thus, it is not surprising that other studies at university level follow similar approaches, e. g. when teaching about organic reaction mechanisms (Eckhard et al., 2022), in general chemistry (Ranga, 2017), or in flipped-classroom scenarios (Pulukuri & Abrams, 2021).

On the other hand, creating concept maps is quite difficult, especially for unexperienced learners (Ghani et al., 2017). This is also reflected in the lower usability scores the students gave to the unfamiliar *CmapTools* software: Despite the training we provided (see phase 'CMP I' in Figure 1), students still had difficulties using the software. In the other two phases, students worked in Moodle, which had been used university-wide throughout the entire semester and they were therefore more familiar with it. Concept mapping in general is an established method for teaching (Chabeli, 2010; Machado & Carvalho, 2020; Novak & Cañas, 2006; Stoyanova & Kommers, 2002). Even though some were unconvinced, most of the students who participated in our study accepted this method as a useful and effective tool. Nevertheless, further support measures need to be implemented to guide them through this process and to help them reflect upon it (Benay et al., 2009).

CONCLUSION AND OUTLOOK

In this study, we developed, implemented, and evaluated a digital-collaborative intervention on MO theory for first-semester chemistry students. The participants first worked with a digital learning environment in the form of interactive learning videos and then created concept maps on key concepts in MO theory. In this article, we described the structure and content of the interactive videos in detail.

Through questionnaires of cognitive load, attractiveness, and usability, we investigated how N = 115 first-year chemistry students assessed the learning materials. All phases were assessed as attractive with high usability. Working with interactive videos was particularly popular with the students. The creation of concept maps was rated slightly lower in terms of usability, due to the unknown software *CmapTools* and the difficult and unfamiliar method. In summary, these results encourage us to continue to integrate this intervention into lecture practice when students physically return to university and to transfer it to other universities as well. For that reason, we adapted the seminar for the following cycle of freshmen chemistry students at our university in the winter semester 2022/2023: Initially, the students again worked independently with the interactive learning videos, as in the previous iteration. However, they were asked to do so at home in preparation for the following session. This gave them the opportunity to do so at their own pace and with as much time as they needed. To create the glossaries and concept maps, they met in person with fellow students at the university instead of digitally via *Zoom*. The glossaries were again filled out in *Moodle.* The concept maps however were not drawn with the *CmapTools* software, but with pen and paper.

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Attachments

Tab. 2 Cognitive Load Scale for the DLE phase, 6-point Likert scale from 1 (totally disagree) to 6 (totally agree), adapted from Leppink et al. (2013). Participants filled out a version that was translated into German.

ITEM NO.	
1	I found the topic too complicated in the last phase of work.
2	I found the explanations too complicated in the last phase of work.
3	I found the concepts too complicated in the last phase of work.
4	The instructions for using the Moodleroom during the last phase of work were confusing.
5	The instructions for using the Moodleroom were useless for learning.
6	The instructions for using the Moodleroom were full of unclear language.
7	The explanations during the last phase of work were confusing.
8	The explanations were useless for learning.
9	The explanations were full of unclear language.
10	The last phase of work improved my understanding of the topics covered.
11	The last phase of work expanded my understanding of chemical bonds.
12	The last phase of work improved my understanding of the concepts covered.
13	The last phase of work has improved my understanding of chemical relationship.

Tab. 3 Attractiveness Scale for the DLE phase and CMP phases, 6-point Likert scale from 1 (totally disagree) to 6 (totally agree), original German scale developed by Greitemann (2022) and Kieserling & Melle (2019), starting from Tepner et al. (2009). Participants filled out the German version.

ITEM NO.	
1	I liked the last phase of work.
2	In the last phase of work, I understood most of it.
3	I am glad that the last phase of work is now over.
4	Other topics should be taught just as in the last phase.
5	In the last phase of work, I was inattentive.
6	In the last phase of work, I did not learn enough.
7	I found the last phase of work interesting.
8	I would like to work more often like I did during the last work phase.
9	The last phase of work was too difficult for me.
10	The last phase of work was fun for me.

Tab. 4 Usability Scale for the DLE phase (reworded accordingly for the CMP phases), 5-point Likert scale from 1 (totally disagree) to 5 (totally agree), adapted from Brooke (1995). Participants filled out a version that was translated into German.

ITEM NO.	
1	I think that I would like to work with such a learning environment frequently.
2	I found the learning environment unnecessarily complex.
3	I thought the learning environment was easy to use.
4	I think that I would need the support of a technical person to be able to use this learning environment.
5	I found the various functions in this learning environment were well integrated.
6	I found it hard to understand the learning environment.
7	I was able to learn to use the learning environment quickly.
8	I found the learning environment very cumbersome to use.
9	I felt very confident using the learning environment.
10	I had to get used to the learning environment before I could be able to work well with it.

Fieldwork in teaching biology

Justyna Mikołajczyk & Małgorzata Nodzyńska-Moroń

Abstract

Fieldwork in teaching natural subjects, including biology, is an important element in shaping the skills and attitudes of young people. Therefore, in Poland, in the core curriculum for teaching biology, there is an obligation for biology teachers to conduct "fieldwork education". On the other hand, numerous limitations, including time, organizational and legal difficulties make it difficult for teachers to fulfill this obligation.

The article presents the results of research of biology teachers regarding their opinions on fieldwork. It was analyzed how respondents assessed the expected effectiveness of fieldwork, defined their ability and willingness to conduct such activities, and determined what external factors influenced their motivation to conduct such activities.

Key words

Education system; Biology education; Biology teaching; Biology fieldwork

INTRODUCTION

One of the most important elements of biological education is certainly its context related to the surrounding nature. Therefore, teachers should implement as much of the content contained in the Core Curriculum as possible outside the classroom, as part of external classes, combining theoretical information with their practical context. Such activities not only show the sense and practical application of the knowledge acquired at school but also constitute an activating and motivating element for students. Such classes also allow the development of the soft skills of students.

Defining the term "fieldwork education", we can say that it is an organized process of learning by students through observation, experience and experimentation during outdoor activities. In the case of such educational activities, nature is a means, a background, but also a pretext for learning. But the term "fieldwork education" is also understood in a broader sense. Then it includes both actual outdoor activities, e.g. field trips, visiting zoos and botanical or educational gardens, physical activities (e.g. swimming, climbing, skiing) and education outside the school walls (e.g. visiting museums, monuments, science). According to Hofman (2011), it is "a comprehensive form of teaching, involving various teaching methods, including, for example, observation, experiment, project method, collaborative methods and experiential pedagogy methods." (pp. 310-311). Therefore, such education should be often used by biology teachers.

Scientific research shows that outdoor education can contribute to many positive changes in students. Such education has been found to improve student achievement, including improved test scores, effective engagement of children's intelligence, and increased learning effectiveness (American Institutes of Research, 2005; Blair, 2009; Dyment, 2005; Lieberman & Hoody, 1998). However, fieldwork education has an impact not only on students' immediate better understanding of biological or geographic content but also has a positive impact on the development of critical thinking skills - understood as a process of conscious self-regulating assessment and decision making, i.e. problem-solving skills including the ability to interpret, analyzing, evaluating, reasoning, explaining and self-regulation (Ernest & Monroe, 2004). Research shows that "fieldwork education" supports not only the intellectual development of students but also emotional and behavioral ones. Students learning in this way develop self-esteem, independence, and self-confidence, as well as creativity, decision-making and problem-solving skills, empathy for others, motor skills, self-discipline and initiative (Chawla, 2006; Kellert, 2005; Lester & Maudsley, 2006). According to research, fieldwork education also improves students' physical, mental and social health and reduces stress levels for both students and teachers (Bell & Dyment, 2006; BTCV, 2009; Dyment & Bell, 2008; Kuo & Faber Taylor, 2004; Muñoz, 2009; Wells & Evans, 2003). It results in better student attitudes towards school, better school behavior and better attendance (American Research Institutes, 2005; Blair, 2009; Dyment, 2005; Lieberman & Hoody, 1998). Fieldwork education helps students better understand their natural and human communities, leading to a sense of place, and developing stronger environmental attitudes and civic behavior (Chawla, 2006; Wells, & Lekies, 2006). "Fieldwork education" can also take place during a pandemic or non-formal education Nodzyńska, & Bilek, 2021; Nodzyńska & Cieśla, 2016). Research by Blair (2009) and Dyment (2005) showed that students prefer this type of learning to traditional learning.

It seems that in view of so many advantages, "fieldwork education" should be used very often by teachers. This is also due to the reforms of education in Poland and the recommendations related to them, which encourage teachers to take action towards practical classes, including outdoor activities. For example, in the Core Curriculum for teaching biology, we can read: "in order to … understand the essence of the science of life, practical knowledge is also indispensable. …requires the student to acquire a range of skills …observation in a school and in the field." As part of the biology subject, there should be field activities (enabling the implementation of content in the field of ecology and the diversity of organisms), and trips to the botanical garden, zoo, forest, meadow or field. During these classes, students should observe and recognize plants, animals, and fungi typical of a given region and phenomena occurring in a specific ecosystem. Students should be shown examples of the process of ecological succession visible in the field, understood as a sequence of biocoenoses, which results in the exchange (sequence) of plant, animal, fungus or other organism species. This process is one of the most important for the subsequent understanding of the nature of species diversity conservation. The work of students in the field should be guided by the teacher."

However, the organization of activities outside the school premises requires the teacher and the school principal to meet many regulations - several dozen ordinances in several different legal acts (Lewandowski, 2018). The teacher, the tour leader, is responsible for, among others duties: developing the program and regulations of the trip, familiarizing students, parents and guardians with the program and regulations of the trip and informing them about the purpose and route of the trip, providing conditions for the full implementation of the trip program and compliance with its regulations and supervises in this respect, acquainting students and trip supervisors with the safety rules and ensuring conditions for their compliance, defining the tasks of trip supervisors in the implementation of the trip program and ensuring the care and safety of students, supervising the supply of students and trip supervisors with appropriate equipment and a first aid kit, organization and supervision of transport, meals and accommodation for students and trip supervisors, division of tasks among students, management of funds allocated for the organization of the trip, summary, assessment and financial settlement in tour after its completion (Lewandowski, 2018). As we can see, the list of teacher duties is long. As a result, teachers in many cases justify the small number of such classes with the lack of time to implement the content contained in the core curriculum and with formal obstacles.

As can be seen from the literature analysis, "fieldwork education" should be an indispensable element of biological education. But what is the real attitude of teachers towards "fieldwork education"?

RESEARCH MODEL AND METHODOLOGY

It was decided to examine teachers' attitudes regarding "fieldwork education". However, due to the fact that there is no person who would question the need and usefulness of field education in science education (compare the literature review above), the search for "non-obvious questions" was started, which would focus more on the emotions and attitudes of teachers and their environment than on field education. Therefore, it was decided to use questions from the Unified Theory of Acceptance and Use of Technology (UTAUT), proposed by Venkatesh et al. (2000). Although we do not refer to new technologies in our research, we thought it would be interesting to use the questions from this questionnaire. Answering questions directly about teachers' attitudes towards "fieldwork education" and the impact of their environment on teachers' behavior related to "fieldwork education" would be trivial and too obvious. In the UTAUT model, five main factors influence human behavior, which have been identified as:

- Expected performance
- Expected effort

• Social impact

• Facilitating conditions

• Behavioral intentions

A research tool was designed in the form of a questionnaire (Table 1) with a 5-point scale using the Likert scale model. The scale labels were as follows:

1. Disagree
2. Partially disagree
3. Neither Agree nor Disagree
4. Partially agree
5. Agree

Tab. 1 The Questionnaire Items based on Unified Theory of Acceptance and Use of Technology UTAUT.

CONSTRUCT	ITEM
PERFORMANCE EXPECTANCY	Fieldwork in teaching biology is useful. Conducting field activities increases the knowledge and skills of students. Field classes in biology increase students' awareness of biodiversity of organisms and human impact on the environment.
EFFORT EXPECTANCY	Preparing a field biology class is simple. Carrying out pre-prepared field activities in biology is simple. Preparing fieldwork in biology takes more time compared to activities carried out in the classroom. Conducting pre-prepared field activities in biology takes more time compared to activities conducted in the classroom.
SOCIAL FACTORS	My superiors think I should conduct field biology classes. My coworkers think I should conduct field biology classes. My students' parents think I should conduct field biology classes. My students think I should conduct field biology classes.
FACILITATING CONDITIONS	I have the appropriate equipment to conduct field classes in biology. I have the support of my superiors in conducting field classes in biology. I have the appropriate knowledge to conduct field classes in biology. I have the opportunity to get help from other teachers in conducting field activities.
BEHAVIOURAL INTENTION	I intend to conduct biology fieldwork in the next school year. I predict that in the next school year I will conduct field classes in biology. I have a plan to conduct field classes in biology in the next school year.

RESULTS

23 biology teachers participated in the study. The vast majority taught biology at primary school – ISCED 1-2 (19) and 4 at secondary school ISCED 3. 11 of them worked full-time and the rest worked part-time.

Answering the questions from the first group concerning Performance Expectancy, the vast majority of teachers stated that: Fieldwork in teaching biology is useful, conducting fieldwork in teaching biology increases students' knowledge and skills, Fieldwork in biology increases students' awareness of the biodiversity of organisms and the impact of humans on the environment (Tab. 2).

Tab. 2 Questionnaire results for Performance Expectancy.

	DISAGREE	PARTIALLY DISAGREE	NEITHER AGREE NOR DISAGREE	PARTIALLY AGREE	AGREE
FIELDWORK IN TEACHING BIOLOGY IS USEFUL.	3	2	0	1	17
CONDUCTING FIELD ACTIVITIES INCREASES THE KNOWLEDGE AND SKILLS OF STUDENTS.	3	2	0	0	18
FIELD CLASSES IN BIOLOGY INCREASE STUDENTS' AWARENESS OF BIODIVERSITY OF ORGANISMS AND HUMAN IMPACT ON THE ENVIRONMENT.	3	2	0	1	17

Only a few people (5) had a different opinion on this subject. It can therefore be concluded that there is unanimity among both researchers and teachers.

However, when teachers were asked about effort expectancy, their answers began to differ significantly (Tab. 3).

Tab. 3 Questionnaire results for Effort Expectancy.

	DISAGREE	PARTIALLY DISAGREE	NEITHER AGREE NOR DISAGREE	PARTIALLY AGREE	AGREE
PREPARING A FIELD BIOLOGY CLASS IS SIMPLE.	4	8	3	6	2
CARRYING OUT PRE-PREPARED FIELD ACTIVITIES IN BIOLOGY IS SIMPLE.	0	6	2	8	7
PREPARING FIELDWORK IN BIOLOGY TAKES MORE TIME COMPARED TO ACTIVITIES CARRIED OUT IN THE CLASSROOM.	0	2	3	8	10
CONDUCTING PRE-PREPARED FIELD ACTIVITIES IN BIOLOGY TAKES MORE TIME COMPARED TO	1	3	1	4	14

ACTIVITIES CONDUCTED IN THE CLASSROOM.	

As many as 12 teachers (out of 23) disagree with the thesis that preparing for external classes is easy. ¼ of teachers believe that even conducting such classes (already prepared in advance) is difficult. 18 teachers agree that both the preparation of these types of classes and their implementation take more time than a typical, traditional lesson. In general, it can be said that teachers consider the preparation and delivery of such lessons to be more time-consuming than traditional lessons.

The third group of questions concerned social factors. We can see a clear difference in the teachers' answers when asked about the expectations of individual groups (Tab. 4).

Tab. 4 Questionnaire results for Social Factors.

	DISAGREE	PARTIALLY DISAGREE	NEITHER AGREE NOR DISAGREE	PARTIALLY AGREE	AGREE
MY SUPERIORS THINK I SHOULD CONDUCT FIELD BIOLOGY CLASSES.	0	5	9	4	5
MY COWORKERS THINK I SHOULD CONDUCT FIELD BIOLOGY CLASSES.	1	4	7	6	5
MY STUDENTS' PARENTS THINK I SHOULD CONDUCT FIELD BIOLOGY CLASSES.	0	2	7	8	6
MY STUDENTS THINK I SHOULD CONDUCT FIELD BIOLOGY CLASSES.	0	0	3	8	12

Teachers are sure (20 people) that their students expect such a form of education. They partly believe that this form of education can also be expected by parents (14 people). It is puzzling that teachers often choose the answer "Neither Agree nor Disagree" - this means that they do not know whether the headmaster, their fellow teachers or parents expect this form of education from them - this may indicate poor communication between individual groups. Particularly puzzling is the fact that teachers believe that the management does not expect such activity from them, even though it is explicitly mentioned in the Polish Core Curriculum and the management's task is to oversee the implementation of the Core Curriculum.

Tab. 5 Questionnaire results for Facilitating Conditions.

	DISAGREE	PARTIALLY DISAGREE	NEITHER AGREE NOR DISAGREE	PARTIALLY AGREE	AGREE
I HAVE THE APPROPRIATE EQUIPMENT TO CONDUCT FIELD CLASSES IN BIOLOGY.	2	6	0	9	6

I HAVE THE SUPPORT OF MY SUPERIORS IN CONDUCTING FIELD CLASSES IN BIOLOGY.	2	3	5	7	6
I HAVE THE APPROPRIATE KNOWLEDGE TO CONDUCT FIELD CLASSES IN BIOLOGY.	0	0	1	8	14
I HAVE THE OPPORTUNITY TO GET HELP FROM OTHER TEACHERS IN CONDUCTING FIELD ACTIVITIES.	1	3	3	10	6

The fourth group of questions concerned Facilitating Conditions (Table 5). Almost all surveyed teachers (22) claim that they have sufficient knowledge of conducting this type of class. 16 teachers declare the help of their colleagues and 13 the headmaster. 8 teachers believe that their laboratories are not equipped in such a way as to be able to conduct this type of class.

The last group of questions concerned teachers' plans for the future (Tab. 6).

Tab. 6 Questionnaire results for Behavioural Intentions. (The questions in the table have been ranked from vague suppositions to hard assertions.)

	DISAGREE	PARTIALLY DISAGREE	NEITHER AGREE NOR DISAGREE	PARTIALLY AGREE	AGREE
I PREDICT THAT IN THE NEXT SCHOOL YEAR I WILL CONDUCT FIELD CLASSES IN BIOLOGY.	3	0	6	5	9
I INTEND TO CONDUCT BIOLOGY FIELDWORK IN THE NEXT SCHOOL YEAR.	1	0	0	3	19
I HAVE A PLAN TO CONDUCT FIELD CLASSES IN BIOLOGY IN THE NEXT SCHOOL YEAR.	1	0	0	3	19

As we can see, most teachers are determined to conduct such classes.

DISCUSION

Research has shown that the vast majority of the surveyed teachers believe that fieldwork in teaching biology is useful, increases the knowledge and skills of students and increases students' awareness of the biodiversity of organisms and human impact on the environment. It can therefore be concluded that there is unanimity here both among teachers and the previously quoted researchers (Blair, 2009; Dyment, 2005; Ernest & Monroe, 2004; Lieberman & Hoody, 1998). However, teachers consider the preparation of this type of activity to be very time-consuming. Perhaps this is related to the formal and legal requirements related to the organization of this type of outdoor classes in force in Poland, which apply to teachers (Lewandowski, 2018). It is puzzling, however, why teachers consider the very conduct of this type of classes to be more time-consuming. As a "typical" lesson, they will probably consider a classic lesson - a lecture. However, in the teaching of biology, such lessons should be in the minority. In biology lessons, students should be allowed to experiment. Experimentation during "fieldwork education" takes no more time than experimentation during classroom lessons. It turned out that teachers are aware that students expect such lessons from them, which is consistent with the research of Blair (2009) and Dyment (2005). However, it is strange that teachers do not know whether the principal, their fellow teachers and parents expect such a form of education from them. This shows poor communication between these people. Particularly astonishing is the fact that teachers feel that the principal does not expect such activity from them. This is against the law in force in Poland. In the Core Curriculum (an obligatory document specifying the framework and content of individual school subjects and the forms of their implementation), trips are explicitly mentioned as obligatory. And the statutory task of the management is to oversee the implementation of the Core Curriculum. It seems, therefore, that Polish principals and teachers do not know the applicable law.

It seems that the belief of teachers about their competence in conducting this type of classes is overestimated (preparing this type of classes takes them a lot of time, and they do not know the educational law).

CONCLUSION

This study provides information on teachers' motivation to conduct "fieldwork education". It shows which factors influence their motivation and which do not. Teachers were found to agree that this type of activity is essential in teaching biology. They also believe that they have the necessary knowledge and skills to do so. However, they believe that both the preparation and conduct of such classes is very difficult and time-consuming. Which contradicts the statement that teachers are well prepared to conduct this type of classes. It seems, therefore, that more practical training in conducting this type of classes should be conducted at teacher training colleges and further training courses. The expectations of students, but not of parents or headmasters, have little influence on the planning of this type of activities by teachers. One may wonder whether the Polish school has a real family atmosphere and the well-being of all stakeholders is taken into account. In addition, teachers do not realize that the school management should require them to conduct this type of classes. It seems that teachers have little knowledge of education law, perhaps more time should be devoted to it during teacher studies and/or further training. Despite this, most teachers declare that they will conduct "fieldwork education" in the near future. To sum up, it seems that the theoretical knowledge of teachers concerning the positives of organizing this type of education clashes with the practical ability to carry out this type of classes.

We are aware of the small research group of teachers, but this research is an introduction to further research. In future research, we plan individual interviews with teachers to, among other things, check their declared skills in conducting this type of classes to find out why they do not know what their students' parents and principals expect.

To sum up, it can be said that the majority of respondents emphasized the need to organize "fieldwork education" in biology, while at the same time lacking time for them. Such results may indicate the need to change the organization of lessons in traditional schools in Poland.

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Using Digital Inquiry-based Multidisciplinary Approach to Gain Knowledge of Temperature

Adéla Hartlová, Martin Slavík, Pavlína Hejsková & Pavlína Hartmanová

Abstract

On the topic of temperature, we present the possibility of using multidisciplinary content through a modified inquiry-based approach that focuses on working with Internet resources. In 2022, pupils from the Liberec region aged 13-15 from primary schools (n = 92) and lower grades of grammar schools (n = 35) filled in a three-part Google form consisting of a socio-demographic part. A part testing the pupils' cross-curricular knowledge of temperature and a part of tasks served as a key to deciding the truth of 12 hypotheses. The questionnaire survey results, processed in the statistical program Jamovi, show weak results for knowledge and quite satisfying results for inquiring.

Keywords

Digital literacy; Critical thinking; Inquiry-based Approach; Cross-curricular relationships

INTRODUCTION

This research is based on the model of trans-didactics (Slavík et al., 2017), the combination of multidisciplinary didactics in one inquiry. We intended to overcome the professional isolation of individual disciplinary didactics and explore a multidisciplinary approach to learning through trans-didactic research on teaching. We chose the integrative theme of temperature as a common ground. In the course called Relations among natural sciences, taught to second-years of the follow-up Master's degree, students prepared a series of assignments with elements of an inquiry approach. Subsequently, the authors of this article tested these tasks on pupils from primary and lower grades of grammar schools using Google Forms.

The aim was:

- to study the possibility of using a digital inquiry-based multidisciplinary approach to gain knowledge of temperature.

THEORETICAL BACKGROUND

Multidisciplinary science teaching is not common in Czech schools. However, several voluntary science seminars are beginning to appear, emphasizing cross-curricular relationships and science teaching. Here we describe the possibilities of the inquiry approach and emphasize the importance of cross-curricular relations.

Cross-curricular relationships and science literacy

Reforms in science education worldwide often call for teaching science by emphasizing scientific literacy. Finding a popular approach to science that engages students means focusing more on the world outside the classroom and less on the traditionally offered disciplinary curricula. (Pelger & Nilsson, 2016). Therefore, current education systems are focused on linking individual subjects' curricula to create a coherent educational foundation that can be developed throughout life. The curriculum integration can be implemented through cross-curricular themes, as envisaged in the curriculum framework. This makes it possible to link individual subjects, create subjects out of several subjects, or, conversely, create several subjects out of one subject (Janoušková et al., 2019). Applying one subject across two (or more) subjects enables students to create meaningful connections between subjects that better reflect the real world. Making connections between seemingly separate curriculum subjects can enhance student learning and impact on cognitive and metacognitive understanding. Although it can also be called curriculum integration, this approach is called cross-curricular teaching and learning (Byrne & Brodie, 2013).

Gaining digital literacy through an Inquiry-based approach

Because of the possibility of gradually increasing complexity of tasks and the emphasis on growing independence, it is appropriate to use the Inquiry-Based Science Education (IBSE) approach, which provides an opportunity to involve pupils more actively (Firman et al., 2019) in the learning process. In addition, implementing IBSE is also a good opportunity for collaboration between different disciplinary didactics (Völklová et al., 2018). The IBSE and inquiry-based approach is often broadly defined as teaching in which pupils are offered the opportunity to use procedures and working methods analogous to those used by professional scientists in their research work (Dorier & Maass, 2014). However, the whole inquiry cycle, consisting of sub-parts, is very demanding and lengthy and can be demotivating for many teachers, especially in the absence of relevant online repositories or methodological publications freely available to teachers (Hartlová, 2022). Inadequate or incorrect guidance of pupils can lead to misconceptions and the acquisition of misconceptions about reality. (Völklová et al., 2018). If the educator is not experienced, if the conditions, materials, and will are not there, compromises have to be sought, which can be either abbreviated research activities, various mysteries (e.g. (TEMI, 2016)) or problem-based tasks. Such activation methods also develop pupils' thinking, perception, imagination, cooperation, and social relations among pupils and shape their career orientation (Hlaváčová, 2017). Pupils' motivation also plays an irreplaceable role here.

Nowadays, as a pedagogical approach for the 21st century, it is required to learn science through inquiry methods, incorporating ICT (Yasin et al., 2021). Inquiry-based teaching also leads to the development of scientific literacy (Samková et al., 2021) and is based on digital literacy ((Puji Lestari et al., 2019). The method of verifying digital literacy is mainly about collecting and analyzing evidence of experienced, learned, explored, or discovered phenomena, as described, for example, in Digital literacy at the nodal points of educational methodology (Růžičková, 2020). In this research, the inquiry method based on digital literacy helps the student collect and analyze the data.

METHODOLOGY

Data acquisition

The data were obtained from a questionnaire survey in which 127 pupils from the Liberec region participated. Of these, 92 pupils (48 girls and 44 boys) aged 13-15 from three primary schools and 35 (14 girls and 21 boys) aged 15 from grammar schools.

A pilot validation preceded this questionnaire survey at a faculty primary school in Liberec. In this research, we participated ten pupils from the ninth class (4 boys and 6 girls). During this pilot validation, we found out that the questionnaire was too long, and one of the proposed tasks, which was supposed to connect knowledge with practical life, was completely abandoned. Question 5 in the second part was split into questions 5A and 5B due to a possible misunderstanding of the picture. However, we wanted to keep it as it was a motivational element in the questionnaire.

Research tool and its evaluation

The questionnaire (designed and circulated in the Czech language) consisted of three parts and was implemented in Google Forms.

The first part collected socio-demographic information about the respondents. The second part of the questionnaire was converted into a Google Forms test to make it easier to evaluate the items. The aim was to replicate the inquiry cycle in that here pupils were asked questions that would generally emerge as an actual class consensus for hypothesis generation during class. Pupils were asked to select one or more statements or correct answers to the questions. This part of the questionnaire served as an insight into the pupils' initial knowledge and also as a knowledge test in the subsequent assessment. The questions for this section were selected from the content of the five science domains (biology, chemistry, physics, geography, and mathematics). The questions were: 1. In severe frost, is a bird more likely to freeze if it is flying or sitting still? 2. Choose all the reactions that give off heat. 3. Mark all true statements about the properties of substances when the temperature changes. 4. Is there a difference between heat and temperature? 5. (5A only pictures, 5B text) Each column contains measured temperatures on a temperature scale. What is the correct order of the temperature scales in each column of the table? 6. Does the surface on which the thermometer is placed affect the temperature measured? 7. If you boil water for tea in a pot on Annapurna, at what temperature will the water boil? 8. Choose the correct statement about latitude and altitude.

The third part of the questionnaire consisted of three inquiry tasks. The first was related to animals' body temperature, and the second to the state of matter under different physical conditions on Earth, Mercury, and Venus. The third task was to find average temperatures in different parts of the Czech Republic. The exploratory thinking was supported by additional questions to which the pupils searched for answers on the Internet. At the end of each task, pupils were presented with four hypotheses they would normally have formed with the teacher, but due to the proposed reduction in the inquiry approach, these were presented to them here. Pupils were then asked to decide on the truth of these hypotheses based on their previous research and the information on the Internet. The hypotheses were: H1. In general, larger animals find it more profitable to produce heat. H2. In general, larger animals find extracting heat from the environment more profitable. H3. In general, smaller animals find it more profitable to produce heat. H4. In general, smaller animals find extracting heat from the environment more advantageous. H5. Water always boils at a higher temperature than nitrogen at the same ambient pressure. H6. Lead can exist in forms other than solid. H7: Nitrogen is always a gas. H8: Above a certain temperature, any substance can be a liquid. H9. The average temperature in Brno in September is higher than in Pec pod Sněžkou. H10. The temperatures in both towns are comparable every month. H11. There are more hours of sunshine in July in Brno than in Pec pod Sněžkou. H12. Both places are warmer in August than in July.

Statistical methods

The data obtained from the questionnaire survey was transferred to Google spreadsheets and then into MS Excel, where it was checked. This edited file was transferred to Jamovi and subjected to subsequent statistical analysis.

RESULTS

The results obtained are assessed from two aspects: whether they are statistically and substantively significant. The results are considered statistically significant at the confidence level of $p < 0.001$. For substantive significance, we mainly assess the value of the correlation coefficient $R \geq 0.3$. Values in the interval <0.1; 0.3> are also considered but are not assessed as substantively significant.

Test of knowledge

Pupils showed minimal knowledge of the questions we asked, as seen in Figure 2, where columns show correct answers from primary and lower grades of grammar schools. The first column always shows the percentage of correct answers for each of the nine questions at primary school, and the second column at grammar school. According to descriptive analysis shown in Figure 1., the average test score for primary schools was 2.48 out of a possible nine (question five was given two points instead of one because it has two parts). For the lower grades of grammar schools, it was 3.03, but according to the Independent Samples T-test, this difference is not statistically significant.

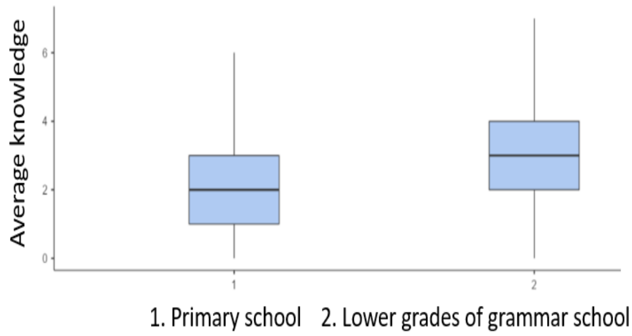

Fig.1 Average test results for primary schools on the left and lower grades of grammar school on the right.

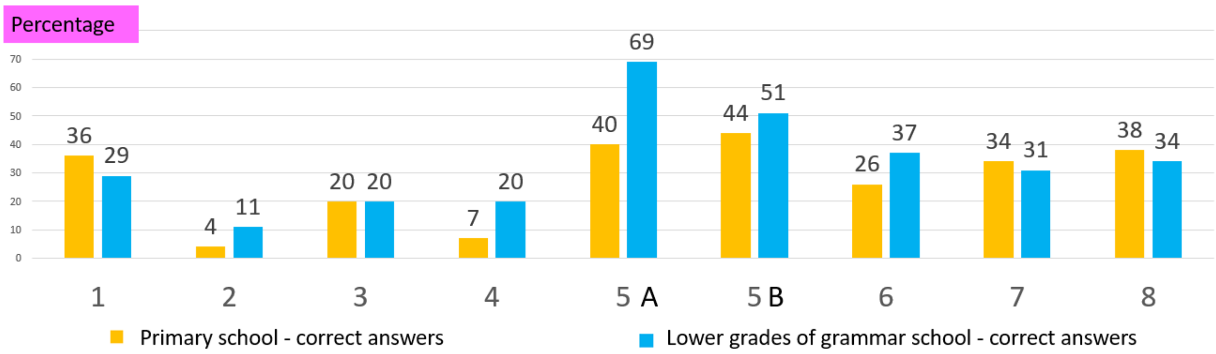

Fig.2 Percentage of correct answers to questions in the knowledge part. They are sorted by type of school.

Internet search results (digital literacy check)

Figure 3 shows the percentage of successful Internet searches by the pupils. On the left are the results from the first inquiry task; on the right, are the results from the second inquiry task. The third inquiry task is not included because most pupils could not solve it. It was due to a lack of time. We can see that these are somewhat above-mean results.

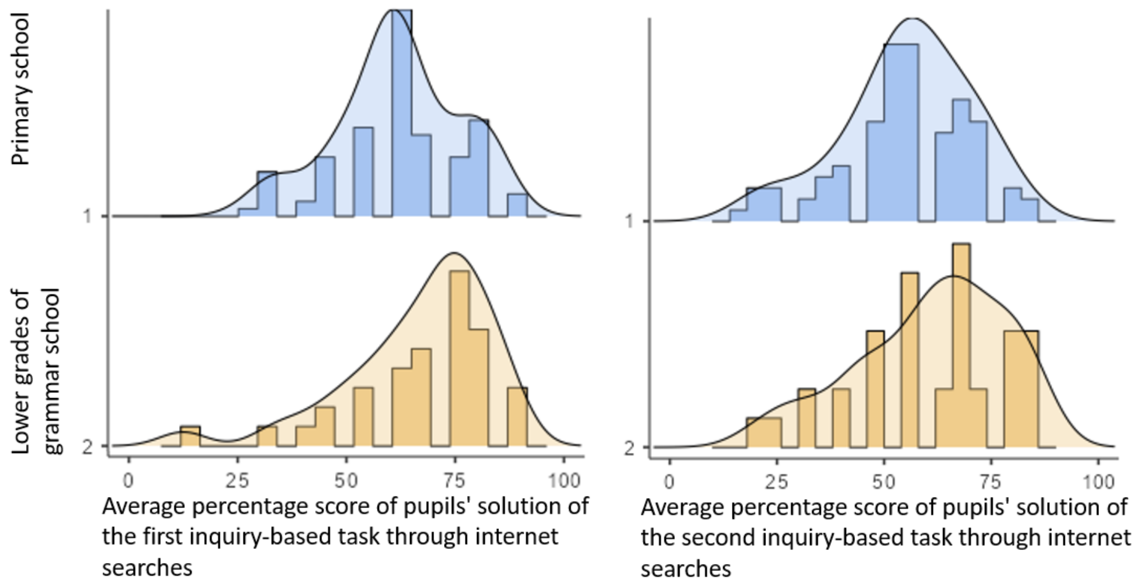

Fig. 3 The percentage of successful Internet searches by the pupils. On the left are the results from the first inquiry task; on the right, there are the results from the second inquiry task.

Results of hypothesis testing

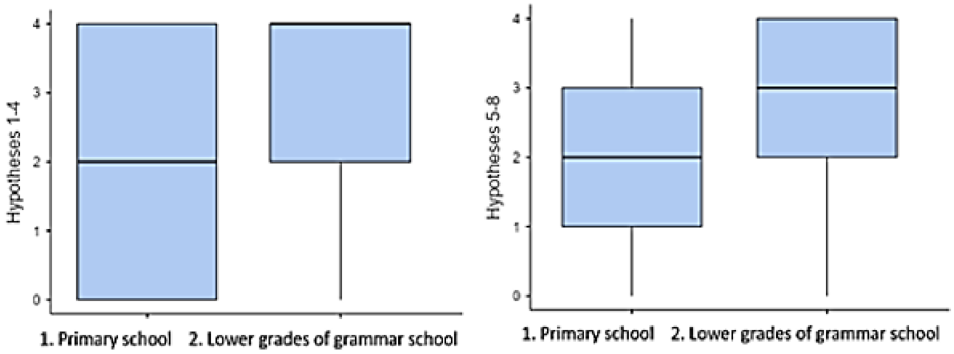

Fig. 4 The mean of correctly tested hypotheses. The maximum points were 4. On the left are the results of testing the first four hypotheses; on the right are the results of testing the following four hypotheses.

Regarding the last part (hypotheses testing), the pupils could test hypotheses to an above-average extent. It can be seen in Figure 4. The knowledge of the topic temperature did not influence the testing of hypotheses when solving the first task. However, according to the coefficient of correlation (0.271), it has some influence on the second task. According to the linear regression, it was 7%. We have found a statistically significant relationship between the school type and the ability to solve hypotheses. The most significant relationship was found in the first task. According to the linear regression, it was 11%, while in the second task, it was only 6%. There was no evidence of regression relationships between Internet searches and hypothesis testing scores.

The inquiry approach adapted to Internet search.

Further tests were then carried out. We wanted to determine whether there was any correlation or regression between the ability to solve such inquiry-based tasks adapted to internet searches, the level of knowledge about the topic of temperature, or the ability to test the hypotheses. We found no statistically significant relationship related to animals' body temperature for the first inquiry-based task.

In the second task related to the state of matter under different physical conditions on Earth, Mercury, and Venus, knowledge with a correlation coefficient of 0.352 could influence solving this task, and it is considered statistically significant. However, according to the linear regression analysis, it has only a 12% influence on solving the given task.

CONCLUSION

We found that pupils' ability to search the Internet was above the mean of our set parameters, so it is possible to implement IBSE in this way, but it will require further research. However, the pupils did not enjoy this work due to the time-consuming nature of the number of tasks. This aligns with (Štípek et al., 2015), where the pupils found working with spreadsheets, which made up most of our tasks, unattractive.

We also found that it is possible to use a digital inquiry-based multidisciplinary approach to gain knowledge of temperature because the pupils could test hypotheses to an above-average extent. According to our research, the correlation with previous knowledge and testing the hypotheses was only proven when solving the second task.

Acknowledgment

At this point, we would like to thank Prof. Jan Picek, prof. Josef Šedlbauer, assoc. Prof. Irena Šlamborová, and prof. Jiří Erhart for fully supporting us in these activities and for trying to develop inter-subject relations in natural sciences.

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From Symbols to Chemistry: Mapping Students' Ability to Work with Chemical Formulas and Their Understanding of Underlying Chemistry Concepts

Lucie Hamerská & Martin Rusek

Abstract

This study focused on connections between students' ability to work with chemical equations and knowledge of relevant underlying concepts. Through a series of tests and tasks, it was tested how knowledge and skills in one area translate into others. The results showed that even freshman university chemistry students did not achieve the expected results and had significant gaps in their understanding of fundamental chemical concepts. The tests including questions about students' knowledge of concerned concepts have not proven to be sufficient to differentiate student achievement reliably. The results also showed that the sub-microscopic level of the phenomena addressed is problematic for students, who tend to cling to the symbolic.

Keywords

Chemistry concepts; chemistry equations; eye-tracking; chemistry education

INTRODUCTION

Several studies (Mulford & Robinson, 2002; Slapnicar et al., 2018) have revealed that students have misconceptions about fundamental chemistry concepts. A recent study on a sample of freshman chemistry university students (Rusek et al., 2022) showed significant deficiencies in students' chemistry calculations skills even though they are often referred to by teachers as one of the critical points in the chemistry curriculum (Rychtera et al., 2018). A particular area within this topic concerning stoichiometry also appears to be problematic (Fach et al., 2007). Students' results in the calculations from chemical equations are one of the worst within the basic chemistry calculation types (Rusek et al., 2022). This confirms a finding reported almost 40 years ago: The teaching of chemistry in this area focuses primarily on the symbolic level and the application of algorithms is necessary to calculate chemical equations. Conceptual understanding of chemical equations is often at a poor level (Nurrenbern & Pickering, 1987)

This study, therefore, followed the work by Hansen (2014) in the endeavour to shed more light on this Gordian knot of chemistry education.

METHODOLOGY

Research Questions

This research aimed to map the understanding of freshman chemistry teacher students in Chemistry with a focus on the education study program at the Faculty of Education of Charles University, Prague, Czechia, in the field of particle composition of substances with emphasis on chemical equations as a notation of chemical reactions. The following research questions guided the research:

With what knowledge concerning particle composition of matter do students of chemistry teaching come to the Faculty of Education of Charles University?

What relationship, if any, is there between the students' chemistry concepts knowledge, ability to work with chemistry representations and their chemistry calculations results?

Methods

Mixed methods were used to answer the research questions in this part of the larger research plan. Firstly, the students filled in two sets of tests (see below). Secondly, based on the tests' results, successful, unsuccessful and average students (four from each group) were asked to participate in the eye-tracking study. This method was chosen because it has been demonstrated to effectively reveal students' cognitive processes alongside their problem-solving outcomes (e.g. Rodemer et al., 2022; Slapnicar et al., 2021; Tóthová, et al., 2021). Only one student from the unsuccessful group refused, therefore the total number of participants was 11. Furthermore, these students were individually given another pre-test (Hansen, 2014) in an electronic form during which the eye-tracking method was used. In the following phase – which is not a part of this paper - the students were given three sets of chemistry formulas to balance taken from phet.colorado.edu, with their eye-behaviour being recorded.

Tools

The chemistry concepts test was taken from Hansen (2014). It tested knowledge about the particle composition of matter. The terms and concepts studied in this area were: atom, molecule, element, chemically pure substance, compound, mixture, solution, chemical bond, chemical transformation, and the law of conservation of mass. One task was specifically designed to test students' conception of chemical reaction and stoichiometry.

The eye-tracking pre-test was, again, taken from Hansen (2014) and only transformed into a PowerPoint presentation with more attractive graphics. It followed the chemistry concept test. The test consisted of four tasks: verbal description of a chemical equation, description of the reaction using pictures of substances, models and formulas, verbal description of the reaction and the equation based on the diagram of the reacting molecules.

The chemistry calculations test Rusek et al. (2022) was used for this purpose. It consisted of five types of basic calculation tasks, two tasks each. Two tasks involved calculations from chemical equations.

Data analysis

The chemistry concepts test was evaluated by one point per item, with special attention to items which concerned chemical reactions and stoichiometry. The resulting scores were converted into percentages to allow respondents' sorting.

As for the eye-tracking parts, each successfully solved task was praised with two points and a partially-successful answer with one point. Students' attention to pre-defined areas of interest was observed and their verbal responses were evaluated.

The calculation test was evaluated following the procedure proposed by its authors (Rusek et al., 2022). The maximum score was 10 – one point per task. Two tasks were focused on stoichiometry – calculations from chemical equations.

RESULTS AND DISCUSSION

Chemistry concepts test

In the chemistry concepts pre-tests, only two students reached 15 points (out of 16). 13 students reached between 12-14 points which equal to a 75-88% success rate and can still be considered a success. Six students reached 8 or 9 points (above 50%) which already points to their lower knowledge of fundamental chemistry concepts.

All the respondents successfully solved only one task – focused on the composition of atoms. The factual knowledge at this level was proved sufficient. On the contrary, the lowest (25%) success was found for the task depicting a chemical reaction see Fig. 1.

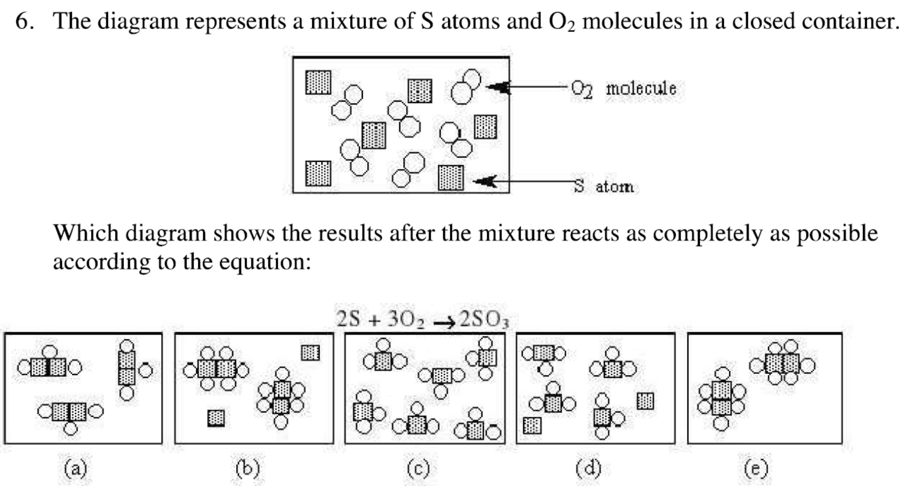

Figure 3 Task 6 (source: Hansen, 2014)

Eye-tracking pre-test

In the first task, the students were asked to read the chemistry formula of carbon's reaction with water. A key showing the names of the reactants and products was provided. The students' verbal responses were evaluated based on their description of the reaction as well as their explicitly mentioning the reaction's stoichiometry. The students' result in the four tasks is shown in Fig. 2.

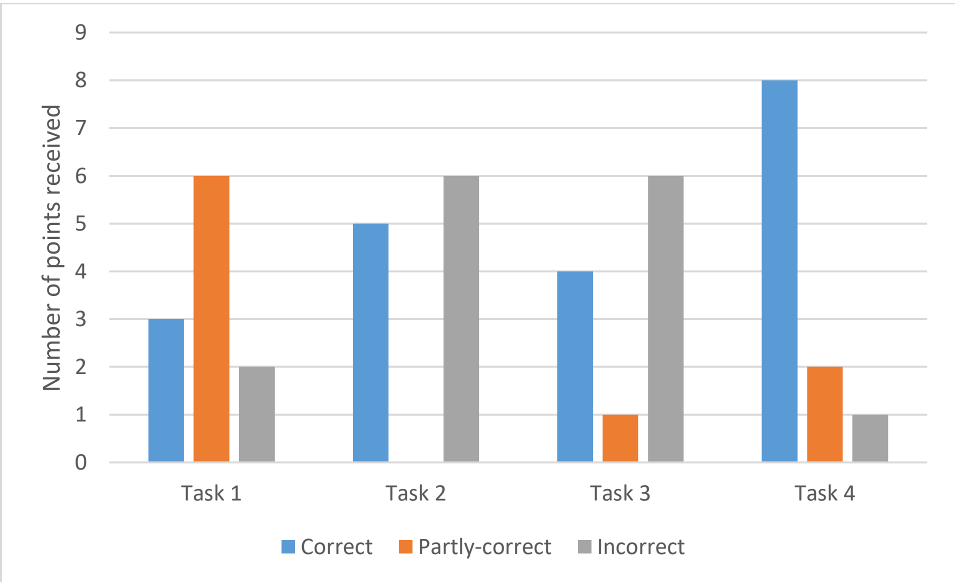

Figure 4 Students' success in the eye-tracking pre-test

Students' conception of chemistry equations was further observed in their attention to particular pictures in eye-tracking task 2 – see Figs. 3 and 4. The students whose response went deeper than a sequence of symbols mentioned other characteristics (see Fig. 3 and the students' fixation on the macro representations). Most students (46 %) considered only the symbolic representations, which shows their visual attention, as shown in Fig. 4.

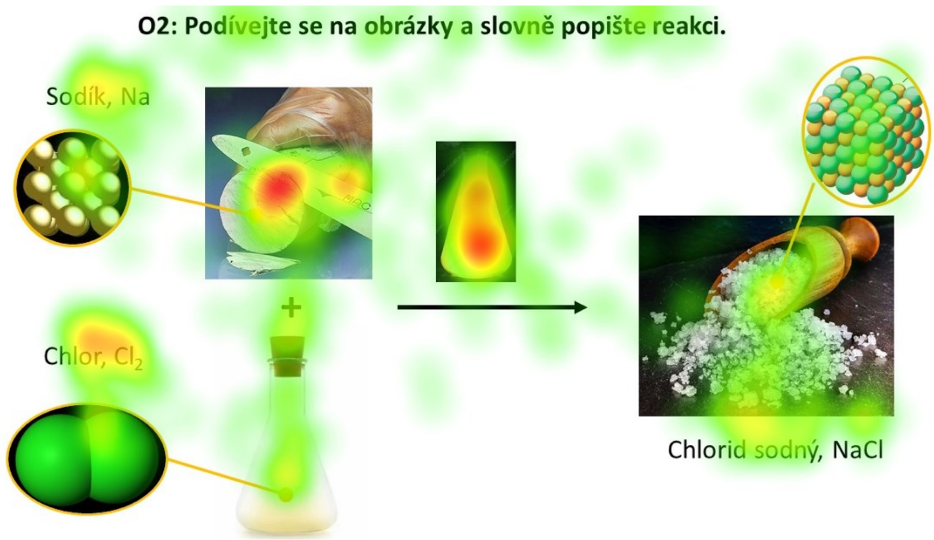

Figure 5 Visual attention of students who also considered macro-representations

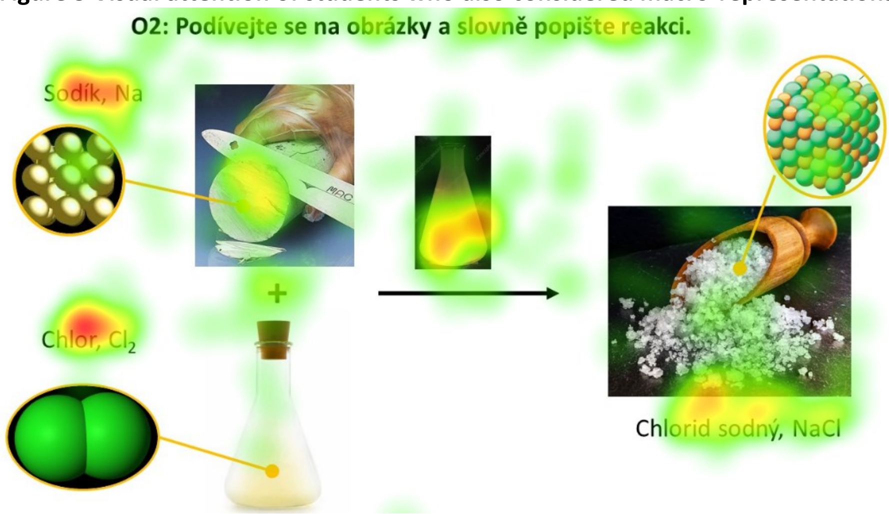

Figure 6 Visual attention of students who also considered symbolic-representations

Chemistry calculations test

Altogether 27 students took the test. Only two students reached 50%, one 40%, two 30%, one 10% and 21 received no point. This result confirms previous results (Rusek et al., 2022) – students' ability to perform chemistry calculations is at a low level. With respect to this research's aim – chemistry calculations, attention was paid to the two tasks on calculations from chemical equations. These tasks were successfully solved only by 4 resp. 3 students (15 resp. 11%). In the task assigned as a word problem, only 11 (41%) of the students managed to write down the formula and balance it. In the task where the reaction scheme was provided, 63% managed to balance the equation. Considering the simplicity of the reactions, these results suggest a negative trend which needs to be treated already at lower levels of education.

Possible reasons for the students' failure could be explained by their responses to the chemistry concept test.

Overall results

Overall results of the selected students are shown in Table 1. It is obvious that only a combination of both tests could serve as a proper key to the students' selection. The chemistry concept result was taken as the primary source though. Also, students' success in either of the paper tests did not reliably predict their success in the eye-tracking pre-test, not to mention the chemistry calculations result.

There were only two students who (one partly) showed the expected correlation of understanding to corresponding chemistry concepts translated to their success in the calculations from chemical equation. The trend was, however, observed in the group of low(er) achieving students. Those, who showed ignorance to the chemistry concepts in both or either of the pre-test, failed to calculate the tasks. Nevertheless, the sample selected for the eye-tracking part does not allow any significant conclusions.

Table 2 The overall results

	Chemistry concepts		**Eye-tracking pre-test**	**Chemistry calculations**		
					Stoichiometry problems	
	Total score	**Equations-related item**		**Total score**	**Balancing formulas**	**with calculations**
Successful	94%	SOLVED	87,5%	30%	100%	0%
	94%	SOLVED	37,5%	40%	50%	0%
	88%	SOLVED	87,5%	50%	100%	100%
	88%	UNSOLVED	87,5%	50%	50%	50%
Average	75%	UNSOLVED	50%	20%	0%	0%
	75%	SOLVED	37,5%	30%	50%	0%
	75%	SOLVED	25%	50%	50%	0%
	81%	SOLVED	12,5%	20%	50%	0%
Unsuccessful	50%	UNSOLVED	75%	20%	0%	0%
	44%	UNSOLVED	75%	20%	50%	0%
	56%	UNSOLVED	37,5%	0%	50%	0
	56%	UNSOLVED		Did not participate		

CONCLUSION AND DISCUSSION

This study's results, in accordance with others, point to the fact that upper-secondary (Fajardo & Bacarrisas, 2017), but also freshman university chemistry student (Bowen & Bunce, 1997) do not understand some fundamental chemistry concepts. It seems chemistry instruction keeps failing at some aspects, which need to be pointed out and this deficiency treated.

Considering the level of the test, the finding that almost a third of the whole group failed the test suggests freshman chemistry teacher students' knowledge and skills when leaving the upper-secondary education may be lower than expected (cf. Rusek et al., 2022).

As for the tests used to identify students' chemistry concepts knowledge, the original test did not prove to be a reliable tool as students' knowledge and skills concerning nomenclature, understanding the energy conservation law and general meaning of chemistry equations were shown not to correspond with their ability to solve tasks aligned with chemistry equations. Only the successful solvers (scored 88% and higher) showed, with one exception, good results both in the eye-tracking pre-test and the chemistry calculations tasks.

The results lead to a conclusion that success in the tests predicts overall ability to solve tasks which is then reflected in their results. However students' successful chemistry equations balancing is not necessarily caused by the students' understanding to the concept of chemical reaction and its notation into a chemical equation. This shows a great formality in chemistry education as equations (or the symbolic representations in general) are not meant to be the content, but rather a way of describing the phenomena. This result is consistent with other studies (Kruse & Roehrig, 2005; Mulford & Robinson, 2002; Salame & Casino, 2021), showing that the phenomenon of chemical reactions is not sufficiently communicated to students in chemistry education.

As argued by Jaber and BouJaoude (2012), using chemical representations leads to a better understanding of chemical concepts. As shown by Hamerská (2023), students tend to skip sub-micro representations of chemistry formulas and stick to the formal/symbolic notation simply because they were not taught any other way. This finding is consistent with recent findings about chemistry textbooks' use of representations – symbolic representations prevail and sub-micro appear only seldom (Chen et al., 2019; Chlumecká, 2021; Krumlová, 2022).

The results of this study were affected by several limitations. First, students from only one department were chosen for the study. To provide more significant results, the sample should be larger so the qualitative study would include possibly a wider spectrum of students' approaches towards chemical equations. However, the students in the sample came from many different upper-secondary schools, which suggests the discovered trends may apply to more schools and chemistry instruction approaches. Also, the results on the selected sample showed a satisfactory amount of theoretical saturation when only several procedures were repeated by the students. Another limitation lies in the use of students' written responses either to the tests or tasks. As shown for example by (Rusek et al., 2019; Tóthová et al., 2021) such tools provide false-positive results therefore, qualitative research methods are suggested to be used in combination. As this study aimed at students' division for further research, this limitation needs to be considered when the subsequent results will be interpreted.

The next step is to conduct the study with students selected in the manner described in this text. A study of their processes when dealing with chemistry calculation tasks has the potential to represent a larger group of students than just the subject of the study as they were selected as representatives of the successful, average and unsuccessful students.

Acknowledgement

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Digital technologies in teaching and learning of photosynthesis from the teachers‘ and students‘ point of view

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Abstract

This contribution focus on opinions of Czech upper secondary school biology teachers and students on the use of digital technologies for learning photosynthesis. From teachers’ point of view the problems in teaching photosynthesis are too much chemistry, invisibility and abstractness and low student interest in plants. They would appreciate to use digital learning tools on photosynthesis including educational videos, learning schemes, real world examples, animations, field experiments and interactive workbooks. Students would prefer to learn photosynthesis via real world examples, field or laboratory experiments using digital technologies and also educational video. They do not like to learn photosynthesis via frontal transmissive education or quiz.

Key words

Teaching of photosynthesis; Digital technologies; Field education

INTRODUCTION

Photosynthesis is one of the most problematic topics in science education (Cañal, 1999; Carlsson, 2002; Marmaroti & Galanopoulou, 2006). As follows from the survey done by Vagnerova et al., (2019), also in Czech science curriculum photosynthesis is considered as one of the critical points. Insufficient understanding of the process of photosynthesis leads to student misconceptions of the plant role in ecosystem which students transfer later into their everyday life (Carlsson, 2002; Keles & Kefeli, 2010). This is very important, because photosynthesis is process crucial for human life, not only as a source of oxygen and primary production in ecosystems, but also as a process leading to the development of plant biomass, primary production of each ecosystem.

Numerous international studies were done to discover the problems in students’ understanding of photosynthesis (Marmaroti & Galanopoulou, 2006; Keles & Kefeli, 2010; Métioui, 2016). Da Silva et al. (2016) considered as one of the main reasons prevailing theoretical education based on memorizing of difficult terms and chemical equations, Hershey (2005) see the main problem in the overall abstraction of photosynthetic process which is by human eye invisible.

Scholars and educators are looking for the more effective and innovative ways for teaching this crucial topic. In our digitalization era digital technologies are believed to increase student motivation, engagement and enhance efficacy of learning process (Alt, 2018; Taber, 2017). The current generation of school students belongs to the so-called alpha generation, which is also referred to as the "touch screen generation" (Pogue, 2015). Working with various digital devices is completely natural for them, they are used to it from an early age (Eurostat, 2015) and they have developed a tendency to use digital educational resources in education as well (Reis, 2018; Pogue, 2015). The benefits of the use of digital technology in science education are among others in the possible visualization of complex or microscopic phenomena or data logging in students experiments (Tran et all. 2017). Barton (2005) pointed out, that the use of digital technologies in science education improve conceptual understanding of the scientific phenomena, ability to interpret data and enhance learners' scientific inquiry skills. In the field of teaching photosynthesis, the use of digital technologies together with constructivist approach are considered as suitable methods (Taber, 2017), positive impact of inquiry-based activity using digital measuring device for oxygen development was discovered by Kuncová & Rusek (2019).

This contribution brings the results of a study done in frame of the project supported by Technology Agency of the Czech Republic (TACR) TL 05000150 aimed on the development of digital learning platform on photosynthesis in relation with plant ecological role in the landscape. For the development of this learning platform monitoring of the teachers' as well as upper secondary school students' needs and opinions on the use of learning platform was necessary. From this reason a didactic survey was done among Czech upper secondary school teachers of biology and their students with an aim to find an answer to following research questions: What are the main problems in teaching photosynthesis at Czech upper secondary schools from teachers' point of view? What is the teachers' and students' opinion on the use of digital technologies for teaching and learning of this topic?

METHODS

In total 315 upper secondary school students (16,7 years old, SD=0,8) and 30 secondary school teachers of biology took part in the survey done in June and September 2021. The respondents – teachers were in average 43.3 years old (SD= 8.7) and have been teaching for 17.1 years (SD=7.2). For both groups the research was done by using a questionnaire. The student questionnaire consisted of 17 questions, but because of limited space of this article for the purposes of this contribution just responses to one question aimed on the way students would like to learn photosynthesis were used.

The questionnaire for teachers consisted of following questions:

1. How would you asses the difficulty of the topic of photosynthesis for your students (mark on the scale from 1 to 5, 1 means easy, 5 means very difficult) (Likert scale)

2. What are the most important problems in teaching photosynthesis according to your opinion? (open type question)
3. Do you personally like to teach photosynthesis?
4. Do you use any digital technologies for teaching photosynthesis? (e.g. computer assisted materials, digital measuring devices in experiments, learning videos…etc.) If yes, specify what exactly are you using. If not, explain the reason why.
5. Would you like to use educational learning platform providing computer assisted materials for teaching photosynthesis?
6. What should such learning platform on photosynthesis include? (multiple choice question)

The results were analysed using descriptive statistics methods (The STATISTICA 12 PC package, Stat Soft Inc.]

RESULTS

Teachers considered the topic of photosynthesis as difficult for students, median 4 (assessed on 5-grade scale, 1= easy, 5= very difficult, Fig.1).

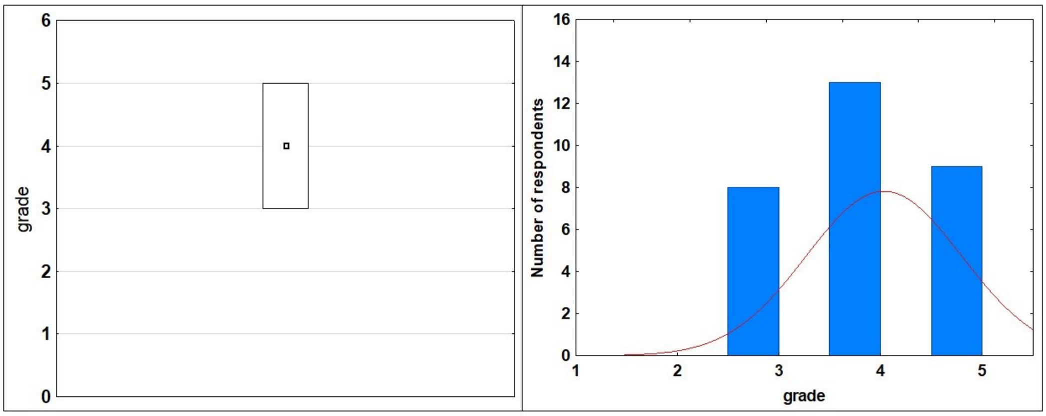

Fig. 1 Teachers' assessment of the level of the difficulty of photosynthesis as a topic of education 5-grade Likert scale, 1= easy, 5= very difficult (left median, right histogram of the distribution of responses, N =30).

The responses concerning the problems in teaching photosynthesis named by teachers were categorized into four categories. The majority of teachers saw the problem in the chemical content of the topic (see Fig. 2). Simple answer "chemistry" or "to much chemical content" was mentioned by 70 % of respondents (21 teachers, 11 of them specified that the main problem is chemic equation of photosynthesis). In total 40 % of teachers considered the topic of photosynthesis as simply "to difficult" without any other explanation, 20 % of respondents pointed out that photosynthesis is "to abstract" or "invisible", and 17 % respondents mentioned low student interest in plants.

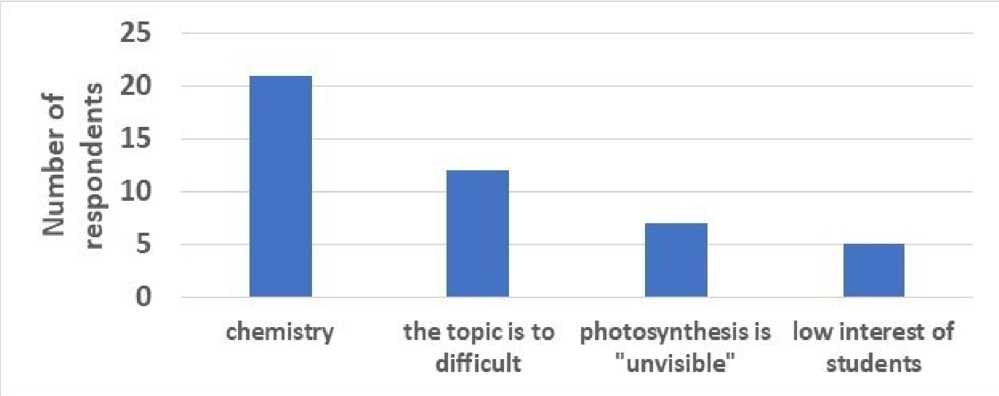

Fig. 2 Analysis of the teachers' answer on the question: „ What are, according to your opinion, the most important problems in teaching photosynthesis ?" (N =30).

Teachers possessed mostly neutral relation to teaching photosynthesis (53 % of respondents), 40 % of them do not like to teach photosynthesis. On the other hand, just 7 % of respondents like to teach this topic. Only 30 % of all respondents used digital technologies for teaching photosynthesis, their own ppt presentations. 70 % (21 teachers) do not use any digital technologies for teaching photosynthesis. As the reason 8 teachers mentioned that the only computer assisted materials they know are in English, 4 teachers mentioned they do not know any suitable computer assisted materials, 2 of them mentioned that their school does not have such equipment and the rest of the respondents did not mentioned any reason why they do not use digital technologies for teaching photosynthesis. All the respondents would like to use learning platform for teaching photosynthesis in their practice.

Teachers' requirements for the content of such platform are described on the Fig.3.

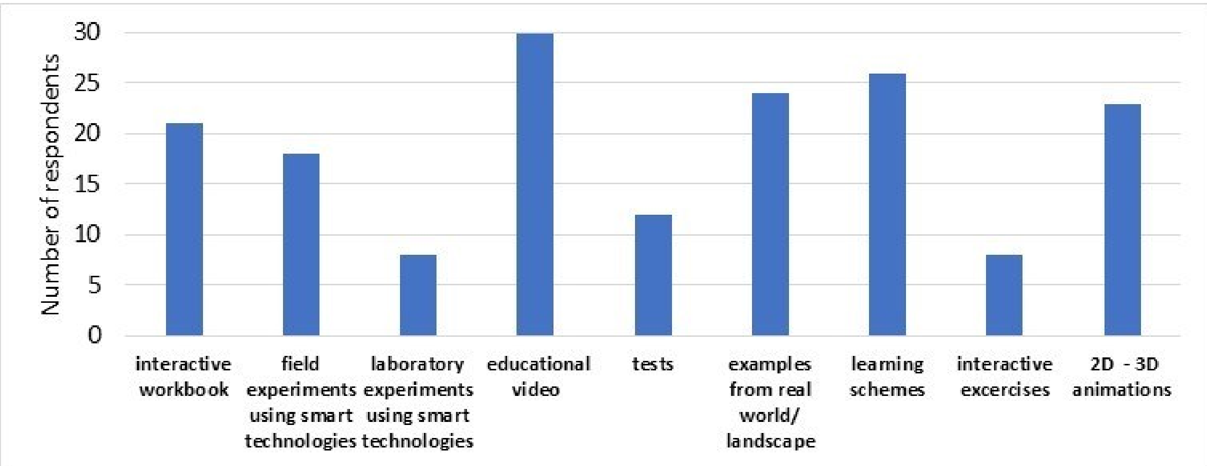

Fig. 3 Analysis of the teachers' answer on the question: „What should learning platform on photosynthesis include?" (N =30).

All teachers would appreciate educational video, 87 % of them learning schemes and 80 % of them examples from real world, 77 % animations, 70 % interactive workbook, but just 23 % of them interactive exercises, 60 % of teachers would like to have field experiments using smart technologies but laboratory experiments using smart technologies were required just by 23 % teachers, 40 % of teachers would like to use prepared tests.

Students' responses on the question ”How would you like to learn photosynthesis? Assess on the scale, 1= I prefer, 5= I dislike" were analysed (fig.4). Based on the results of the students' assessment of several possibilities for learning photosynthesis on 5-point Likert scale we can conclude, that they prefer to study photosynthesis in particular via field experiments using digital technologies (median=1) and via the examples from real world. Educational video and laboratory experiments using digital technologies would be appreciated by students as well. On the other hand, students do not prefer formal transmissive education and also do not like to learn photosynthesis via quiz.

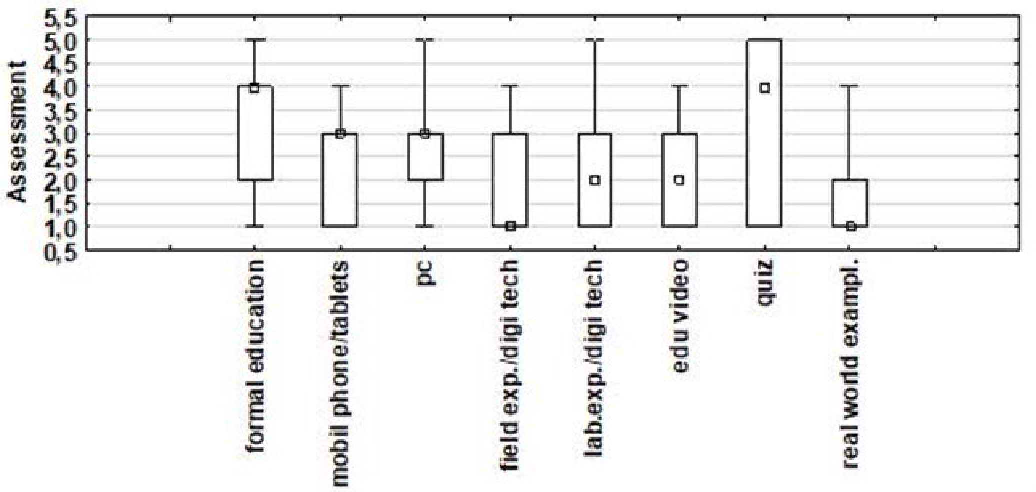

Fig. 4 Students' assessment of different possibilities of learning photosynthesis. Analysis of the answer on the question: „How would you like to learn photosynthesis?" 5-grade Likert scale, (1= I prefer, 5= I dislike, N =315).

DISCUSSION

In agreement with the results of previous research (Métioui et al., 2016) upper secondary school teachers of biology considered the topic of photosynthesis as difficult. They mentioned 4 areas of problems. In majority of cases chemical content of the topic was mentioned, 11 from 30 respondents considered the description of photosynthesis by chemical equation as inadequate to the age of the pupils. Further reason of difficulties mentioned by the teachers was the invisibility of photosynthesis for human eye and therefore the abstractness of the topic for the students. This could be the reason why the majority of teachers required tools enhancing visibility of the photosynthesis for students as a part of learning platform on photosynthesis which they would use for teaching (educational videos, animations and learning schemes, 2d-3D animations). Teplá et al., (2021), pointed out that the use of 3D models and animations in teaching process led to a significant increase in students' intrinsic motivation in chemistry and biology. Teachers' opinion on the content of digital learning platform partly meet the students' preferences in different ways of learning photosynthesis. Students appreciate almost all possibilities of learning photosynthesis which include the use of any digital tool. They like to learn photosynthesis by using educational videos, but they would better use examples form real world and field experiments using digital technology for learning. This finding highlighted the necessity to teach photosynthesis in relation with its ecological impact in human environment. As follows from previous research, extraction of the topic of photosynthesis from the ecological context of the plant in the landscape (Carlsson, 2002) and overall isolation of this process from everyday life (da Silva et al., 2016) can be important reasons of difficulties in learning photosynthesis. An "ecological approach" to teaching photosynthesis could also help to overcome further serious problem in teaching photosynthesis mentioned by teachers (fig.2) which is low students' interest in plants. This is related with the overall spread phenomenon of plant blindness (Amprazis & Papadopoulou, 2020; Ryplová, 2017) and to cope this phenomenon has been a challenge for biology educators for many years. Based on these findings the use of real-world examples and field experiments on photosynthesis supported by digital technologies seems to be a possible way for the improvement of teaching photosynthesis. To prove this hypothesis is an aim of our future research aimed on the impact of such learning activities on students understanding of photosynthesis.

CONCLUSION

Biology teachers at upper secondary schools taking part in this study consider the topic of photosynthesis as difficult for their students. They see the reasons of the problems in chemical content of photosynthesis, invisibility and abstractness of this process and low student interest in plants. Despite just a minority of teachers uses digital technologies for teaching photosynthesis (their own ppt presentations only), they would appreciate the possibility of using digital learning platform on photosynthesis. Such platform should include mainly educational videos, learning schemes, 2D-3D animations and interactive workbooks. Both, teachers as well as students would appreciate real world examples and field experiments using digital tools as a part of learning platform.

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