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THE TABLE OF CONTENTS

Editorial

What the 2020 pandemic measures took on the possibility to meet in person, they added to the richness of topics participating authors focused on in their contributions. Focus of the papers is far beyond project-based education. The conference's participants clearly indicated their effort to present their topics related to science education research.

A traditional group of papers dealt with an evergreen topic – is project-based education effective? What evidence is at our disposal? Its comparison with traditional teaching approach was included. Its effect was investigated both in a traditional classroom setting as well as outdoors. Another fixed star inquiry-based education was completed with papers targeting teachers' attitudes towards this method or, similarly to the aforementioned group, teaching out-of-classroom. Within the PBE's growing scope, several authors focused on concrete topics such as how to teach the topic acids and bases, others investigated the influence of 3D models on students' learning or examined the state of chemistry experiments in Czech schools. Other cluster of papers focused on results of students' learning. It was namely their attitudes towards genetically modified organisms, knowledge on this topic as well as a pilot of three-tier tasks for a more informative student assessment within the topic of the periodic table of elements. These were followed by investigation of students' conception of an atom. From a different angle, researchers also focused on university students' problem-solving skills, and their professional development, also in the field of their professional vision. It is these papers research results find more concrete use and influence the quality of education.

From the overview of papers included in the PBE 2020 proceedings, it is evident that the conference expanded far beyond the project-only focus to other fields which jointly aim at science education improvement via better understanding of the field. For the following years, connecting in-service teachers with researchers e.g. via action research seems to be desirable, as valuable information about education will not take their effect unless teachers decide to act on them, including evidence-based changes in their instruction.

Martin Rusek

LUMA2020 – Inquiring and Innovating Together in Central Finland

Tuomas Nurmi, Piia Parviainen, Otto Virkkula & Anna-Leena Kähkönen

Abstract

LUMA2020 development program ran from mid-2019 to the end of 2020. The program aimed to support studying of, and engaging in, STEAM subjects in early childhood education and care (ECEC), and upper secondary and vocational schools. Other goals included evaluating the effectiveness of the program, constructing Massive Open Online Courses, supporting the participation in StarT platform, and other smaller entities. Approx. 160 learning communities took part in the program in Finland, of which 9 in Central Finland. The program was well-received, various teachers' pedagogical ideas were realised, and the training provided for teachers in ECEC was seen to be particularly successful.

Keywords

Development program; project-based education support; early childhood education and care; upper secondary schools; MOOC

INTRODUCTION

LUMA Centre Finland is a network of Finnish universities, which aims to inspire and motivate children and youth into mathematics, science and technology, and to support teachers (Aksela et al., 2020). Previously, the primary target of the activities had been basic education. In spring 2019, preparations for LUMA2020, a development program funded by the Finnish Ministry of Education and Culture, were begun. Three main targets were to support 1) the further development of formal education, from early childhood education and care (ECEC) to second degree, 2) the lifelong learning of personnel, and 3) development of non-formal science education.

The content of the program was to be based around four themes, "Sustainable development", "Mathematics around us", "Technology around us", and "My LUMA", thus aligning with the StarT program and competition (Aksela et al., 2020, p. 50; LUMA Centre Finland, 2020a) themes for season 2019-2020. Previous LUMA programmes were targeting especially basic education students, from ages 6 to 16. LUMA2020 was to be the first to specifically include ECEC, also with increased emphasis on upper secondary schools and vocational education, and target age group was set to be from 3 to 19 years. Due to technical reasons, the duration of the program was to be somewhat short – one and a half years. The program started in autumn 2019, and it ran until the end of 2020.

THEORETICAL BACKGROUND

LUMA Centre Finland and StarT program

StarT is a project-based learning platform and competition, organized by LUMA Centre Finland since 2016 (LUMA Centre Finland, 2020a). The StarT program is built as a support for teachers realising project-based education, curriculum reform and new pedagogy.

Research on StarT projects in Central Finland has identified various important aspects: e.g. the difficulty of identifying subject matter learning goals for project based learning causing teachers to favour goals that are soft skills or group work oriented (Pensasmaa, 2019), the difficulty of setting meaningful learning goals and finding time for projects as they don't appear as parts of subject studies, and the difficulty in evaluating project-based learning and uncertainty about using projects as assessments for subject matter learning (Mononen, 2018). Reddy (2020) has shown that ready-made materials found can heavily direct how teachers take on project-based learning. Thus unsuitable materials may hurt the self-directedness of children working on the project and change the teacher's understandings of project-based learning.

A central idea of StarT is to solve these kinds of problems by enabling sharing of ideas and inspiring solutions, both by teachers' live sharing, and ideas appended to StarT online material collection, in addition to providing a science-fair like fun event for children to get excited about STEAM.

Holistic Model for The Development of Early Mathematical Skills

The holistic model for the development of early mathematical skills is a research-based model that categorises the development of early mathematical skills, which children develop from birth to seven, into three skills categories (Parviainen, 2019). The skills categories are 1) numerical skills, 2) spatial thinking skills and 3) mathematical thinking and reasoning skills, which all include several skills areas and subskills. Versatile early mathematical skills develop simultaneously during early childhood, and there is a developmental interconnection between the aforementioned skills categories. Thus, children use numerical skills and mathematical thinking and reasoning skills while learning spatial thinking skills, and vice versa, they use spatial thinking skills and mathematical thinking and reasoning skills while learning numerical skills.

As early mathematical skills have shown to predict mathematical learning difficulties (e.g. Merkley & Ansari, 2016) and having a significant role in mathematical learning at school age (e.g. Hannula-Sormunen, Lehtinen, & Räsänen, 2015), it is essential to strengthen children's learning of versatile early mathematical skills in ECEC. Parviainen's (2919) holistic model for the development of early mathematical skills can be used as a base while training teachers in ECEC to develop their teaching of mathematics for young children. Hence, the aim is to enhance conscious teaching of mathematics comprehensively, covering all early mathematical skills children develop and learn before school age.

ACTIVITIES IN THE LUMA2020 PROGRAM

Shared national activities

A series of expert lecture videos on the themes of the program was planned to be a major in-service training resource for the participants. Online "project planning form" was also introduced, as a support for the participants in their planning, and as a method to centrally monitor the progress in the program. However, shortly after the release of the first videos, it became evident that the demand for them was limited, and in the end, only a few were produced. The "planning form" also failed to gain a central role. Instead, more effort was put into interaction with the communities and supporting them by finding and collaboratively developing solutions for their needs.

Due to the COVID-19 pandemic, national live events, e.g. National LUMA Days and StarT Gala, which were supposed to include a grand meeting of LUMA2020 participants from all Finland, as well as the closing seminar in late 2020, originally planned to include workshops based on the activities developed in the program, were cancelled. These were partially replaced with online events, and new virtual activities were set up, e.g. regular "StarT Teachers' Lounges" where teachers can connect and share ideas nationally. The projects by the participating learning communities were also compiled as a browsable online collection (LUMA Centre Finland, 2020b).

Other goals for the program included e.g. producing Massive Open Online Courses (MOOCs) based on the participants' projects and ideas, and developing methodology for evaluating the program and commencing the evaluation, a task currently worked on by the Finnish Institute for Educational Research. Three MOOCs, providing ideas for project-based learning in early and basic education, and upper secondary school, were published in autumn 2020, and were well received.

Activities by local LUMA Centres

Approximately 160 different learning communities took part in the program around Finland, each working with their local LUMA Centre. The distribution of the educational stages of the participating communities varied regionally, and as the main aim everywhere was to listen to and help the participants based on each one's needs, the actual activities organized by different centres varied somewhat. In addition to collaborating with participating learning communities, local LUMA Centres in different cities organized various separate events and activities, ranging from science clubs and camps for children and youth to brainstorming days for university teachers.

LUMA2020 IN CENTRAL FINLAND

Following the focus areas of previous LUMA programs, Central Finland LUMA Centre had a long tradition of working with basic education schools, and had also done successful collaborations with upper secondary schools. Knowledge and connections from the previous programs were to be leveraged in LUMA2020. Since experience in working with ECEC institutions was limited, personnel from the discipline of Early Childhood Education were also invited to collaborate in the program.

A total of 9 learning communities in Central Finland applied for and were selected in the program: 4 early education centres (EECs), 2 basic education schools and 3 upper secondary schools. Different motivating factors for participation were identified: for teachers in ECEC, the trust that the program would actually be beneficial for their everyday teaching, stemming from their previous contacts with the Early Childhood Education personnel, was instrumental. Basic education schools had participated in earlier LUMA programs and probably recognized the new program as a way to secure support resources for their own needs. The interest in participating in a "national development program" was mostly visible in upper secondary schools, who also benefited from various synergies between LUMA2020 program and other projects and teaching development they had been doing or planning.

Monthly meetings with all the participants were held, where national themes and materials were presented, and ideas from the learning communities developed. Visits to the communities by LUMA2020 personnel were an important form of activity, especially in ECEC. Due to the COVID-19 pandemic, the emphasis shifted from regional meetings to national online activities in spring 2020.

Central Finland: Early Childhood Education and Care

An ongoing research on the holistic model for the development of early mathematical skills (Parviainen, 2019) could be used to support the participating teachers in ECEC, participants also synergically producing data for the ongoing research project. Although participating in the research required some effort from the teachers, it was well received, as it also aimed to serve as part of their planning work, and as a tool for pedagogical assessment of the teaching methods and contents.

Some of the teachers in ECEC had previously participated in the StarT program, and descriptions of their previous projects were a major inspiration for those less experienced. Peer example was also an important support resource during the work on the projects, and it probably also explains similarities of the themes and topics of some resulting StarT projects.

During the LUMA2020 program, empowerment among the teachers in ECEC was very notable, and they were especially enthused by the fact that the program was actually tailored to their needs, in contrast to the common situation of trainings with pre-defined contents. Retrospectively, the ability to start the program with live meetings was instrumental in the success of the training for teachers in ECEC: although the trainings could be continued online at to some extent proficiently, the fact that the group dynamics were already formed in physical meetings was probably important especially to those who were less experienced with the training topics and project-based learning.

Central Finland: Upper Secondary Schools

Preparing the students for matriculation examination is caricaturely seen as the most important mission for Finnish upper secondary schools. Therefore, project-based education is often considered as "extra", and its usage on obligatory courses is limited. Finding the time and context for projects was a theme often discussed with the participants. While this problem will remain, it is hoped that new solutions and practices can be found and shared between the teachers nationally.

For the most part, upper secondary school teachers had existing educational practices they wanted to work on, or exhibit, in the program. Specifically, some teachers were provided with scientific and technical support, e.g. data sources and forecasts on the effect of global warming on the local environment, and guidance on portraying these changes through doing image manipulations with students, and energy science background for a school-wide project, which would develop a long-term "tradition" of following the school’s environmental impact, to be passed on to future classes.

Other Local Activities in Central Finland

The basic education schools could be provided with support for various topics, including planning of a multidisciplinary week, ideas on how to better engage in project-based education, and contacts with foreign visitors at the university. Other local activities included organizing and recording an event on employment possibilities of STEAM careers to assist the national expert lecture video effort, and sponsoring a series of game development courses for youth during summer 2020, among others.

Resulting StarT projects in Central Finland

Similar to the motivations of participation in the LUMA2020 program, two distinct characteristics can be identified in StarT projects by the participants: Some actively sought to engage in new ideas with their projects, while others took advantage of the opportunity built in StarT to use the competition as a platform to exhibit work originally done for some other purpose, but during the StarT season. E.g. various urban development and "recognizing mathematics in their vicinity" projects of the participating EECs are of the former type, and particle accelerator contest entry materials and algorithms done on an Artificial Intelligence course by upper secondary schools are of the latter.

Many projects demonstrate very inspiring results in what can be achieved when e.g. a teacher "catches" an outstanding question from a student and seizes the opportunity to start a project work, when a teacher successfully embraces the role of "someone who helps to find the answers" instead of "someone who has all the answers", and when a teacher realises that a project could ascend to next level by doing it together with their foreign partner school. As the pandemic situation prevented the organisation of a physical StarT festival in Central Finland, an online showcase of the submitted StarT projects was compiled instead (Central Finland LUMA Centre, 2020).

LOCAL OBSERVATIONS AND NATIONAL QUESTIONNAIRE RESULTS

According to Mäkelä (2020), the LUMA Centre personnel interviews suggest that all the targets – development of formal education, lifelong learning of personnel, and development of non-formal science education – were significantly advanced. Although formal education received most effort, e.g. various virtual science clubs demonstrate non-formal development done in LUMA2020 program. Also, as visible in the participants' end questionnaire data (FIER, 2020) presented in Tab. 1, the results of the national end questionnaire support the subjective observations by the Central Finland LUMA2020 personnel. Namely, the in-service training answers reflect the smaller role of centrally coordinated training materials, and the other shown results exhibit the facts that the participants were happy with the way their needs could be taken into account, and that positive results could be achieved by supporting StarT participation. The Finnish Institute for Educational Research will publish the evaluation of the program and a broader analysis of the questionnaire results later.

Tab. 1 Excerpts from the LUMA2020 participant end questionnaire results (FIER, 2020)

QUESTION (1: strongly disagree, 2: somewhat disagree, 3: somewhat agree, 4: strongly agree)	1	2	3	4
StarT provided an opportunity to develop my teaching (n=150)	0	5	56	89
StarT improved the pupils' learning outcomes (n=146)	2	25	88	31
StarT provided an in-service training opportunity for teachers (n=147)	11	36	51	49
I received assistance from local LUMA centre when needed (n=154)	4	11	48	91
Participating in the program developed the skills of the teaching personnel (n=151)	2	14	82	53
The program encouraged our learning community to try something new (n=153)	3	14	61	75

CONCLUSION

Although the limited central coordination in program activities set some extra challenges for the national construction of the MOOCs, three courses were published as planned, and the compiled online collection of the participants' projects is a valuable resource for demonstrating different kinds of project-based learning ideas. On the other hand, the characteristics of coordination left more space for inter-participant activities. New contacts and collaboration opportunities emerged amidst both the participating teachers and the organizing university personnel: between learning communities regionally and nationally, teachers of different age groups, and between different departments of the university.

The ability to tailor the activities of the program to respond to the actual needs of the participants was very beneficial, especially since the teachers were participating at least partially on a voluntary basis. Personal contact was often important when learning communities and teachers were considering participating in the program, and peer examples had a major role in encouraging new teachers to engage in project-based learning activities.

Various underlying needs were encountered during the program, and it was observable and supported by the program's questionnaires that such programs, where e.g. organizers have previous experience on similar activities and experts at a university can easily be leveraged, are a welcome and accessible form of support for the teachers, helping them realise their pedagogical visions and enabling them to further develop their skills and teaching. Further, using the holistic model for the development of early mathematical skills as a base for training proved to be feasible for the teachers in ECEC, and results thereof will be published later.

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Teachers' beliefs about and dispositions towards Inquiry-based Science Education

Elisabeth Hofer, Brigitte Koliander & Sandra Puddu

Abstract

Inquiry-based Learning (IBL) has been considered an essential element of science education for several years. Nevertheless, teachers rarely implement IBL in their own classes. To counter this, professional development (PD) programmes need to examine teachers' reservations. In this study, we supported five teams of science and technology teachers in developing and realising IBL units for their own classes. To investigate teachers' beliefs about and dispositions towards IBL, we conducted group discussions at the beginning and the end of this programme. Applying qualitative content analysis, we could identify substantial changes regarding learning environments, goals and scaffolding for IBL.

Keywords

Inquiry-based science education; teacher professional development; beliefs and dispositions

INTRODUCTION

Inquiry-based Learning (IBL) describes an instructional approach in which students are actively involved in the process of scientific inquiry and thereby "develop knowledge and understanding of scientific ideas, as well as an understanding of how scientists study the natural world" (National Research Council, 1996, p. 23). Accordingly, IBL might help students acquiring scientific literacy and therefore, it has been considered an essential element of science education for several years (Barron & Darling-Hammond, 2010; Roberts & Bybee, 2014). Even though great effort has been made to foster the implementation of IBL in science classes (Gray, 2015; Rundgren, 2018), teachers' classroom practice has not changed significantly so far (e. g. Capps et al., 2016; Čiháková, 2018; Crawford, 2014; Hofer et al., 2016). Research findings suggest that especially teachers' beliefs and dispositions determine whether they apply instructional approaches such as IBL and in what way they apply them (Jones & Carter, 2007; Jones & Leagon, 2014). Hence, effective professional development programmes need to address not only teachers' knowledge and skills, but also their beliefs and dispositions (Capps et al., 2012; Darling-Hammond et al., 2017). According to the *Interconnected Model of Professional Growth* (Clarke & Hollingsworth, 2002), teachers' beliefs and dispositions continually change through the ongoing interaction between *enactment* and *reflection*. Only if teachers dare to put new instructional strategies and approaches into practice will they be able to engage in evidence-based reflection, which constitutes a crucial point of professional development. Tackling this issue, the initiative *IMST* (Innovations Make Schools Top!) aims at fostering educational innovation in Austrian schools by supporting teachers in implementing innovative instructional approaches, such as IBL (for further information see www.imst.ac.at).

IMST was initiated in 1998 by the University of Klagenfurt and considers itself a flexible support system for teachers. Financed by the Austrian Federal Ministry of Education, Science and Research, *IMST* provides teachers with the opportunity to conduct their own development and action research projects (Feldman et al., 2018), thus promoting targeted school development. As one of the possible support measures, teachers might collaborate with science education researchers for a period of one year. During this time, teachers and researchers jointly develop, plan, realise and evaluate particular lesson units or whole implementation projects in mathematics, computer science, the natural sciences, German and technology (Krainer et al., 2019).

PURPOSE AND AIM

In the context of *IMST*, we developed a professional development (PD) programme called 'Inquiry Steps' that aims at supporting teachers in planning and applying IBL units in their own science and technology classes. Within the scope of this PD programme, we also investigated how far the participation in the programme influenced the teachers' beliefs about and their dispositions towards IBL. The questions to be answered are the following:

1. What beliefs about and dispositions towards IBL do the participating teachers have at the beginning of the PD programme?
2. What beliefs about and dispositions towards IBL do the participating teachers have at the end of the PD programme?
3. How far did the participating teachers' beliefs about and dispositions towards IBL change over the course of the PD programme?

DESIGN AND METHOD

The developed PD programme was designed for the duration of one school year. Advertised in the annual programme of the College of Teacher Education in Lower Austria and promoted by the *IMST* network, schools were asked to apply for the PD programme with their own project ideas belonging to the natural sciences (biology, chemistry, physics), technology or related fields. After having specified these project ideas, teams from five schools (all levels from primary to upper secondary school) were invited to participate in the PD programme and to realise their implementation projects within this framework.

In order to support the teachers' implementation projects on the one hand and to pursue our research interest on the other hand, we decided to carry out the PD programme in two closely interlinked strands (see Fig 1): the PD strand (coloured in green) and the research strand (coloured in blue).

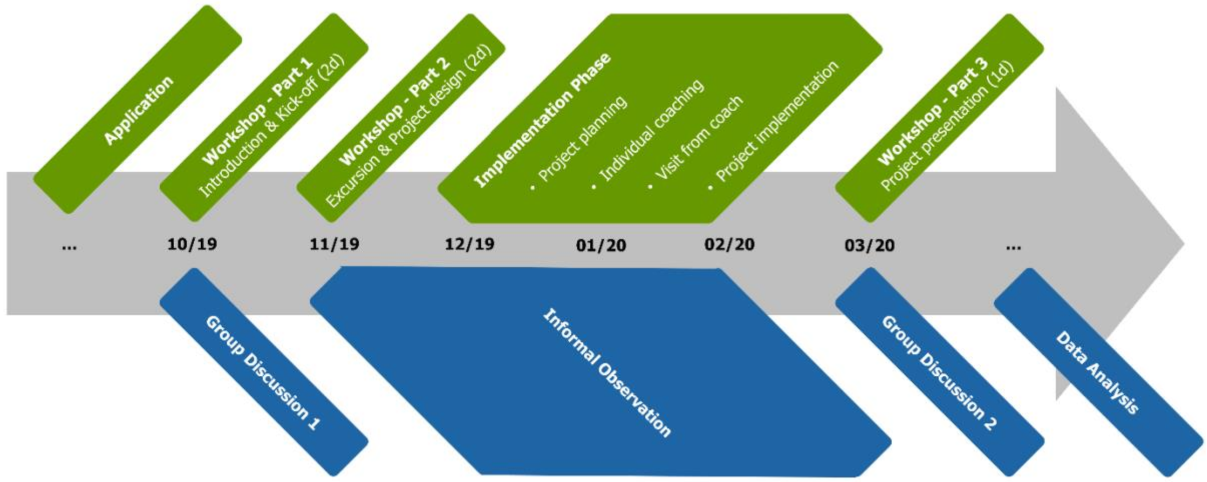

Fig. 1 Schedule of the professional development programme with its two interlinked strands: the professional development strand (green) and the research strand (blue).

The professional development strand

The PD strand consisted of four main parts: three workshop parts at the College of Teacher Education (5 days overall) and an implementation phase at the teachers' own schools. At the first joint meeting (Part 1; Oct. 2019), the participants (teams of two or three teachers from each participating school) presented their project ideas. Furthermore, we introduced theoretical underpinnings to IBL, such as the instructional goals (Abrams et al., 2008), the levels of openness (Blanchard et al., 2010), measures of scaffolding (Hammond & Gibbons, 2005) as well as the Universal Design for Learning (Baumann et al., 2018). Based on this, the teachers revised and redesigned their initial project ideas on the second day. Part 2 of the workshop focused on inquiry in real settings (visit to one research institute) and the teachers' beliefs about inquiry and Nature of Science (Lederman et al., 2013). Beyond that, the teams continued working on their implementation projects and started to create first instruction sheets for the IBL units.

Part 2 of the workshop was followed by the implementation phase. The participating teams successively concretised their IBL units and developed the respective materials. As IBL does not predetermine one specific teaching method, but allows various ways of implementation, it was open to the participating teachers to include aspects of problem-based (technology class), context-oriented, cooperative, autonomous or even project-based learning (Hofer & Puddu, 2020; Mayer & Ziemek, 2006). Upon consultation with the researchers, the planned projects were realised in the following contexts:

- primary school, grade 1, topic: ‘paper’, 9 short IBL units to answer questions like: “How absorbent are different types of paper?” or “How can I make paper particularly stable?”, each lasting 50 minutes.
- middle school, grade 5, topic: ‘wood’, 1 unit lasting 180 minutes
- lower secondary school, grade 8, topic: ‘methods of scientific investigation’, 3 IBL units (one in biology, chemistry and physics each) lasting 50 minutes each, implemented over the course of one week
- Secondary College of Business Administration, grade 9, topic: ‘bionics’, 3 IBL tasks lasting 20 minutes each, small groups of students worked on one of these tasks each
- Higher Federal Technical College for Electronics and Computer Technology, grade 10, topic: ‘field-effect transistors’, 3 IBL tasks lasting 200 minutes overall, implemented en bloc

Planning these units and developing instructional material, the teachers were supported individually by science education researchers, who also visited the teachers in their own schools. By March 2020 (part 3 of the workshop), every team was supposed to have implemented the developed IBL units or have developed their project to such an extent that the teachers could provide an insight into their experiences. Moreover, the teams should outline their future plans.

The research strand

To investigate the questions stated above, we decided to apply a variation of a pre-post design. For this purpose, we conducted a guided group discussion (Cohen et al., 2011) at both the beginning (Workshop – Part 1) and the end (Workshop – Part 3) of the PD programme (see Fig. 1). Both discussions lasted about 60 minutes and were audiotaped and fully transcribed. Between the two group discussions, we informally observed the teachers when they were working on their implementation projects.

To analyse the teachers’ statements from both group discussions, we applied the method of qualitative content analysis combining a deductive and inductive approach (Kuckartz, 2014). Based on the coding manual of Hofer et al. (2018), we initially focused on teachers’ views on learning environment, objectives and scaffolding. Relating to Abrams et al. (2008), we incorporated the three instructional goals for IBL (learning to inquire, learning about inquiry, constructing learner’s scientific knowledge) in a first step and completed the coding manual inductively with categories and subcategories – especially for the category ‘Teachers’ Considerations on Scaffolding’ – in a second step. Tab. 1 provides an overview of the coding system consisting of three dimensions, twelve main categories and several subcategories.

Tab. 1 The coding system for the qualitative content analysis.

Dimension	Main categories and subcategories
Learning environment	Engaging Setting draws interest, arouses curiosity, creates motivation // provides an engaging stimulus // activates students // includes practical work // is designed adaptively Openness general statements regarding openness // question and purpose // students' autonomy // differentiation Grouping Non-personal Requirements
Goals	Learning to Inquire thinking scientifically //developing interest // handling devices and substances //solving problems creatively and persistently Constructing Learner's Scientific Knowledge gaining scientific knowledge through action // understanding relationships // constructing scientific knowledge sustainably Interacting in Groups
Teachers' considerations on scaffolding	Macro Scaffolding Micro Scaffolding Students' Requirements Teachers' Self-Efficacy Teachers' beliefs // Joy of learning // Concealing learning Teachers' Intentions

For the purpose of validation, the data material was coded by two researchers individually including the determination of intercoder reliability (Mayring, 2014). For the dimensions 'Learning Environment' and 'Goals' we could reach a satisfactory score greater than 80%, for the dimension 'Teachers' Considerations on Scaffolding' the score was less than 70%. Thus, we applied the method of peer debriefing to reach an agreement for the codings (Creswell & Miller, 2000).

INSIGHT INTO FIRST RESULTS

To provide an insight into first results of this study, we will depict exemplary aspects of each dimension in the following. As the data for analysis originate from a group discussion, many of the statements arose not primarily from interaction between interviewer and respondents, but rather from interaction between the respondents (i.e. the participating teachers) by themselves. Hence, we did not differentiate between the beliefs and attitudes of individual teachers, but we took the statements as a collective rather than as an individual view (Cohen et al., 2011).

In the first group discussion, the participating teachers regarded IBL as an open, minimally guided instructional approach and, accordingly, also as a counterpoint to teacher-centred classes. Due to its openness, the teachers expressed concerns whether IBL would be effective to fulfil the curriculum (especially in upper secondary school) and how far it could be realised under the prevailing conditions (time, material etc.). In the second discussion, teachers assumed IBL to be a goal-oriented and flexible instructional approach and saw various opportunities to deal with the framework conditions in their own science and technology classes. Nevertheless, a few concerns – in particularly regarding the compatibility with curricula – persisted.

Regarding the dimension 'Goals', the teachers priorly focused on 'constructing learner's scientific knowledge'. In doing so, they emphasised the importance of conducting investigations to gain knowledge and attain sustainable learning through students' activity. At the end of the PD programme, the teachers stated additional goals, such as 'developing interest in scientific issues and science in general'. Moreover, they appreciated the importance of IBL for meeting goals, such as 'handling equipment' and 'learning to inquire'.

Talking about the implementation of IBL, teachers put emphasis on the differences between younger students (who "inquire intuitively") and older students (who "cannot inquire anymore"). Their statements regarding the realisation of IBL units in their own classes remained vague; only few concrete ideas were stated. In the second group discussion, the ideas for implementing IBL increased in number and became more concrete. The teachers introduced issues of classroom management and maintained their view that there are crucial differences of IBL regarding students' age.

DISCUSSION OF SELECTED ASPECTS

Altogether, the results indicate that the teachers extended and deepened their knowledge about IBL in the framework of the PD programme. However, teachers did not refer to the absolute necessity of a question introducing IBL neither in the first nor in the second discussion. Thus, they neglected one of the essential features of IBL defined in the National Science Education Standards (National Research Council, 2000). Another "blind spot" concerns the goals for IBL. As presented in Tab. 1, the goal 'learning about inquiry' is not included in the coding system although we deductively applied the three instructional goals by Abrams et al. (2008) as subcategories. The reason for this is that we could not identify any statements belonging to this epistemic goal of IBL. This raises the question of how teachers can be supported in order to become aware of the importance of Nature of Science. The results from this study suggest that onetime visits of real research institutes – even if teachers have the opportunity to talk to and discuss with the scientists – are insufficient measures for this purpose. Moreover, the statements indicated that a few of the teachers had even problems in conceptualising basic inquiry skill, such as formulating questions or hypotheses. Similar results were found by Priškinová et al. (2020) and by Janštová and Pavlasová (2019), who advocate a frequent implementation of IBL in teacher education and PD.

In the course of the PD programme, the participants' awareness concerning micro-scaffolding (Hammond & Gibbons, 2005) increased. This is shown in the number of statements belonging to this category. While there was just one statement in the first group discussion, we identified ten respective passages in the transcript of the second discussion. Nevertheless, teachers remained still vague in their descriptions of concrete teaching situations – a transfer of the presented instructional strategies to their own teaching has still not been achieved at the end of the PD programme.

CONCLUSION AND OUTLOOK

The findings of this study show that the developed PD programme seems to be appropriate to support teachers in developing and realising IBL units for their own science and technology classes. However, there is scope for improvement regarding teachers' transfer skills and views on Nature of Science.

Inspired by the results of the qualitative content analysis, we aim at conducting an in-depth analysis of the group discussions by applying the documentary method (Bohnsack, 2010). In a further step, the experiences from the PD programme and the findings of both the qualitative content analysis and the documentary method are used to develop a curriculum for an instructional course dealing with IBL in science lessons at primary schools.

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IBSE and Outdoor Education Activates Both Children and Teachers

Kateřina Čiháková

Abstract

Both outdoor education and inquiry-based science education (IBSE) are rather rare phenomena in Czech schools. The contribution offers an insight into the community of teachers motivated to start outdoor education that entered online course "Učíme se venku" (Learning Outdoors) in 2020. We analyse answers from 752 respondents (mainly primary school teachers) to reveal the correlation between the frequency of teaching outdoors and teacher's self-efficacy, knowledge and use of IBSE and the frequency of involving pupils in designing their own experiments. We compare the results of this quantitative study with the opinions about IBSE implementation expressed by experienced teacher mentors in focus group discussion.

Keywords

Inquiry-based education; outdoor education; online course; self-efficacy

INTRODUCTION

Both outdoor education and inquiry-based science education (IBSE) have numerous benefits for pupils´ outcomes and well-being (as summarized in Daniš, 2019), that is well understood by teachers who attend professional development programs (PDP) in order to change their practice, but still are rather rare phenomena in Czech schools (Novosák et al. 2020, Činčera & Holec, 2016). Czech pupils gained above average results in scientific literacy in PISA 2018 compared to other OECD countries, but they regularly get low scores in *Evaluating and designing scientific enquiry* (Blažek & Příhodová, 2016). There is an ongoing debate over the relationship of scientific literacy and the frequency of various inquiry-based instructional strategies (Oliver et al., 2019). However, it is obvious that teachers should enable pupils to experience e.g. "*designing scientific enquiry"* at least in some lessons.

Group of Czech lower secondary school teachers addressed recently by Rokos and Lišková (2020) expressed opinions about limited potential of using IBSE (confirming findings of Papáček, 2010), partly because they were referring to authentic inquiry only, with high demands on pupils´ experience with the hypotheses and experiment design. Radvanová et al. (2018) found out that using IBSE has risen from 3,43% observed lessons in 2012 to 6,82% observed lessons in 2017. However, the results of this study do not tell us which steps of IBSE the pupils really experienced. Frequency of using particular IBSE steps (such as pupils´ questions, involving pupils in experiment design etc.) in Czech primary and lower secondary schools is still unknown. Teaching of science subjects in Czech lower secondary schools is dominated by teacher-centred instruction which was observed by ČŠI (Czech School Inspectorate) in 70% lessons in 2016/2017 (ČŠI, 2018). Correlation was found between test scores in science literacy and the frequency of activating strategies, such as working with graphs and tables. IBSE could not be measured as it occurred in less than 5% of observed lessons. High proportion of teacher-centred lessons usually stems from teachers´ beliefs when the science is perceived as an objective body of knowledge handed down from a knowledgeable authority (Kotuľáková, 2019).

According to the survey on environmental literacy (Novosák et al., 2020) only 30% of schools reported that they teach ecological principles outdoors and 32% reported to use IBSE. Pupils (8^{th} graders) disagreed with the statement "We often learn outdoors". How to start the change of science subjects´ instruction from teacher-centred to more student-centred approach, outdoor education and through inquiry or project-based education in line with recommendation of ČŠI (Novosák et al., 2020)?

According to "influence model" (Lawson & Price, 2003) the main factors for successful transformation of decentralized systems are i) beliefs, ii) skills for change, iii) reinforcing systems and iv) consistent role models. For science education this would mean that teachers (i) understand their contribution to improving pupils´ results in scientific literacy and pupils´ well-being, (ii) teachers have pedagogical and content knowledge and skills to organize the instruction process, (iii) systems of support and rewards maintain new behaviour and (iv) teacher observe respected peers and teacher leaders showing the new type of behaviour and enthusiasm.

Observing teachers who demonstrate mastery of particular method is described as one of the sources of teachers´ self-efficacy (sensu Bandura, 1997). Arguments for outdoor education that could serve for changing teachers´ beliefs are popularised in Czech Republic both through website and Facebook Učíme se venku (over 19 000 fb followers and over 6000 fb group members) and the book *Tajemství školy za školou* (Daniš, 2019) published by Ministry of Environment. These serve as a source of teaching materials, tutorials and in the same time they provide reinforcement and the role models for teachers.

Unlike for outdoor education there doesn´t exist such common platform for promoting IBSE in the Czech Republic so far, although much has been done to disseminate the method by various NGOs and universities (e.g. University of South Bohemia). That´s why we assume that knowledge and use of IBSE will be disproportionally lower even in the sample of highly motivated teachers. It turns out that even teachers who declare knowledge of IBSE in questionnaires have difficulties to characterize it when asked during interviews (Rokos & Lišková, 2020). Additionally, teachers state various barriers for IBSE implementation (time, lack of pupils´ skills, etc.). Enderle et al. (2014) and other researchers point out that teachers can change their beliefs via reflection about classroom practice. Knowledge of IBSE per se doesn´t imply its use, frequency or quality, e.g. the knowledge of IBSE was stated by 66,5% high school teachers, but only 41,7% high school teachers declared the use of IBSE with low frequency (Radvanová et al., 2018).

The quality of IBSE in Czech Republic is not reflected using common framework so far probably because the IBSE is being disseminated through various actors (universities, NGOs). This is in contrast with the situation in neighbouring countries (Poland, Slovakia), where self-reflection and observation tools from Fibonacci project (Harlen, 2012) where translated and used e.g. to assess the outcomes of professional development programs in IBSE (Bernard & Dudek-Różycki, 2020). The reflection of IBSE lessons using the adopted tool from Fibonacci Project was part of PDP Subject Mentoring (Oborový mentoring) described in detail in Čiháková (2020) where teacher-mentors addressed in focus group in this study were trained.

Despite the observable rising trend of knowledge and using IBSE among high school teachers, only 9% teachers allow high school students to design their own experiments monthly (Radvanová et al., 2018). Rokos & Lišková (2020) found only one teacher (out of 41 teachers trained in the IBSE methods) who used IBSE monthly. The knowledge of IBSE and frequency of using IBSE in primary schools is still unknown. According to the "influence model" we should be looking for teachers serving as role models performing high quality IBSE in each school or at least virtually on an online platform. Can we find these teachers among online course participants?

Research questions

1. Is the frequency of outdoor education among teachers participating in online course „Učíme se venku" (Learning Outdoors) correlated with knowledge of IBSE?
2. Is the frequency of outdoor education among teachers participating in online course „Učíme se venku" (Learning Outdoors) correlated with high scores of teachers´ self-efficacy?
3. Is the frequency of lessons when pupils are encouraged to design their own experiments correlated to frequency of outdoor education or teachers´ knowledge of IBSE? Does it differ between primary and lower-secondary teachers?
4. What kind of professional development leads to higher frequency of IBSE? What is recommended by experienced teachers themselves?

METHODS

Online questionnaires were filled by teachers and other educators prior to attending online course "Učíme se venku" (Learning Outdoors) during March - June 2020. The online course consisted mainly of arguments about benefits of outdoor education and inspiration for acquiring and using unsophisticated equipment for outdoor education. Data from 752 respondents (381 primary and secondary school teachers, 160 preschool teachers, 72 home-schooling parents, 88 afterschool club guides, 51 other educators) was used for correlation between frequency of teaching outdoors and using IBSE, their self-declared knowledge of IBSE and the frequency of involving pupils in experiment design.

Dataset (N=381) from teachers´ responses only (256 teachers: ISCED 1- primary schools and 125 teachers: ISCED 2 – lower secondary schools) was used for correlations between the frequency of teaching outdoors, IBSE knowledge and teacher's self-efficacy (TSE). The TSE subscale "effect on school" was applied using 5 point Likert scale (sensu Smetáčková et al., 2017) with the responses later abbreviated as: TSE.opinion – express opinions on important issue, TSE.problem – contribute to solving a problem, TSE.influence- influence decisions at school, TSE.change – enforce change in school practice among colleagues. Other responses were categorized as follows: frequency of teaching outdoors (abbreviated as Outdoors): 0 - never, 1 - rarely, 2 – once per term, 3 - several times per term, 4 – monthly or more often); IBSE knowledge: 0 – method unknown, 1 – read about the method, 2 – attended one workshop, 3 – extensive PDP training; involving pupils in experiment design (abbreviated as Design.Pupils): 1 – never, 2 – once per term, 3 - several times per term, 4 – monthly or more often), planning ("I prepare year plan for teaching outdoors according to observable nature phenomena": 4 – strongly agree, 3- agree, 2 – disagree, 1 – strongly disagree); Using IBSE (1-yes, 0-no); Science (1 - science teacher, 2 – other subject teacher).

All tests were conducted using package R, version 3.3.1 (R Core Team 2018) using function *cor.test.* Relationship between teaching outdoors and frequency of involving pupils in experiment design and teaching at primary school was fitted using generalized additive model with binomial distribution (primary school teacher or not). The additive part of the model (teacher responses) was smoothed using penalized regression splines with parameters selected using the Generalized Cross Validation (GCV) criterion from the package mgcv ver. 1.8-33 (Wood 2004). Mutual relationship among the teachers´ responses were analysed using Principal Component Analysis (PCA) of their correlation matrix. PCA was conducted using package *vegan,* ver. 2.5-7 (Oksanen et al., 2020).

We compare the results of this quantitative study with the opinions about IBSE and outdoor education from teachers who finished long-term program of professional development „Oborový mentoring" (Subject Mentoring) in IBSE, described in detail in Čiháková (2020). The responses were gained in focus group discussion with 8 teachers (6 primary school teachers, 2 lower secondary teachers) in October 2020 lead by 2 teacher educators from Muzeum Říčany. The group was rather diverse: 2 primary teachers have longer experience than 10 years (teaching in small rural school), 3 teachers have 5-10 years' experience (both in large and in small rural school) and 3 teachers have less than 5 years teaching experience. Two teachers work at private schools, one of them in "forest school" where all subjects are taught mainly outdoors. These questions were asked during the focus group discussion: 1. How does outdoor education relate to IBSE according to your experience? 2. What approaches would you recommend to be used at schools to promote IBSE? 3. What kind of peer support and cooperation would you recommend based on experience at your school?

RESULTS

Teaching outdoors and IBSE shows correlation together with other responses as shown by Principal component Analysis (PCA), that divided teachers along the main axis that we interpret as "activity score", where teachers with high TSE, knowledge of IBSE, independent lesson planning and high frequency of teaching outdoors are mostly primary school teachers. The second axis divided teachers with high TSE who are able to induce a change in their schools from those who focus on their own teaching practice (Fig.1).

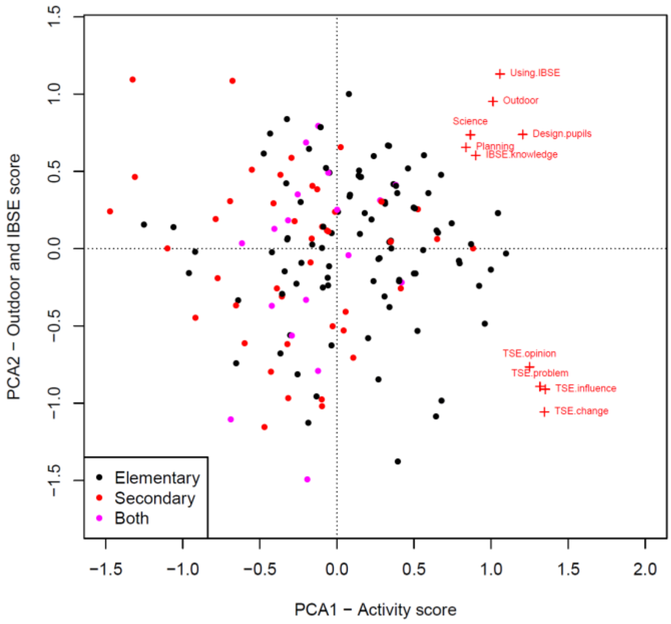

Fig. 1 Principal Component Analysis of teacher responses. The first and second axes explained 38% variability and 17% of variability respectively (Elementary – ISCED 1, Secondary – ISCED 2)

Most primary school teachers teach outside regularly (Fig.2) and involve pupils in designing their own observation or experiments, whereas most lower-secondary teachers teach outdoors rarely and never involve pupils in experiment design.

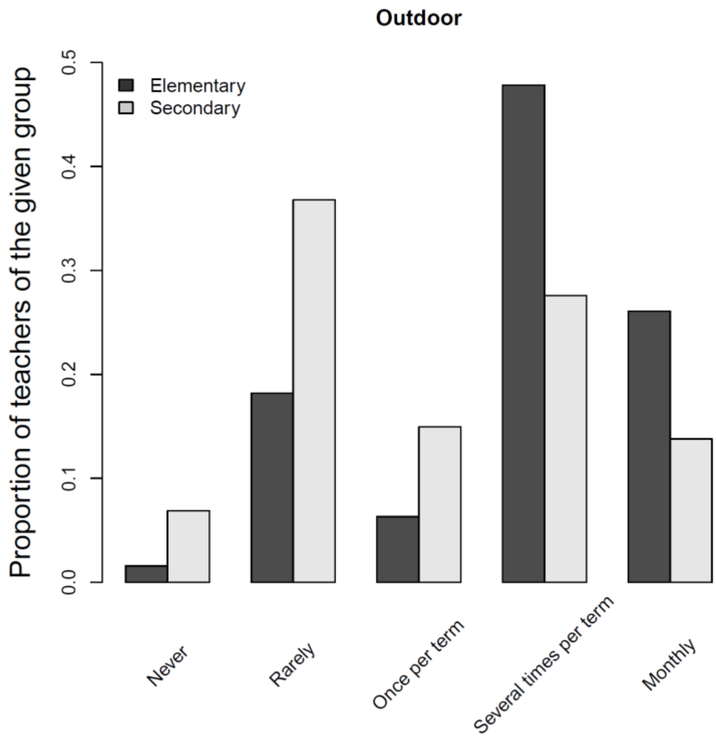

Fig. 2 Proportion of teachers teaching outdoors (Elementary – ISCED 1, Secondary – ISCED 2)

Stronger correlation (Spearman r =0,42) was found between the frequency of lessons where pupils are allowed to design their own experiments and frequency of teaching outdoors (Fig.3) than between teaching outdoors and using IBSE (Spearman r = 0.29) and teaching outdoors and knowledge of IBSE (Spearman r = 0,177).

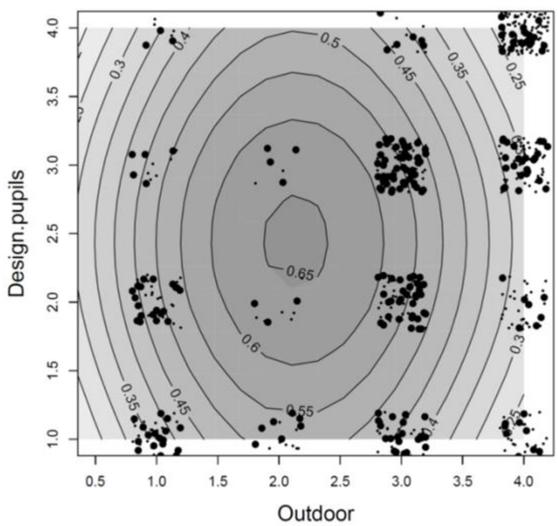

Fig. 3 Frequency of teaching outdoors and frequency of involving pupils in experiment design (Spearman r =0,42*), large points indicate primary school teachers (ISCED 1), small points indicate lower secondary teachers (ISCED 2).**

Although 67,5% of all teachers declared knowledge of IBSE, still over 30% of primary teachers have no knowledge about IBSE. Knowledge of IBSE was not correlated with average scores of teachers´ self-efficacy (TSE). Group of teachers with high self-efficacy doesn´t have no knowledge or experience with IBSE (Fig.4). Teachers participating in focus group have above average scores in TSE, teach outdoors and use IBSE at least once a month, but still report difficulties in promoting IBSE in their schools.

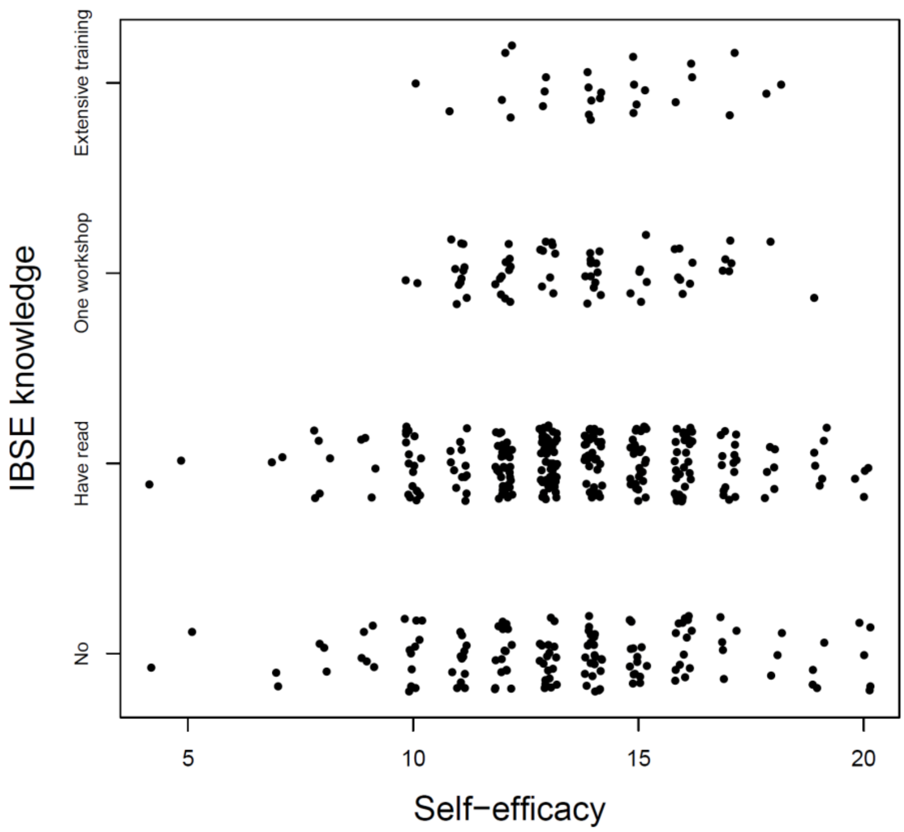

Fig. 4 Relationship between knowledge of IBSE and average scores of teachers´ self-efficacy (TSE).

DISCUSSION

We identified group of teachers among the participants of online course that are highly motivated, teach outdoors frequently, with high scores of self-efficacy and self-reported knowledge of IBSE, using IBSE in their daily practice. This group consist mainly of primary school teachers. We are aware of the fact that self-reported outcomes may not be in line with the reality in the school practice as pointed out by Lee, Hart, Cuevas and Enders (2004). We found that primary teachers report involving pupils in experiment design even though they do not have the knowledge of IBSE. This result is puzzling as this element of IBSE was described in the group of practices that take longer time to adapt and therefore was not reported at all in the study of Polish teachers (Bernard & Dudek-Różycki 2020).

We assume that primary school teachers who do not declare knowledge of IBSE have only vague idea (unconscious incompetence) how to plan experiment correctly using control groups and fair testing

(Harlen, 2006). It would be necessary to observe the lesson using commonly approved tool (e.g. Harlen, 2012) or to assess pupils´ outcomes in test as realized by Kotuľáková et al. (2019) who adopted standard tests from Victoria, Canada. Nevertheless, it is obvious that primary school teachers demonstrate more student-centred approach than lower-secondary teachers in our sample group and they could be trained to perform the elements of inquiry that involve activating pupils and they could serve as role models for their peers then.

Teachers that finished the PDP Subject Mentoring recommend in focus group discussion to develop more video-training and tutorials for IBSE lessons illustrating the particular steps of inquiry (e.g. scientific questioning, experiment design…) to be used together with the self-reflection tools. Furthermore, they suggested teaching in tandem with a colleague experienced in IBSE for implementation of IBSE.

Interestingly we found comparable proportion of teachers declaring knowledge of IBSE (67,5%) as Radvanová et al. (2018) in upper secondary schools (65,5%), but as mentioned above, this does not impose the actual use of IBSE in instruction. This proportion was found in our sample of highly motivated outdoor education enthusiasts and it is probably lower among other teachers.

CONCLUSION

There has been much effort to disseminate IBSE through initiatives of universities or NGOs in Czech Republic, but still the use of methods is rather rare even among motivated teachers. A few videos from IBSE lessons from Czech teachers can be found on website www.badatele.cz, but there is probably a substantial quantity of IBSE lessons videotaped for research, teacher education or other purposes, that were not published yet. Lessons videotaped during PDP Subject Mentoring (*Oborový mentoring)* are now being processed and will be published on Youtube channel Muzeum Říčany.

An ambitious project "Learning Hyperspace for Formative Assessment and Inquiry Based Science Teaching" which is currently elaborated by University of South Bohemia in České Budějovice and Masaryk University in Brno (Závodská et al., 2019) should provide multimedia with rich-media content, including many methodical materials, videos from real STEM instruction and pedagogical diagnostic tools. From our perspective we recommend introducing online courses using videotaped IBSE lessons, verified self-reflection tools, reinforcing systems and role models such as fb groups for teachers interested in IBSE. Apart from online support more trained teacher mentors with high self-efficacy would be needed because without a sufficient and correct understanding of inquiry and the nature of science, there is no reflection or possibility for change.

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LITERATURE

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Pupils' creativity in designing their own experiment within inquiry task in Biology lesson

Lukáš Rokos & Kateřina Martincová

Abstract

The evaluation of pupils' creativity in solving of the inquiry task within Biology lesson was done with a simple coding tool. 53 7th graders participated in the study. The analysis included the evaluation of the correctness as well as the level of creativity in the individual solutions. The overall success rate in solving the task was 47.4% and 37.4% in the point of view of creativity signs. The pupils had the highest success rate in the originality of designing experiment and in the elaboration of the design of the experiment. The pupils also achieved relatively good results in the elaboration of the scheme of the experiment.

Keywords

Creativity; originality; inquiry task; biology lesson; lower-secondary level

INTRODUCTION

Creativity is a very commonly used term in many areas of activities and it is one of the valued skills. Creative person is successful in most fields, they can cope with different conditions, and they are able to come up with a solution to a problem in a fast and creative way. Creativity can be developed from an early age, so it should be embedded in school education. The importance and development of creativity in education is also promoted by the fact that tests of pupils' creativity will be incorporated into the PISA (Programme for International Student Assessment). Teachers should be able to recognise the creative potential of pupils and strive its further development. They can use various methods to develop creativity, e.g., inquiry-based education and problem-based education solving characterized by transfer knowledge in different way, their acquisition, and application in practice.

CREATIVITY

Creativity is characterised as generating new, unusual, useful thoughts and ideas (Dacey & Lennon, 2000; Meusburger et al., 2009). It is a set of abilities presented by artistic, scientific, or other creative activities (Sternberg, 2018). Creative thinking is a prerequisite for problem solving, the ability to recognize issues in a new context, using own knowledge originally or innovatively and seeing suggestions for solutions where they are not obvious at first sight (Guilford, 1967; Sternberg, 2018).

The real creativity emerges at primary school so the teachers should try to implement tasks with divergent character (Dacey & Lennon, 2000). Pupils could be encouraged to ask questions and present their own thoughts and ideas (Ceran et al., 2014; Morais & Azevedo, 2011). The pupil does not have the opportunity to experience failure during creative teaching because there are no right and wrong answers (Snopek, 2008). Creative teachers should try to create an environment in which pupils are not afraid of taking new steps in problem solving (Longshaw, 2009), should promote unpredictable situations, offer pupils space to express their opinions, implement self-assessment and self-criticism into the lessons (Morais & Azevedo, 2011).

If creativity is a part of the teaching process, for example within inquiry or problem tasks, we need to have tools to assess its level. Although there are standardized tools, they are rarely used in their original form and they are shortened or modified (Weiping, 2002). The evaluation of creativity is therefore to some extend burdened by the subjective view of the assessor (Blamires & Peterson, 2014) and the validity of the used methodology.

There are eight categories designed to assess creativity: tests of divergent thinking, attitude and interest inventories, personality inventories, biographical inventories, ratings by teachers, peers and supervisors, judgements of products, eminence, and self-reported creative activities and achievements (Hocevar & Bachelor, 1989, p. 53). The divergent thinking test is used to identify intellectual traits – especially fluency, flexibility, originality, the ability to look at a problem with multiple solutions, and elaboration (Hocevar & Bachelor, 1989). Creative personality can be characterised by six intellectual abilities (Guilford, 1967; Sternberg, 2018), namely, fluency, flexibility, originality, sensitivity, redefinition, and elaboration. We focused on fluency, elaboration, and originality. Fluency ensures the fluidity of ideas or alternative solutions. Elaboration is characterised as the ability to find a solution to the problem or to specify the procedure to create a complete solution (Guilford, 1967; Snopek, 2008). Originality represents a new solution assessed as unique in the group of pupils. "Scientific creativity" is often described as pupils' ability to use basic scientific knowledge to produce simple and original ideas (Pekmez et al., 2009; Stumpf, 1995). For example, pupils apply some theoretical knowledge when formulation their own hypotheses or compiling the procedure for their own experiments (Longshaw, 2009).

The importance of creativity in Czech education is visible in the explicit mention in the list of key competencies in the Strategy of Education Policy of the Czech Republic until 2030+ published by Ministry of Education, Youth and Sports (MoEYS, 2020). The emphasis should be placed on the use of acquired knowledge in creative activities and in team cooperation. Inquiry-based and project-based education are said to be suitable approaches for development of creative thinking and they should be used together with STEM concepts in the modernized curriculum (MoEYS, 2020).

EFFICACY OF INQUIRY-BASED AND PROBLEM-BASED EDUCATION

As it was mentioned above the creativity could be developed within inquiry-based or project-based education. Activities carried out according to the principles of these two approaches often include pupils' practical tasks in the form of observation or performing experiments (Rusek & Gabriel, 2013). However, there is evidence that laboratory works do not always achieve proclaimed goals and may also be ineffective (van den Berg, 2013). It is necessary to formulate clear learning goals (Millar, 2010), pupils should be able to record their learning progress independently, e.g., in laboratory or research diaries (Fiala & Honskusová, 2020) and they should be able to work with equipment based on their thinking operations and not just follow the manual from teacher (van den Berg, 2013).

Of course, the efficacy of inquiry activities also depends on many other factors. If teachers should acquire the necessary competences for the appropriate implementation of this approach into teaching, it is desirable that they get familiar with it during their undergraduate preparation and try them from the point of view of teacher as well as the pupil. For example, it is proven that future teachers have a problem with determining the educational goal of the task (Pavlasová et al., 2018).

We can find two big groups of researches in relation to inquiry-based education and project based education in the Czech Republic. The first group is represented by studies focused on the in-service teachers' perspective on inquiry tasks (e.g., Janštová & Pavlasová, 2019; Radvanová et al,, 2019; Radvanová et al., 2018), respectively the pre-service teachers' perspective (Janštová & Míková, 2019; Vácha & Rokos, 2017) and their ability to solve inquiry tasks (Pavlasová et al., 2018). The second group of researches investigates the impact of inquiry and/or problem activities on the level of acquired knowledge and skills of pupils and students (e.g., Kuncová & Rusek, 2020; Rokos & Vomáčková, 2017; Rokos & Závodská, 2020; Vácha et al., 2020, etc.). The authors usually report a significant positive impact on the level of acquired skills, there is often no significant difference in the case of knowledge and a small sample of respondents does not enable to generalize the results. New studies are action researches and they are more focused on pupils and their solutions of inquiry or problem tasks (e.g., Tóthová & Rusek, 2020).

METHODOLOGY

The task followed a guided inquiry and the pupils investigated the need of water for the plant and the ways of distribution of it through the plant body (see the link at the end of this contribution). The task enabled to develop pupils' creativity (e.g., the possibility to draw a scheme of the experiment) and to encourage pupils to interpret the information found and evaluate the own results of experiment.

Research questions were following: 1) What is the pupils' score in relation to correctness and level of creativity?, 2) What results do pupils have in relation to selected abilities related to creativity in the steps of the inquiry cycle?; and 3) Is there a difference between girls and boys in the correctness and creativity?

Data collection and research sample

A didactic test (in the form of a printed protocol for pupils, see https://tinyurl.com/m9h6bp5d) was used at one elementary school in April 2019. 53 7th graders (28 girls and 25 boys) from the three classes were involved in this study (meets condition for a minimum statistically representative sample – cf. Gavora (2000)).

Didactic test

The didactic test contained nine open items related to steps in the inquiry cycle and pupils had the possibility to return to three of them and try to elaborate them again. Thus, they had space for their own decision-making and expression of their ideas, as well as a subsequent reflection of new knowledge. Each pupil completed the didactic test alone and after that they conducted the experiment in pairs. It took 60 – 70 minutes to complete the whole test and perform the experiment.

Data analysis

The data was analysed with a coding tool (see https://tinyurl.com/cpsx4e4w) derived and modified from tools used for the analysis of a creative product with elements of intellectual abilities that characterize a creative personality (e.g., Weiping, 2002; Pekmez et al., 2009; Siew et al., 2014; Usta & Akkanat, 2015) and Guilford's (1967) structure of creative personality (such as originality, elaboration, or fluency) was used. The pre-prepared four-step scale was used for each item in relation to the correctness and the level of creativity (see the link at the end of this contribution). The evaluation was done by two evaluators independently. Subsequently, the data was analysed using descriptive statistics methods in Microsoft Office Excel and t-test (with significance level 0.05) was used for statistical significance testing.

RESULTS

Didactic tests were evaluated using the coding tool in two levels: 1) in terms of the correctness of the solution and 2) in terms of the level of creativity in the presented solution. In total, the didactic test contained nine items. For each of them, the correctness was assessed and five items were evaluated for different components of creativity. The best possible achievable result of the correctness was 13 points, and on the contrary, the worst possible result was 51 points. Pupils could get 10 points as the best result for creativity and 37 points as the worst result. Therefore, pupils who had fewer points overall achieved a better result. The best possible result in the didactic test was 23 points, while the worst possible result was 88 points. However, since the creative solution may not always be correct, the evaluation of the overall score is to some extent misleading.

Class B had the best average success rate from the three involved classes, but there was a minimal difference from class A (Tab. 1). The best result was identified in the class A with the pupil gaining a total score of 41 points. The classes A and B are taught by the same teacher who tries to involve inquiry tasks in her classes about once a month and develops creative skills among pupils. The lower average result was found in class C that is taught by another teacher who includes the elements of inquiry and creative teaching in the lessons only sporadically. The t-test found a statistically significant difference between the overall performance of boys and girls to benefit for girls ($F_{1,51} = 2.01$; $p = 0.001$).

Tab. 1 Result of classes and the difference between boys and girls (N = 53)

Class	Number of respondents	Average test score			Correctness	Creativity
		total	boys	girls		
A	18	53.33	63.50	51.25	26.61	26.72
B	16	53.25	55.38	51.13	28.37	24.88
C	19	62.32	64.64	59.13	33.53	28.79
Total	**53**	**57.21**	**61.40**	**53.46**	**30.3**	**26.91**

From the point of correctness, it was most problematic for pupils to propose other solutions to the problem or to consider the limits of their procedure. In general, pupils have a problem with the formulation of the hypothesis, as it was found in this study too because only 7.55% of pupils were able to formulate the hypothesis correctly and accurately. More than a fifth of the pupils (22.64%) got the correct results from the experiment and interpreted them correctly, while 56.60% of pupils got the correct results but were unable to interpret them correctly. On the other hand, pupils were most successful in the formulation of the conclusion (77.36%), but they had difficulty in connecting the findings with the initial hypothesis (32.08%). A comparison of the results in relation to individual skills in terms of correctness and creativity is summarised in Table 2. The stress was put on the formulation of the hypothesis, design of the experiment, and scheme of its implementation.

Tab. 2 Summary of results according to the percentage success rate of pupils in selected items (N = 53)

Steps of inquiry cycle	Correctness	Creativity		
		Originality	Elaboration	Fluency
Formulation of hypothesis	67.92%	51.89%	-	-
Design of experiment	43.40%	52.83%	42.14%	
Scheme of experiment	57.23%	-	52.20%	-
List of aids	64.78%	44.34%	-	-
Results	62.89%	-	-	-
Relation to initial hypothesis	30.19%	-	-	-
Proposal of alternative solution	5.03%	6.92%	-	5.66%
Conclusion	58.49%	-	-	-

Girls had an average result of 42.33% for creativity and boys 31.85%, it was a statistically significant difference between boys and girls ($F_{1,51} = 2.009$; $p = 0.02$). Majority of pupils (88.68%) proposed a uniform hypothesis that the plant distributes water in its body from roots to leaves and to all its parts. In terms of originality, 7.55% of the pupils could be considered to have been creative in relation to the whole group. For example, one pupil said: "The plant distributes water from the roots to the leaves, but there may also be plants that take water through the leaves."

In terms of elaboration, 7.55% of pupils proposed a methodology that was highly sophisticated and would lead to a verification of the hypothesis. In 32.08% of cases, the methodology contained shortcomings, 39.62% of pupils had little elaborated methodology, and 20.75% of the pupils did not write any procedure or their methodology was not sophisticated at all. From the perspective of originality, the methodology of 11.32% pupils could be evaluated as creative and originally designed. These solutions were unique and unconventional in the classroom. For example, the following methodology could be considered as an original solution to the problem: "We take two glasses and put some water in them. In one glass, we dip the plant with only roots in water (therefore, the plant will receive water). We dip the flower of plant in the second glass so it will not take water because it has no possibility how to do it."

About a fifth of the pupils (20.75%) created a correct and accurate scheme. However, only in three cases was the correctness of the sketch related to the correctness of the written procedure of the experiment. 20.75% of pupils had highly sophisticated schemes in relation to their elaboration. For most of these pupils, the scheme was also an example of proper procedure.

DISCUSSION

There are not similar researches in the Czech Republic and the comparison with most foreign studies is complicated by the specific concepts of their research designs, which are not fully applicable in the

Czech educational system. Only one selected school participated in this study, so it is not possible to generalize the results. This study had the character of a probe and it will be possible to prepare follow-up research based on its findings.

Compared to other researches, pupils achieved relatively low results in our study. For example, Usta and Akkanat (2015) investigated the scientific creativity of Turkish 7th graders. Respondents in their study were one year younger (i.e., 11 years old) but achieved an average result of 51.34%. Ceran et al. (2014) in the group of pupils aged 9 – 12 found similar results (55.64%). The data was collected using a personal information questionnaire and a creativity test (Ceran et al., 2014).

It was found that pupils have no problem explaining scientific phenomena that are based on acquired knowledge but have a problem with compiling their own experiment. These findings correspond to the results of the PISA 2015, in which Czech pupils showed good results in demonstrating knowledge, but already worse ability to put these knowledge into practice (Blažek & Příhodová, 2016).

When assessing the creative solution of pupils, this assessment has proved to be a highly subjective matter and the use of such tasks for classification seems to be very challenging, as creative solutions may not be the right solutions to lead to the expected results. In this case, the teacher faces the problem of how to evaluate the pupil’s work (Bolden et al., 2020). Self-assessment seems to be one possible approach, in which pupils are asked to which extend they think their work is original (Goldstein & Naglieri, 2011; Kaufman, 2006). In this case, the development of pupils’ creativity and inquiry tasks is combined with another present phenomenon in education, formative assessment (Bolden et al., 2020; Klapwijk, 2018).

CONCLUSION

The simple coding tool was used to evaluate the creativity in pupils’ solving of the inquiry task within Biology lesson. It enabled to identify the differences in the author’s solution of individual pupils, and it was based on the definition of creativity by Guilford (1967) and used the criteria for its evaluation, such as originality, elaboration and fluency (Blamires & Peterson, 2014). 53 pupils from 7th grade participated in the study. The analysis of the protocols included the evaluation of their correctness as well as the level of creativity of the individual solutions. It showed that the overall success rate in solving the task was 47.4% and 37.4% in the point of view of creativity signs. The pupils had the highest success rate in the originality of designing experiment and in the elaboration of the design of the experiment. The pupil also achieved relatively good results in the elaboration of the scheme of the experiment. The girls were more successful in the correctness of the submitted protocol as well as in proposing creative answers. Some pupils were able to design their own innovative solutions in certain steps of the inquiry task, but it could be assumed that the lower success rate was influenced by the not very frequent implementation of this type of tasks in the biology lessons.

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Application of models in the geography teaching process from the teachers' perspective

Martina Škodová

Abstract

The paper focuses on analysing the attitudes of primary school teachers to the use of school models in inquiry-based teaching of geography. Teaching several geographical topics in a transmissive way is very abstract and not very motivating for pupils. The solution offers a research approach supported by the active use of models. The analysis of the data obtained by the questionnaire survey showed that most teachers perceive the positive effects of implementing the evaluated geographical models on the effectiveness of teaching and increase the motivation of pupils. However, in addition to perceiving the models' benefits, their motivation also depends on the methods' time and financial demands.

Keywords

School geography; inquiry-based education; school models; motivation; ISCED 2

INTRODUCTION

We are currently observing a considerable increase and development of didactic active learning tools on a global scale (Janštová & Rusek, 2015). The effort to change the approach to education in Slovakia is also evident from the innovative curricular documents (State Pedagogical Institute, 2014). In the field of geographical education, a constructivist approach is used, representing the starting point for inquiry-based teaching (Bybee, 2006; Rocard et al., 2007), in which the pupil is not offered ready-made knowledge, but he creates it themselves based on the information acquired during research activity and previous experience with the particular phenomenon (Chmúrová & Juricová, 2011). However, the possibility of often observing very interesting phenomena in the country is limited. Many pupils have almost no direct experience with them. Therefore, teaching some geographical topics in a transmissive way is very abstract and not motivating for pupils. The solution offers a research approach supported by the use of models. Besides, if pupils have the opportunity to work and experiment with these models, the degree of the correct understanding of the modeled phenomena and the development of the skills of scientific work increase. However, an essential element in implementing models in the teaching of geography is also the teacher and his belief in the importance of models as teaching aids. The paper presents several possibilities of using models in inquiry-based teaching, as well as the results of a questionnaire survey aimed at gaining teachers' views on the use of specific models in research activities. These activities were created within the ExpEdícia project – try, research, get to know, which seeks to implement a constructivist approach to Geography, among other subjects, through workbooks and methodological support for teachers (more Indícia, 2016).

MODEL AS THE TEACHING AID

Compared to reality, school models represent simplified three-dimensional teaching aids (Crawford & Jordan, 2013), presenting a specific phenomenon or object statically or dynamically (Turek, 2010). Models often miss those elements that are of little importance in terms of understanding the nature of the object or phenomenon. On the other hand, the critical parts are stressed out (e.g. using colours) (Driensky & Hrmo, 2004). In terms of functionality, a distinction is made between models representing an object into details, models representing a principle, symbolic and functional models. Models can be miniatures of large structures or enlargements of small objects. Models and modeling play an essential role in science education. One of the reasons for their inclusion in teaching is that they contribute to "authentic" science education. Models and modeling also allow pupils to think and research scientifically, although research (e.g. Jordan et al., 2017) suggests that teachers perceive school models more as representational and communication tools. The use of models offers a range of benefits from the cognitive area of pupil development through their clarity, facilitating the understanding of phenomena, as shown by Kishore's research (2009) to the impact on pupil motivation (Carnahan et al., 2014). The risks of using models include that with incorrect didactic procedures, pupils can only remember the model, not the concept intended to illustrate, and pupils can mismatch aspects of several different models. The model can also lead to excessive simplification of the concept. Lack of time and material can also be considered an issue (Jordan et al., 2017).

The creation of models and other teaching aids must be realized based on didactic principles (Turek, 2010; Fančovičová & Prokop, 2011). The precondition for these principles to be kept is fulfilling a set of ergonomic, aesthetic, technical and economic requirements (Driensky & Hrmo, 2004; Turek, 2010), which must also be respected in the models.

Didactic methods connected to the using of models

To make the best use of the models' didactic potential, it is necessary to include them in teaching, connected with appropriate methods. The choice of didactic methods for the use of models in school in geography should depend on the learning objective, the pupils, the pupil's maturity, and other factors. The use of models in schools is often limited to the transient demonstration of the observed phenomenon or object by teachers, and students rarely have the opportunity to use these representations to analyze, predict or understand the reasons behind the dynamic processes (Van Driel & Verloop, 1999; Treagust and et al., 2002). Many studies (e.g. Carey & Smith, 1993) in 14 to 18 year olds students confirm that it is more effective if the model becomes a means of active student research

– if models are used as a tool for research and reasoning if pupils have the opportunity to create these models themselves or in groups, create forecasts, experiment, analyse and generalize. For example, in the research of Jordan et al. (2017), up to 80% of teachers of 12 to 15 years old pupils, surveyed defined a model as a way to show, illustrate, explain or represent a scientific concept, while only 20% of teachers discussed the dynamic features of models that help pupils to research. It is possible to use demonstration, heuristic, discussion, problematic, project, situational and staging, manipulation, research, and experimental methods when working with models from didactic methods. It is essential to require pupils to think more deeply about modeled processes and phenomena. Considering the teaching, cooperative (pair, group) teaching in the classroom is mostly used. When creating "live" models, using a school corridor or schoolyard is more suitable considering the space aspect.

Using models in geographical education

Great emphasis should be placed on using different teaching aids and sources of information in the teaching of the subject of geography. Several studies show that students perceive visual teaching aids very positively in geography (Horo & Alam, 2016; Carnahan et al., 2014). In the past, schools were mostly well equipped with globes, telluriums, models of the composition of the Earth or soil profiles, which in many cases are already outdated. New, commercially available models are relatively expensive, and teachers do not have enough leisure time to look for inspiration to create models. Therefore, teachers often prefer static or dynamic projections to demonstrate phenomena or objects on Earth and space (Edsall & Wentz, 2007). However, research of Kishore (2009) confirms, that pupils remember much more when they involve the learning process's senses. Besides, when pupils come to the principles of natural laws or relationships themselves when modeling phenomena, the effectiveness of learning increases even more. A partial solution for older pupils is virtual models (Google Earth, Earth Space Lab.com, etc.) while developing their abstraction and information and communication competencies. However, some research shows that while using a computer is attractive for pupils, it is not significantly helpful for older pupils and students to understand complex geographical concepts compared to physical models. For the pupils with a lower degree of abstraction, physical models are more appropriate (Edsall & Wentz, 2007). It is most appropriate to include methods focused on working with models in the 5th grade of primary school. Partly because the curriculum's content (focused on planetary geography, physical geography and cartography) is very suitable for modeling and increased lessons of geography compared to other primary school grades. In addition to static or dynamic models created from available materials such as water, ice, play dough, foam, paper, foil, polystyrene, sand and other natural materials and objects such as a lamp, globe, various balls, containers, etc. it is also possible to create a "live" model, where pupils represent its static or dynamic parts (e.g., live map or solar system), which, among other benefits, also supports the movement activity of pupils in the lesson and their coordination (Jain, 2004). Since the objects and events demonstrated by school models are very simplified compared to reality, it is the teacher's task to discuss what the model corresponds to and what does not correspond to the real situation and what information obtained through the model can be generalized.

AIM AND METHODOLOGY

The research aims to evaluate the view of teachers on the use of models in the teaching of geography, implemented activities using inquiry-based education created within the project ExpEdícia – try, research, get to know (n.o. Indícia). The research was carried out concerning the following research questions:

1. Research question 1: To what extent are teachers motivated to use models?
2. Research question 2: What is the teachers' opinion of models' effect on students' motivation?
3. Research question 3: To what extent do teachers assess models' usefulness in acquiring knowledge and skills?

The respondents were 9 geography teachers (N = 9) from eight pilot primary schools (4 private, 2 church and 2 state ones) from seven cities in Slovakia involved in the particular project. The teaching of research activities using models was led by pilot teachers (respondents) in the years 2018 to 2020 in 118 classes (approximately 3,000 pupils in the 5th year of primary school) (Tab. 1).

Teachers evaluated models in thirteen inquiry-based activities from the ExpEdícia workbooks for the 5th year of elementary school (Schubertová et al., 2019a, 2019b; Škodová et al., 2020) (Tab. 1). The activities follow the State educational program (State Pedagogical Institute, 2014). According to Bell et al. (2005), activities have structured research with a research cycle based on Llewellyn (2002). They use several features of constructivist teaching (Murphy, 1997).

After verifying the models in practice, we obtained feedback on several aspects of their use through a questionnaire survey (10 questionnaire items for 13 models, 130 items). The items of the questionnaire focus on three areas: 1. Motivation of teachers to use models (3 items – I would be willing to do the activity with this model again**.** The creation of this model is not time/financially demanding), 2. The impact of the model use on the pupils´ motivation (3 items – This model was interesting for the pupils. Pupils knew how to make the model or work with this model. I think that pupils feel safe and relaxed while making or working with this model), 3. The usefulness of knowledge and skills acquired through using models (4 items – The use of this model makes teaching more effective. The pupils were more active than teacher in the creation and demonstration of this model. Making or working with this model helped the pupils to understand the given natural phenomenon. This model involved all pupils).

Respondents in most items chose a value on a five-point Likert scale (from 5 – definitely yes / strongly agree to 1 – definitely no / strongly disagree).

Tab. 1 An overview of proven models used in inquiry-based activities in the 5th grade of elementary school.

No	Model	Topic	Characteristics	No. of verif.
M1	Mountain range model	Surface contour lines	Pupils create a mountain range model with the modeling material, cut it into slices and create contour lines by drawing them on paper.	17
M2	Cloud in a bottle	Processes in the atmosphere	Pupils create a cloud in the glass using hot water, ice and spray.	16
M3	Rain in the bottle		Pupils use water, foam and colored water to create rain in the cup.	14
M4	Sand landscape model	Water activity in the landscape	Pupils model the activity of the river in the sand countryside model.	12
M5	Golf stream model	Sea currents	Pupils observe the effect of air blowing on a model of a Gulf Stream in a container of water.	1
M6	Lithospheric plate model	The internal structure of the Earth	Pupils model the movement of lithospheric cardboard plates on the surface of the water in the container.	11
M7	Seismograph model	Earthquake	Pupils create a seismograph from a box and a hanging pencil.	11
M8	Wrinkle layering model of the Himalayas	The formation of mountains	Pupils model the wrinkling folds of the mountains by compressing the layers of sand and flour laterally.	8
M9	Pocket globe	What we see on the globe	Pupils draw fundamental parallels and meridians on a polystyrene ball on a stick and using this globe, they determine the continents' position.	6
M10	Diorama	Types of countries on Earth	Pupils from different materials form dioramas of the desert, savannah, etc. and present them.	10
M11	A "live" model of the Earth's rotation	Time zones	Pupils create a "live" rotating Earth and observe how its parts are illuminated during the day.	2
M12	A "live" model of the solar system	Solar system	Each pupil in the group represents a different body in the solar system; the "live" model is demonstrated by pupils.	6
M13	Moon is a ball	Phases of the Moon	Pupils divided into couples light using a flashlight in a mobile phone and the ball and observed its illuminated part.	4

We analysed teachers' answers within the individual questionnaire items, both quantitatively and qualitatively, based on nine completed questionnaires. We used statistical techniques, such as the average of the obtained absolute and relative scores of evaluated areas within individual activities and cumulatively for all activities.

RESEARCH RESULTS

The way a teacher decides to use models can vary greatly. The main factor in the effective use of models is whether they can use them for pupils' research activities, not only as a tool for demonstrating and describing phenomena in nature. We ensured the meaningful use of models so that teachers used a set of inquiry-based activities and methodological materials for their implementation. The questionnaire survey results showed that all interviewed teachers think that modeling natural phenomena in geography are justified. Some models were included in teaching often (M1-M3), some only 1 or 2 times (M5, M11) (Tab. 1). The motivation for this frequency is especially the complexity of implementing models (financial, time), or the topic of the modelled process or object. The motivation of teachers to use activities with models is expressed in Figures 1-2. The view of teachers on the influence of models on the motivation of pupils is clear; most teachers see their great potential in this area (96.5% of the maximum possible score, Fig. 1). The highest scores were achieved by the M1, M2, M9 and M12 models (Fig. 2). The perception of individual models' usefulness in acquired knowledge and skills is expressed in Figure 2. Teachers considering this aspect rated the best models M9, M10, M12 and M13, on the contrary, as less useful – they claimed model M5 (however, this may be distorted by the low frequency of M5 verification.

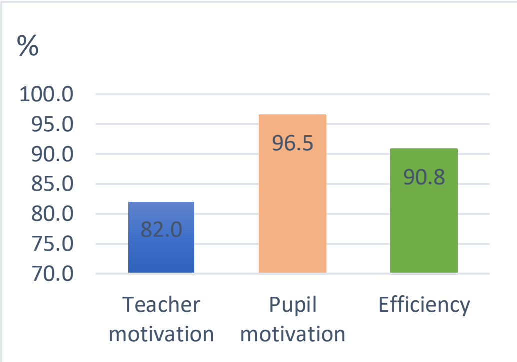

Fig. 1 Average relative scores of evaluated models within the monitored fields.

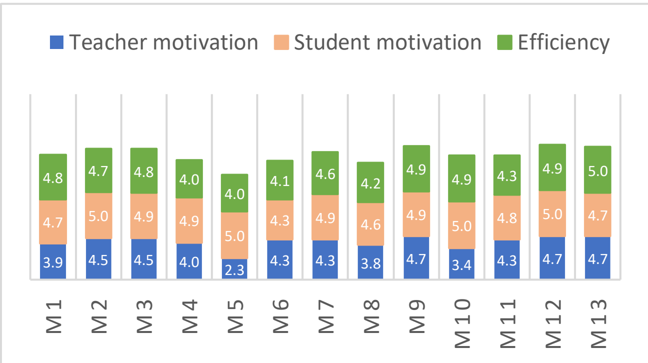

Fig. 2 Average scores per teacher within the evaluated areas and individual models

DISCUSSION AND CONCLUSION

The use of school models enables the involvement of pupils in authentic scientific thinking. However, the implementation of inquiry-based teaching using models requires the teacher to be convinced of its meaningfulness and effectiveness. This approach directly depends on the teacher's specific skills and abilities to lead such oriented teaching and the teacher's motivation. A great benefit is practical instructions for implementing such teaching with the possibility of reflecting on possible issues.

Therefore, we created 13 methodologies of inquiry-based teaching supported by the use of models, verified by nine teachers from practice and gave us feedback on the effects of using models. Due to their long experience with inquiry-based teaching, the questioned teachers mostly perceived the models as teaching aids enabling pupils to research, not just to present concepts, as suggested by other research (e.g. Carey & Smith, 1993). Teachers agreed that the most significant benefit of using models is increasing pupil motivation and a deeper understanding of scientific phenomena. These results are consistent with the findings of Jordan et al. (2017). Therefore, we can confirm that teachers perceive the positive effects of implementing the evaluated models on the effectiveness of teaching and increase pupils' motivation. However, teachers' motivation to use models also depends on the time and financial demands of specific models.

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Effectiveness of Project-based Education: A Review of Science Education Oriented Papers

Martin Rusek

Abstract

In this paper, attention was given to proofs of project-based education (PBE) effectiveness and other related issues reported in recent literature oriented on science education. First, PBE method is set into a context together with problem- and inquiry-based education. Second, a literature search was conducted resulting in 77 papers published on this topic. After a more detailed evaluation 18 papers which fit the scope of the research were analysed. Reported values of PBE's effectiveness reaching up to 97% suggest that when implemented carefully PBE outperforms the traditional teaching approach. Apart from the effectiveness, the analysed papers offer insights into the state of the art which is transformed into concrete implications for teachers, students and researchers in this paper.

Keywords

Project-based education; method effectiveness; science education; literature review

INTRODUCTION

The main goal of the PBE conference (Project-based education and other activating strategies in science education – pbe.pedf.cuni.cz) has been to promote the student-centred approach (Armbruster et al., 2009; Granger et al., 2012; Kaya, 2008) in science education. Apart from examples of good practice in terms of:

- integrated thematic education units (Šindelková et al., 2016),
- inquiry-based activities (Fiala & Honskusová, 2020; Kuncová & Rusek, 2020; Teplá et al., 2020; Vojíř et al., 2019) or
- projects (Hlavacova, 2016; Machková et al., 2016; Rusek, 2015; Vojíř, 2020).

There were many other papers published on these methods (Rusek & Vojíř, 2018). However, their effectiveness has been evaluated only partially via activities' effect on students' knowledge, skills, or attitudes. For this reason, in this paper, proofs of project-based education's effectiveness are analysed in order to provide more theoretical background for the ongoing activities in this respect.

THEORETICAL BACKGROUND

For more than a decade now, a goal standing above individual curricular objectives emerged – 21st century skills (e.g. Bellanca, 2010; Hiong & Osman, 2013). One of the most commonly used infographics depicts their division into three domains: foundational literacies, competencies and character qualities (see Fig. 1). Another, considerably wide stream, - *scientific literacy* - was mentioned as a part of the 21st century skills, however it is seen as the goal of science education by the OECD. It has been brought into broad public's attention especially by PISA research. It represents a person's ability to: explain phenomena scientifically, interpret data and evidence scientifically, evaluate and design scientific enquiry (Co-operation & Development, 2016). Another approach sees it as a combination of *scientific terms and concepts, nature of science* and *interaction of science with society* (Murcia, 2006).

With regards to curricula (cf. e.g. Elmas et al., 2020), this outline directly suggests innovation as mere subject-matter focused performance very probably does not lead to these skills' development. Several authors (see Johnstone, 2010; Vojíř & Rusek, 2020) suggest there is still a considerable persistence of the traditional approach towards science education. The so-called curriculum time lag (OECD, 2020) leads to the use of obsolete textbooks long after a new curriculum is brought into action or even new textbooks being written based on former curricula (see Vojíř & Rusek, 2020).

A shift from the traditional to the above-mentioned seems to require a solid evidence not only for teachers but also for other curriculum stakeholders. In this respect, there are national tests, controls by ministerial organs such as school inspectorates or the already-mentioned international surveys such as PISA, TIMSS, PIRLS etc. From the Czech perspectives, the information from these resources accordingly suggest a considerable room for improvement (see Blažek & Příhodová, 2016).

As suggested above, a key to a successful education is a participating active learner. As far as *topics* are concerned, real-life or relevant topics as well as science in context (Díaz et al., 2018; Elster, 2009) are a key agent in student activisation. In one of his renowned papers, Alex Johnstone published asked a question whether we can get *there* from *here* (Johnstone, 2010). He suggested the need for a change within chemistry education based on complete reconsidering the steady subject-matter order or even out-of-date information which remain in the curricula simply "because it has always been so". This phenomenon only leads to school science being its own world as it neither reflects contemporary state of the art, neither matches the students' needs. Rather than "having *students learn* science" education aims at "*teaching* students *about* the *history* of science". In addition, sufficiently complex goals accent social interactions and provoke sharing knowledge and understanding within an interest group.

Several methods connect the aforementioned aspects. Their effectiveness is known from several meta-analyses. First, Problem-based learning (PBL), a method based on participants' encounter of a discrepant event or other unexpected situation which drives them from their comfort zone, builds on participants sharing goals through collaboration (Barrows, 1996; Duch et al., 2001). From 21 meta-analyses covering 794 studies on 96 275 students, we can learn that the mean effect-size of PBL in comparison to traditional education is .35 (medium effect-size), however it is .57 when only studies from the last decade are considered, which suggests a large power of the effect.

Second, *Inquiry-based education* (IBE), or Inquiry-based science education (IBSE) in a way expands PBL adding the focus on experimentation or inquiry. It is also built upon students' active role which is initiated by a research question, problems and scenario. The method is quite old (see Schwab, 1960), however experienced a revival especially after the so called Rocard's report (Rocard et al., 2007) publishing. There are eight meta-analyses covering 353 studies on 15 728 students available for IBSE effectiveness assessment. Similarly to the previous case, the mean effect-size is .46 medium, however .72 (large) when only the last decade is taken into account (*Visible LEarning Metax*, 2021).

The two described methods intersect in their focus on: centrality, driving question, constructive investigations, autonomy (students' collaboration) and realism (Thomas, 2000). Kwon et al. (2014) also mention students' presentation. By adding a focus on a product or an artefact, such activities are considered projects (PBE) (Blumendelf et al., 1991; Helle et al., 2006).

The importance of distinguishing between ordinary school activities, integrated thematic education and project-based education has already been discussed in the literature (Rusek & Becker, 2011; Rusek & Dlabola, 2013; Šindelková et al., 2016). PBE's parameters can be summed up as follows:

- engages students in complex, real-world tasks resulting in a product (Barron & Darling-Hammond, 2008),
- builds upon new knowledge transformation and reorganizing prior knowledge (Blumendelf et al., 1991; Thomas, 2000),
- enforces students' investigations (Thomas, 2000),
- offers an environment in which students and teachers come together (Barak & Raz, 2000).

GOALS AND METHODS

In this paper, a literature review focused on project-based education's effectiveness is described. Special attention is given to the sample, methodology and tools used for PBE effectiveness' evaluation.

For this purpose, the following combination of key was used:

TI=((project-based OR project) AND (education or teaching OR method OR learning)) AND TI=(effectiveness OR effect OR evaluation) AND TS=((science OR chemistry OR biology OR physics OR geography OR STEM) AND (teaching OR instruction OR learning OR education))[1]

The search was performer on the Web of Science core collection. The results were refined to:

- papers published after 2000,
- journal papers and conference papers,
- papers in English or Czech.

The resulting number of 77 papers' abstracts were subsequently submitted to an analysis. 14 papers were found suitable for a thorough analysis. The reason for the other papers' exclusion was mostly their focus on different field but science education (medical, technical, IT etc.), different meaning of the "project" word or the aim of papers different than the method evaluation. To support the body of research, a secondary search focused on literature reviews and/or meta analyses was performed. This search added another four papers. Altogether, 18 papers were submitted for the analysis.

REVIEW RESULTS

General findings

Papers of this nature have been appearing since 2010. Journal articles prevail, over a considerable number of conference papers was noted. Authors focus on the following aspects of PBE's effectiveness:

- junior high students' scientific literacy development (Tati et al., 2017),
- secondary school students' physics problem-solving skills (Parno et al., 2020),
- American high school students' math and science achievement (Craig & Marshall, 2019),
- Secondary school teachers' attitudes towards STEM (Kampe et al., 2011),
- pre-service teachers self-efficacy and science and technology teaching achievement (Bilgin et al., 2015), creativity or ability to process data (Retnowati et al., 2018),
- six year olds' level of Nature of Science concept (Can et al., 2017),
- seven graders' academic achievement and motivation towards science (Kizkapan & Bektas, 2017).

[1] TI stands is used to search in the title, TS in the topics (keywords and abstracts).

As far as the literature reviews are concerned (Hasni et al., 2016; Chen & Yang, 2019; Kokotsaki et al., 2016; Markham et al., 2003; Thomas, 2000), reported PBE effectiveness' has been improving from Thomas' (2000) results up to 2000 over Markham et al.'s (2003) results up to 2012 to Chen and Yang (2019). In their meta-analysis, they concluded the effect is growing up to the 97% effectiveness of PBE (Chen & Yang, 2019) by 2018. Other authors, however, are more conservative. Kokotsaki et al. (2016) concluded that PBE is too complex to be measured. This is also the reason there are not so many studies compared to PBL or IBSE. Other issues why PBE's effectiveness research is quite limited is the need to work with an actual classroom on an actual curricular objective for a considerable amount of time. This, naturally, violates pure educational research conditions – lack of random sampling or student distribution into experimental and control group (Kokotsaki et al., 2016). For this reason, it is complicated to declare a casual link between the use of PBE and students' improvement in any of the observed areas. A systematic data collection combining closer foci on particular aspects of student development would bring more reliable data in time.

In addition to the above-mentioned methodological issues, Chen and Yang (2019) concluded that only a limited number of papers focused on PBE effectiveness' evaluation include reliable data with reported effect-size. They concluded most studies focus on PBE's effect on students' academic achievement. The authors studied a broader share of the literature. They concluded that PBE is reported to be more effective in social sciences, technology and science & mathematics than in other disciplines. Out of the mentioned, PBE was the most effective in social sciences. However, most studies focused on PBE in science education. This could be caused by their nature which is not transformed into an integrated school subject in many countries (cf. Blonder & Mamlok-Naaman, 2019).

Tools used to assess PBE effectiveness'

As far as the most common research methods are concerned Chen and Yang (2019) found pedagogical-experiment to be the most frequent method within PBE effectiveness' research. Thys et al. (2016) identified surveys and questionnaires to be the most frequent, followed by observation protocols and document analysis.

In their work Thys et al. (2016) provided an overview of tools available for PBE effectiveness' evaluation. Apart from the quasi-experimental setting, there is a solid body of instruments ready to be used or at least to be adapted for use in international conditions. With respect to the PBE conference's mission (Rusek & Vojíř, 2018), verified research tools' use will only bring increase of research reliability, higher comparability and more evidence into this area (cf. Chen & Yang, 2019).

Thys et al. (2016) identified the following groups of tools:

- Anticipating students' prior knowledge and background (Teacher's anticipation scale, students' engagement, teacher's communication etc.),
- Connection to reality (project topics' connection to real world context, personal relevance),
- Science as inquiry (scales, observation sheets and guidelines for experiment implementation),
- Interesting activities (engagement and active participation sheet, satisfaction scale),
- Groupwork (providing opportunities for groupwork, sustainability of materials and activities, scientific discourse scale, etc.),
- Level of initiative (level of students' freedom, critical voice scale, shared control etc.),
- Fostering understanding (scales addressing understanding, phenomena representations, working on models or simulations, etc.),
- Use of new technology (availability, use or satisfaction with technology in the classroom),
- Teacher's intervention (teacher's encouraging students, opportunities provided by a teacher, teacher's intervention with their students' work),
- Teacher's content knowledge,
- Evaluating students' understanding (summative and formative evaluation tools, instruments assessing evaluating tools' fitness with respect to learning goals, profound understanding assessment, etc.).

DISCUSSION AND CONCLUSION

This paper brought an overview of the state of art in the field of PBE effectiveness' evaluation. Despite the numbers look good (97% effect), PBE being more effective than traditional teaching, several methodological issues affect the findings and they, therefore, need to be interpreted cautiously. With a certain simplification, PBE's effectiveness could be considered increasing. This might be due to an increased body of research as well as practical examples. Also, this could be due to improved research tools which help capture particular aspects of PBE providing data.

The author of this paper stresses the importance of a certain terminological purity as far as project-based education is concerned, so it would be possible to further refine information about its effectiveness and, more importantly, provide information how to put it into school practice. For this reason, this paper also contains an overview of already created and used instruments for a wide range of aspects which can be evaluated on.

The data showed that there is a promising body of research showing a proof for student-centred methods inclusion in education. These arguments could be used to persuade conservative teachers to include these in their teaching practice (cf. Rogers, 2003).

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Slovenian Chemistry Teachers' Understanding of Project-based Learning

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Abstract

The popularity of PBL is constantly rising. However, PBL is hard to understand and therefore harder to implement in schools. The study deals with the topic of understanding how Slovenian chemistry teachers understand PBL and implement it in their teaching of chemistry or related subjects. 130 responses were gathered through questionnaire which was sent to Slovenian chemistry teachers of all lower secondary and general upper secondary schools. Results show that teachers barely understand PBL and that contrary to their opinion they do not use frequently PBL in practice. Project-based learning is often confused for problem-based learning, which is the main confusion for the teachers. Respondents believe that, because of extensive curriculum and lack of time, it is not possible to fully implement PBL in Slovenian secondary schools.

Keywords

Project-based learning understanding; chemistry teachers; secondary chemistry education

INTRODUCTION

World is rapidly changing as new technologies are being developed and new discoveries being made. These changes require new knowledge and skills, which should start developing already in lower and upper secondary education. Therefore, over the last few decades, the educational system has been improving, introducing new teaching methods as well as technology in schools worldwide. One of those methods is also project-based learning (now on PBL). PBL is a teaching method through which students gain knowledge and skills while working on a project for an extended period of time and create own project (Bilek & Machkova, 2014). They investigate and respond to an authentic, engaging, and complex problem (Kokotsaki et al., 2016). Even though PBL is a popular method, it is difficult to understand and therefore improperly implement in schools. In our research we wanted to investigate how Slovenian chemistry teachers understand PBL, and how do they implement its characteristics in their teaching of chemistry or chemistry related subjects (Bujas, 2020).

AIM AND RESEARCH QUESTIONS

We noticed that many schoolteachers believe that PBL is rarely or almost never used in chemistry and science teaching. The problem starts already at understanding the term project-based learning. The term is often confused for project work, which is a concept of its own. Therefore, we wanted to provide data that supports the theory – chemistry teachers have misconceptions about PBL. With that in mind, we set following research questions:

- R1: How do chemistry teachers define project-based learning?
- R2: How do chemistry teachers incorporate project-based learning activities in their classes?
- R3: Are there differences between lower and upper secondary chemistry teachers in understanding of project-based learning?
- R4: Are there differences between chemistry teachers from different Slovenian regions in understanding of project-based learning?
- R5: Are there differences between chemistry teachers with different teaching experience in understanding of project-based learning?
- R6: Are there differences between chemistry teachers who teach only chemistry and those who teach additional subject(s) in understanding of project-based learning?
- R7: Do chemistry teachers implement PBL in its full definition?
- R8: Are there any obstacles for project-based learning implementation in chemistry teaching?

RESEARCH METHODOLOGY

The research was based on the survey, which was sent to all the lower and general upper secondary school chemistry teachers in Slovenia. The survey consisted questions on PBL definition and 3 clusters of statements on which respondents agreed on Likert's scale:

1. List of statements describing PBL characteristics.
2. List of statements describing a teaching style closely connected to PLB characteristics.
3. List of statements describing specifics of a project in PBL.

The accuracy of the teachers' definition was graded with Rubrics assessment. The Rubrics offer criterion for grading subjective assignments, it provides clear and defined goals (Rubrics: useful assessment tools, n.d.). We used analytic rubric which grades responses by specific component. The task specific Rubrics assessment (such as ours) is used when one wants to know whether "respondents know particular facts, equations, methods, or procedures" (Arter & McTighe, 2001, p 28). We added a percentage value to each component (word) of the definition. We derived the words from multiple descriptions of PBL, basing it mainly on the following definition: "Project Based Learning is a teaching method in which students gain knowledge and skills by working on a project for an extended period of time to investigate and respond to an authentic, engaging, and complex question, problem, or challenge." (What is PBL, n.d.). The gathered data was processed in IBM SPSS Statistics 25.0. We used Mann-Whitney U test for the differences between two independent samples, Kruskal-Wallis for the differences between more groups of an independent variable and Chi-square tests. The Cohen's *d* effect size, which indicates the standardised difference between the means, had also been calculated.

Sample

We gathered 130 responses out of which 95 were lower secondary school teachers and 35 general upper secondary school teachers. Meaning, according to a qualified estimate, 73.1% of Slovenian lower secondary chemistry teachers and 26.9% of general upper secondary chemistry teachers. In the sample, 53 out of 130 respondents teach only Chemistry, while 19 teach also integrated subject Natural sciences, 18 also Biology, and 36 also both Natural sciences and Biology. Respondents are teaching across whole Slovenia, covering all 12 statistical regions. These are mostly teachers of age 40 or higher (73.8%). When it comes to teaching experience, 50.7% have been teaching more than 20 years, 30% between 10 and 20 years 11.5% between 3 to 10 years and only 7.7% under 3 years.

FINDINGS

From the responses we can define that 66% of respondents stated that they use PBL in their class, when 34% do not. More than 50% of teachers use PBL in regular chemistry class, following with 33% using it in optional chemistry related class and approx. 27% using it when working with talented students.

Defining PBL

The evaluation of teachers' PBE defining we used rubric. We assigned points for the words which should be used in PBL definition. More crucial words were appointed more points (such as authentic, project, problem) and less points for less important (often occurring) words (such as knowledge, teaching, extended time period). Each definition was appointed points for the words used. From rubric assessment, only 11.5% definitions gathered 50 or more points out of 100. Out of those, only one person gathered 80 points, which is also the highest score. Teachers who stated that they use PBL have gathered higher points than those who did not. The word that was most used in the definitions is "investigating" (41%). Highly ranked definitions also mentioned "complex problems" and "student-driven activities". On the other hand, only 7% of the definitions contained the word "product", meaning that the respondents most probably do not differentiate project-based from problem-based learning.

Opinion on PBL characteristics

Majority of teachers agreed that school projects engage students in constructive investigation (71.5%), are realistic and relevant (47%) and student driven (63%). They also agree that students detect problems (61.5%), should do the research on relevant topics (69%), and need to analyse the results of the research they do (84.5%). However, 52.3% of the teachers do not agree that PBL should be central and not peripheral activity to the Slovenian chemistry curriculum. There were significant differences in answers of teachers who teach only chemistry and those who teach additional subject. Latter agree in higher percentage that PBL should be central to the Slovenian chemistry curriculum (p = 0.01; d_{Cohen} = 0.563).

PBL in teaching styles

Teachers are indecisive when asked if they would describe themselves as mentors or lecturers – 23% answered mentor, when 38.5% answered lecturer. On the other hand, 38.5% are also neutral and don't see themselves as strictly mentor or strictly lecturer. Most respondents (68.5%) stated that they decide which activities are done during the PBL activities, minority (9.3%) consequentially stated that students decide on the activities done. Respondents also believe that their classes are interdisciplinary, engage students into critical thinking and provide frequent feedback to students. Somewhat more lower secondary school teachers have interdisciplinary classes (p = 0.009; d_{Cohen} = 0.446) and provide frequent feedback (p = 0.003; d_{Cohen} = 0.491) than the upper secondary teachers. Interestingly, more teachers who teach additional subject also graded their classes interdisciplinary than those who teach only chemistry (p = 0.043 d_{Cohen} = 0.443). More teachers of age under 40 and over 50 believe they engage students into critical thinking than those age 40 to 50 (p = 0.025; d_{Cohen} = 0.419).

Specifics of PBL project in teachers' class

Majority of respondents stated that students research on relevant information (73.8%), analyse the results of the research done under the project (69.2%), work in teams (78.5%), present their school project work (85.4%), develop techniques for analyzation of the project results (47.7%) and have a choice on how to report their school project work (66.2%). Nevertheless, most teachers are neutral when it comes to students detecting problems (43.1%), deciding on the research topic (36.2%), and establishing the criteria on which their school project work is assessed (29.2%). Higher number of general upper secondary teachers (80%) believe that students research relevant information during the school project (p = 0.048; d_{Cohen} = 0.329). More lower secondary school teachers (22%) believe that their students develop techniques for analysation of the school project results (p = 0.014; d_{Cohen} =0.491) and 24% more that the students establish the assessment criteria (p = 0.001; d_{Cohen} = 0.619). Teachers who additionally teach biology or both biology and natural sciences agreed in higher percentage (50%) that students establish assessment criteria for the project work (p = 0.019; d_{Cohen} = 0.308). Students from Carinthia (100%) and Littoral-Inner Carniola (57%) decide on the research topic of the school project significantly more (p = 0,035; d_{Cohen} = 0.555) than those in other regions. Teachers from Drava

(91%) and Littoral-Inner Carniola (100%) believe that their students research on relevant information during the school project (p = 0,012; d_{Cohen} = 0.663). Over 70% of respondents from the Mura and Carinthia region tend to include students in establishing criteria while others not as much (p = 0.036; d_{Cohen} = 0.55). Over 30% Central Slovenia teachers do not assess project formatively, while in other regions less than 5% do not. Teachers of the age 40 to 50 tend to only slightly agree that students present project work to others, choose how to report the work and that their work is being assessed formatively, whereas those under age 40 and over 50 agree fully.

Limitations to the PBL implementation

Exact 50% of respondents stated that PBL can be fully implemented in Slovenian schools and other 50% that it cannot. Teachers listed in total 14 limitations for the implementation of PBL in schools, which frequencies are visible in Table 1. Most frequently limitations are lack of time and prescribed curriculum.

Tab. 1 Limitations to PBL implementation

Limitation	N	F (%)
lack of time	70	53.8
Curriculum	50	38.5
student's susceptibility	25	19.2
high number of students in class	20	15.4
teacher's work overload	20	15.4
various students' abilities	17	13.1
teacher's susceptibility	16	12.3
inadequate equipment	16	12.3
lack of money	10	7.7
lack of students' knowledge	9	6.9
lack of teacher's knowledge on PBL	8	6.2
grading difficulties	8	6.2
prescribed final exam (matura) lessons	7	5.4
student's overload	3	2.3

PBL in practice

According to the lists of statements in the survey, which described typical PBL characteristics, we could get a rough view on each individual respondent and his understanding and usage of PBL. Respondents ranked how much characteristics apply to their teaching on Likert's scale from 1 to 5, 1 being "False" and 5 "True". Therefore, for one statement (characteristic) a person could've gained a maximum of 5 points and a minimum of 1 point. Table 2 shows how many points did the respondents reach, hence in what amount do they use PBL characteristics in practice.

Tab. 2 PBL characteristics usage points

Points (/80)	N "I use PBL"	N "I do not use PBL"	N total
21 – 30	1	1	2
31 – 40	1	0	1
41 – 50	9	8	17
51 – 60	37	20	57
61 – 70	37	13	50
71 – 80	1	2	3

DISCUSSION

Majority of teachers had trouble to define PBL correctly. The definitions were too vague, broad, and easily mistaken for problem-based learning. According to Krajcik and Shin (2014) the project must involve the creation of a tangible product that addresses the driving question of the unit or curriculum and offers a physical representation of student learning. In our study, only 28% of teachers mentioned product in their definitions. Interestingly, the teacher with highest definition score did not mention product or project, which makes even their definition applicable to both project- and problem-based learning.

Teachers in our study know and understand the characteristics of PBL, however, when it comes to implementing them, they are interpreted differently. Similarly, Slovak teachers have a correct understanding of most PBE characteristics in the science education, but only the mutual interaction between these characteristics can result in a successful learning process (Schubertová & Cepková, 2013). In Slovenia, modern teaching methods are usually promoted on conferences or during the education of future teachers, which explains why there are no differences in understanding of teachers from different regions. Additionally, all schools must follow the same curricula, which gives little freedom to the teachers. We expected that teachers with more teaching experience will have higher understanding of, however our results showed that there are no significant differences between teachers of different experience. It is usual in Slovenia for teachers to teach more than one subject. Most of the teachers teach combination of scientific subjects, which makes it easier to create and overview an interdisciplinary project. For this reason, we assumed that the multidisciplinary teachers would have higher PBL understanding and usage. However, the results have not confirmed our assumptions. Our study has not shown any differences between teachers of different age. However, Chytrý et al. (2017) results have shown that the older Czech students of primary school teacher education studies have better overview of the PBL, main reason being higher frequency of PBL course and seminar attendance. They are also stating that older teachers tend to have higher confidence in own teaching skills.

We believe that teachers understand that their role is changed from classical lecturer, but not fully formed into mentor. In another research (Han et al., 2015), Texian teachers believed that STEM PBL classes in high schools are organized differently from traditional classes and teachers are assigned specific functions. Schubertová and Cepková (2013) found that Slovak teachers set the goals and activities for students, however students have freedom to execute the activities however they prefer. We assume that this could be the situation with our respondents. Nonetheless, teachers engage students into critical thinking, give frequent feedback to students throughout the school year and give students freedom in research, analysing and presenting the results.

Lower secondary school teachers use more PBL characteristics than general upper secondary school teachers. There are significant differences between the teachers from different regions. We cannot fully explain why, because results are specific for certain regions and we would need more information from the teachers on how they came to use certain PBL characteristics. The results have shown no significant difference between teachers of different experience. Han et al. (2015) compared Texas teachers of different experience and their professional STEM PBL development. STEM PBL activities execution of two teachers who had 3 years of professional development in PBL was better than the other teachers in the study, which shows that it is more important to attend professional development events in order to implement the PBL rather than having extensive teaching experience without professional development. Interestingly there were significant differences between the teachers of different age. Younger teachers have higher motivation and "energy", which might be the reason why they give students more freedom of activity and action choices than the older teachers. Besides younger teachers, our respondents over age 50 also have higher usage of PBL characteristics. We believe that the reason is the pre-retirement phase, where teachers tend to relax and explore.

Respondents stated that the curriculum has too many goals which must be achieved during the year, which gives them less time to organise a PBL class to successfully fulfil these goals. Teachers have faced with many students that are not interested in learning through PBL. The student readiness is a critical factor in implementing STEM PBL (Han et al., 2015).

CONCLUSION

Study provided clearer picture of the Slovenian chemistry teachers' view on PBL. Majority has trouble with understanding and implementing PBL, often mistaking it with project-based learning. Teachers decide if the learning objective is solely problem solution or the creation of the product, therefore they should have clear understanding of both methods and set a clear objective. A high number of teachers states that they use PBL, however they are using only some PBL characteristics in practice. The curriculum is restrictive, therefore giving less freedom of choice to both teachers and students, which is one of the main qualities of PBL. Nonetheless, many teachers are working towards enacting as many PBL elements in the activities as possible. It is important to understand how PBL is promoted to the teachers (e.g., university, courses, conferences) and how do they process the given information, for it is the most crucial stage of understanding the PBL. We did not focus on the results of the individual classes and on the effect of the understanding on the teaching result (effect on the knowledge the students gained). Therefore, in our opinion, further research would have to be done in order to provide detailed view on the understanding and the implementation of the PBL in chemistry classes in Slovenian schools.

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Comparison of the Inquiry, Project-Based and Conventional Approach in Teaching – Botanical Case Study

Renata Ryplová

Abstract

This contribution brings the results of the survey done to find the most suitable method for teaching the topic of cooling effect of vegetation. The ninth-grade basic school pupils were taught through different approaches – inquiry-based teaching, project-based teaching and conventional, teacher-centred teaching. An improvement of pupils' knowledge, their attitudes to vegetation and teachers' opinion on focused approaches were investigated. Despite the fact that all approaches led to the particular improvement of pupils' knowledge, project and inquiry-based groups showed increase of positive attitudes to vegetation. Ambiguous teachers' opinion on different teaching approaches are discussed.

Keywords

Project-based education; inquiry-based education; botany education; teacher centred education

INTRODUCTION

Recent international studies reported decreasing interest of young generation in botany (Balas & Momsen, 2014) related to overall plant blindness of public (Wandersee & Schussler, 1999). Plant blindness is supposed to be a reason for plant illiteracy (Uno, 2009) of general public, a dangerous phenomenon for the future of human-being, because ignorance of plant physiological processes could have serious consequences for sustainable development (Amprazis & Papadopoulou, 2020). Therefore, botany educators focus their effort to increase the attractiveness of botany education for young generation. To reach this goal, activating strategies based on problem-solving approaches, hands-on activities etc. are used. Among modern didactic approaches especially inquiry-based education (Janstova et al., 2013) as well as project-based education (Rusek & Becker, 2011; Rusek & Dlabola, 2013; Lindner, 2014) are frequently used in teaching science to enhance students' engagement and motivation for learning.

Our previous papers have brought evidence for the low level of pupils understanding of air-conditioning function of vegetation (Ryplova & Pokorny, 2020a; 2020b). From this reason, new teaching activities were developed on this topic to be implemented into biology education at basic schools (Ryplova & Pokorny, 2020a; 2020b). Understanding of air-conditioning function of vegetation is important, because via the air-conditioning vegetation helps to retain water in the landscape. Solar energy is converted into the latent heat by water vapour from vegetation and due to later condensation in cold places the water is returned back into the landscape in a form of precipitation (for detail description of the air-conditioning function of vegetation see Ryplova & Pokorny, 2018; 2019).

During the development of the new teaching activities, three different teaching approaches were tested to find the most efficient and suitable one. This contribution brings results of a didactic survey focused on the comparison of inquiry approach, project-based approach and traditional teacher-centred approach used for teaching the topic of air-conditioning function of vegetation. The aim of the survey was to find an answer on the research question: Which one of these three different teaching approaches is the most efficient for pupils and the most suitable from the teachers' point of view?

METHODS

A teaching activity on air-conditioning function of vegetation was developed in three variants providing the same information to the pupils but using three different didactic approaches:

1. Inquiry approach (for detail design of the inquiry teaching activity see Ryplova & Pokorny, 2020b). The teaching activity was based on the 5E-model of inquiry (Engagement, Exploration, Explanation, Elaboration and Evaluation, Carin et al., 2005). The aim of this activity was to answer a question 'Why is the shadow under the tree cooler than the shadow under an umbrella?' (90 minutes lesson).
2. Project based approach. The participants worked according to the project-based instruction in team format activities in order to solve the problem how to cool down the town square. The activity was divided into two parts. In the first part, the participants were motivated by using the thermovision pictures, obtained a short explanation from teacher and absolved an outdoor activity including measurement of the cooling effect of vegetation. During home activity, they should prepare proposals for cooling the town square by vegetation. The whole activity was finalized in second part via introduction of individual proposals and discussion with a peers and teacher (2x 45 minutes + homework).
3. Traditional teacher-centred approach combined with students' outdoor activity. After initial motivation via the thermovision pictures, the participants obtained the teacher's explanation and in the second part of the activity, they proved the cooling function of vegetation via their own field measurement (45 minutes lesson).

Each variant of the activity was introduced by the same motivation accompanied by the thermovision picture of cooling effect of vegetation; each variant included also hands-on activity – field measurement of solar radiation and surface temperatures of different surfaces in the close surrounding of the school (or school garden). Each variant of teaching activity was tested with one group of nine grade students (15 years old), number of respondents in one group varied among 24 – 30. The same teacher taught all three variants of the activity.

During the didactic survey three different aspect were investigated: Pupils knowledge and its' improvement, pupils' attitudes and engagement and teachers' opinion. The participants faced to pre-tests a day before teaching, post-tests immediately after the intervention and follow- up tests a week after the intervention. The aim of the didactic survey was to test:

A) The knowledge:

- an improvement of pupils' understanding of the cooling function of the vegetation was tested via the questionnaire consisting of nine questions (max. total test score = 9 points, pre-test /post-test experimental design, the differences in a total score among pre-test and post-test were analysed using Wilcoxon test (The STATISTICA 12 PC package, StatSoft Inc., for the detail description of the questionnaire see Ryplova & Pokorny, 2020b).
- Deeper understanding was tested via one question in follow-up test one week after the absolved education. The pupils were asked to draw the scheme of solar energy distribution in the landscape – max. amount of 6 point.

B) The pupils' attitudes to vegetation and botany education:

- The change in pupils' attitudes to vegetation and botany education was tested in pre- and post-test together with the test of knowledge via 3 questions:
  a. Do you think learning about plants is amazing?
  b. Do you think understanding of plant life is important for human?
  c. Do you think it is necessary to have trees in the city?

C) Teachers' attitudes to the use of this topic in the education

Twenty basic school teachers of biology got familiar with written form of teaching methodology of prepared activities and were asked to fill short questionnaire consisting of two semi-opened questions:

a. Do you think, the teaching about air-conditioning function of vegetation is reasonable? (Why yes or why not?)

b. Would you choose any of prepared activity for your practise? Which one and why?

RESULTS AND DISCUSSION

There is a clear evidence that all three didactic approaches lead to the significant improvement of participants' knowledge, which was very low before the teaching. Participants of all three courses reached significant improvement of their knowledge (Tab.1). The biggest improvement showed participants of inquiry learning (277%), followed by participants of project-based learning (216%) and traditionally taught pupils (204%). Different situation was observed in the case of drawing scheme of solar energy distribution. In this question the participants taught by traditional way were the most successful (mean score 3.5 from 6 possible) on the contrary to participants of inquiry (mean score 1.5 from 6 possible) as well as project-based teaching (mean score 1.8 from 6 possible), showing low ability of drawing scheme of solar energy distribution. The scheme of solar energy distribution describes conceptual understanding of cooling function of vegetation. This question seemed to be too much difficult for participants of inquiry as well as project-based activity. The participants of these two groups have not seen the scheme before; they should conclude it from their knowledge obtained during the teaching activity. The respondents taught by traditional approach were faced to this scheme already before during the teachers' explanation. From the findings we can conclude, that although inquiry or project-based approach improve significantly students' knowledge, in case of biology principles, which are quite difficult to be understand (solar energy distribution in the landscape), the conventional approach could be more efficient. According to the Kirschner, Sweller & Clark (2014), there are cases, when minimally guided approaches are less effective than strongly guided approaches, because of low pupils' prior knowledge, which is in agreement with our pre-test results.

Tab. 1 Analysis of the improvement of pupils' knowledge. Mean test score reached by students in pre-test/post-test and percentage change between pre- and post-test mean score (* = statistically significant difference)

Approach variant	Pre-test mean score	Post-test mean score	% change	Wilcoxon test	Effect Size	Solar energy distribution scheme score
Inquiry based	2.6	7.2*	277%	z = -4.828, p = 0.0001	r = 0.61	1.5
Project based	3.1	6.7*	216%	z = -2.829, p = 0,005	r = 0.46	1.8
Traditional	2.8	5.7*	204%	z = -2,741, p = 0,005	r = 0.37	3.5

On the other hand, both inquiry as well as project-based approach, lead to higher engagement of pupils and positive change in their attitudes to plants and botany. During the pre-tests similarly, low amount of respondents in all three groups (from 16% to 38% - Fig.1), consider learning about plants as amazing, understanding of plant life as important and trees in the city as necessary. The most positive change in attitudes showed participants of project-based learning (increase 44%, 52%, 47% of respondents who consider learning about plants as amazing, understanding of plant life as important and trees in the city as necessary), followed by participants of inquiry-based learning (increase 35%, 40%, 38%) and finally participants of conventional learning showing just a low increase (11%, 15%, 30%). These results are in agreement with previous works documenting high motivation for education due to project-based (Ilter, 2014) or inquiry-based education (Ryplova, 2017).

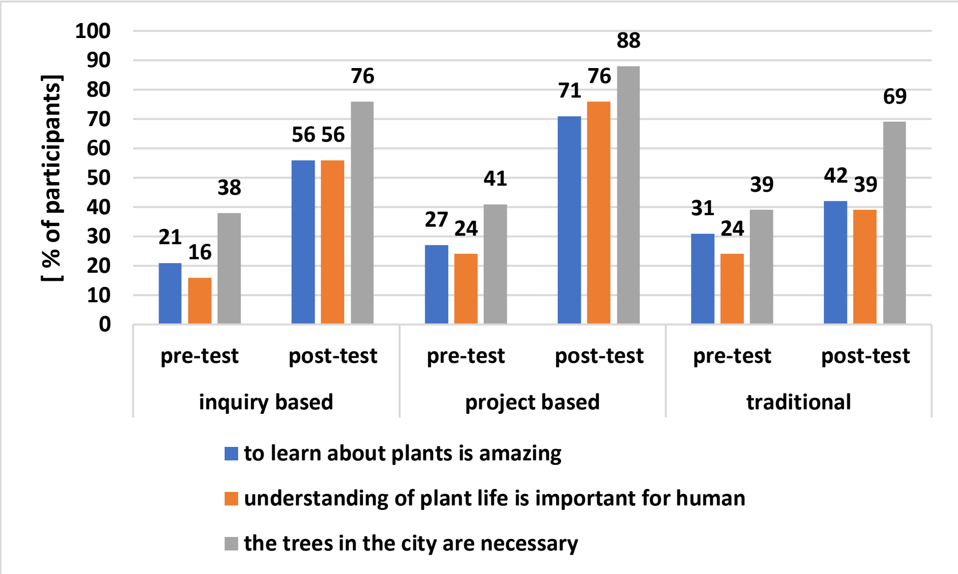

Fig. 1 Analysis of the change in pupils' attitudes to plants and botany education

A positive effect of all kinds of learning could be caused also by interdisciplinarity of the air conditioning function of vegetation combining physical sciences and botany. According to Lehmann, (2008), interdisciplinarity is one of the key features of project-based learning, thus this kind of approach seems to be suitable.

The teachers assessed the teaching of air-conditioning function of vegetation as reasonable, all twenty basic school teachers answered 'yes' to first question. As the reason they mentioned mostly the importance of vegetation for human environment, increasing drought or the pupils experience of air-conditioning principles from their everyday life (everybody knows, that the air in the forest is much cooler than in the city). Nine of the teachers would use traditional approach for teaching of this topic in their practise. As the reason they mostly mentioned time and school schedule (biology lesson is once a week in duration 45 minutes). Six teachers would prefer inquiry–based approach (the reasons mentioned were: the pupils have the possibility to earn the experience with the cooling function of vegetation on their own; 90 minutes lesson is better because pupils need more time for the outside measurement; it is a topic, pupils know from their life and this is the good reason to use inquiry learning). Five teachers choose project–based learning, the reasons were similar like for inquiry-based learning (pupils need more time than 45 minutes; this is a good way to use school knowledge in relation with everyday life).

CONCLUSIONS

All three activities using different didactic approaches led to significant increase of pupils' knowledge. For the complex understanding of solar energy, distribution in the landscape a direct explanation by the teacher seems to be more appropriate than less guided inquiry or project-based approach. Participants of project-based activities showed the most positive change in their attitudes to plants and botany. The majority of the teachers would prefer traditional teaching approach for the topic of air-conditioning function of vegetation, prevailingly from the reason of time and organization of school hours.

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Teachers' Views on Suitability of Incorporating Current Vertebrate – Zoology Topics in Teaching Practice in Relation to IBSE

Adéla Hartlová & Jan Andreska

Abstract

Due to the gradual return of large carnivores to the central European countryside, the topic is both the subject of social debate and the content of the school curriculum. Therefore, we asked ourselves which teaching method could be suitable for incorporating such topic into best teaching practice. We also wanted to know whether there is a difference among teachers who use IBSE and those who do not when they integrate such topics into teaching, alongside additional relevant factors. Finally, we focused on the teacher's views on integrating such topic using IBSE[1] and other teaching methods. The questionnaire survey ascertained the relationship between the teacher's awareness of IBSE and the incorporation of current topics into teaching.

Keywords

Reintroduction; inquiry-based science education; teachers; attitudes

INTRODUCTION

In this article, we are attempting to identify the suitable ways of incorporating the current topic of returning animals into biology lessons via the IBSE method. These animals have been exterminated from our country and their renewed presence provokes fear. Thus, they are perceived as an economical or physical threat (Andreska et al., 2019).

During the twentieth century, the attitude towards native species of animals began to change (Bruskotter et al., 2007,). These are usually large vertebrate species, most often mammals, e.g., Wild Boar, Elk, Wolf, Eurasian Lynx, and Brown Bear, but also birds such as Cormorants, which have been exterminated for various reasons from central Europe in the past (Andreska, 2012a, 2012b, 2013, 2014). At present, their return to the regions where extinction and extermination have occurred is considered desirable (Kutal et al., 2017) and is supported by both National Legislation[2] and European

[1] Inquiry-Based Science Education
[2] In the Czech Republic Act No. 114/92 Coll.

Union law[3]. However, for species that provoke fear (Rádlová et al., 2018), or that are somehow harmful (Dvořáková, 2012), the social acceptance of their return is complicated and burdened with prejudice. A change in attitudes towards these species can be made with an appropriate form of education (Andreska, et al., 2019). At present, in addition to traditional teaching methods, it is recommended to choose methods of teaching that encourage the active participation of pupils in education as well as their active thinking (Čtrnáctová & Mokrejšová, 2013; Nezvalová, 2010; Papáček, 2010) especially if they are well considered by the teacher, appropriately selected and to some extent directed (Kršková, 2016) despite obstacles (Papáček, 2010; Radvanová et al., 2018), which are associated with such a method of teaching, although they have possible solutions. (Edelson et al., 199; Ryplová & Reháková, 2011)

Such teaching methods could include an Inquiry-Based Science Education (IBSE) (Dobber, 2017). It is an educational direction based on the ideas of Piaget, Bruner and Dewey, allowing a deeper understanding of the issues in a broader context (Vojíř et al., 2019). Despite, there were teachers' views (Tal et al. 2019) and attitudes (DiBiase & McDonald, 2015) towards IBSE surveyed, we have not found surveys on teachers' attitudes towards the topic of returning animals in the context of IBSE.

Therefore, it seems desirable to determine the difference between the approach of integrating the current topic of returning vertebrate species in teaching among teachers who use the IBSE method and those who do not. In addition, it should be reviewed which additional variables influence teachers' willingness to integrate such topic. We also want to learn other approaches teachers employ incorporating the current topic of returning animals into biology lessons alongside their process of selecting methods appropriate for the topic at hand.

Thus, we are looking for answers to the three following research questions:

1. Do teachers regularly using the IBSE method integrate current topics of vertebrates more often?
2. What could affect the process of incorporating such topic into biology lessons?
3. What are teachers' views on incorporating the current topic of returning animals into biology lessons using IBSE and other teaching methods or approaches?

[3] Council Directive No. 92/43/EEC of 21 May 1992 on the protection of natural habitats, wild fauna and flora

METHODOLOGY

We obtained the data via a questionnaire survey realized in spring 2019. The questionnaires were designed for and circulated amongst grammar school teachers and helped collect data from 106 ISCED3 biology teachers. The content of the questionnaire included items related to the characteristics of the respondent:

1. What is your gender?
2. How many years of teaching experience do you have?

Subsequent questions focused on teaching with IBSE and integrating the topic of reintroduction and spontaneous return of the above-mentioned vertebrate species into biology lessons. Three questions concerned background information:

3. Are you aware of IBSE?
4. Do you use IBSE in your zoology lessons?
5. Do you integrate the topic of reintroduction and spontaneous return of vertebrate species into lessons?

Eight questions were attitudinal statements based on 5-point Likert type scale. The data was converted to Excel 2016 and Statistica 12 and analysed. First, we performed the initial component analysis (PCA) with varimax rotation on the data from the attitudinal part, which produced 1 meaningful principal component with 4 statements. See Tab.1.

Tab.1 Selected Attitudinal Statements

Do you agree with these statements?

1 = strongly agree;2= agree; 3= not sure;4 = disagree; 5 = strongly disagree

Cronbach's alpha = 0,83	**Principal component**
5. It is suitable to incorporate such topic using more than one teaching method.	0,841
6. It is suitable to incorporate such topics via IBSE.	0,837
7. It is suitable to incorporate such topics regularly.	0.830
8.it is suitable to incorporate such topic through excursions.	0.686

Next, we analysed data collected as background information by Pivot Tables with chi-square authentication. The differences were considered statistically significant when $p < 0.01$. The correlation analysis and logistic regression followed.

For comparison, a questionnaire from Radvanová et al. (2018) was used in which an item focusing on teachers' knowledge of IBSE corresponded to our survey and as such was discussed.

RESULTS AND DISCUSSION

By comparing part of our research with the work of Radvanová et al. (2018), we have found that the difference of 4% for teachers of grammar schools reporting having knowledge of the IBSE is minimal. Thus, we observe that the percentage of teachers knowing the IBSE is probably not increasing over time. However, our number of respondents was only half of those involved in the referenced study. See Tab. 2. As there is quite a high number of teachers who know about the IBSE, we conclude that enough respondents justify further comparisons and statistics, provided the teachers both understand the term inquiry and are able to apply the method (Jnaštová & Pavlasová, 2019).

Tab.2 Comparison with Radvanová et al., (2018)

Comparison with Radvanová et al. (2018)	Number of respondents		Results of Hartlová, Andreska	Percentage of respondents		Results of Hartlová, Andreska
Do you know IBSE?	2012	2017	2020	2012	2017	2020
Yes	71	133	64	27,80%	64,50%	60,40%
Total	255	206	106			

Since our discussed topic is a part of environmental education, the inquiry-based approach could be considered a suitable method as teachers can draw inspiration from their surroundings and everyday life (Ryplová & Reháková, 2011). A lot of authors have proved that it also enhances the attractiveness of lessons (Ryplová, 2017), promotes the scientific method, which provides students with the necessary skills (Čtrnáctová, 2016), can increase pupils' motivation to study biology and improve their achievements (Pavlasová et al., 2017).

Our research shows that 67 respondents (63%) integrated the current topic of vertebrate zoology in their lesson, 39 (37%) did not do it at all. One-third of the respondents know and use the IBSE, 28 (26%) and 42 (40%) did not know about the IBSE at all. Of those who know the IBSE and use it, 30 respondents (47%) integrate it in their lessons. And by contrast, 14 respondents (22%) of those who do not know the IBSE do not include current topics in their teaching practice (see Fig. 1A and B).

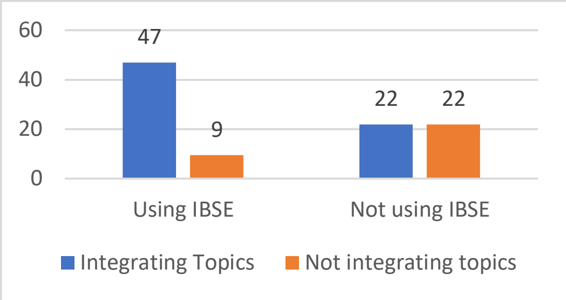

Fig. 1A The difference between integrating the current topic of returning vertebrate species among grammar school teachers who use the IBSE and those who do not

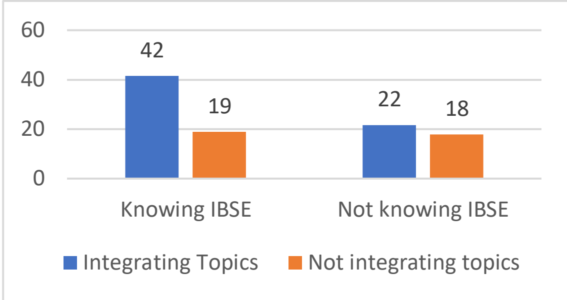

Fig. 1B The difference between integrating the current topic of returning vertebrate species among grammar school teachers who are aware of IBSE and those who do not

Tests have revealed a moderate correlation between teachers who use IBSE and incorporate current issues into teaching. The calculated value of the test criterion was 8,145, i.e. higher than the critical value $x^2_{0.001}(1)=6,635$, which refutes the zero hypotheses: H_o = There is no dependence between integrating the actual topics into teaching and being aware and using IBSE and confirms the alternative hypothesis H_1 = there is dependency.

After the correlation analysis, we have discovered that the coefficient of determination is 0.357. Therefore, using IBSE in lessons could affect the integrating of actual topics only in 13%, while 87% is a result of other factors. Those factors could be the teachers' attitude as it is evident that teachers with positive attitude integrate the topic in their lessons. The coefficient of determination here is 0.72. Therefore, 72% of teachers with positive attitude integrate this topic in their lessons. We also tested other factors like gender, length of pedagogical practise and the fact that teachers teach not only in the classroom. However, the model done in the logistic regression in the next step showed that these factors, except the length of pedagogical practise, are not significant. However, with the growing length of pedagogical practise, the probability of integrating such topics is growing every five years[4] at $e^{0.315}$ which means 1.37 times.

The attitudes of respondents are illustrated in Fig. 2. It is obvious that 15% of respondents think that it is suitable to incorporate such topic using IBSE which is almost the same number of respondents as those who think that students prefer IBSE over other teaching methods. Almost one half of respondents think that current topics of zoology should be integrated regularly into zoology lessons

[4] The groups were divided after 5 years.

and by more than one teaching method. Only 17% of respondents would not take students to excursions when teaching this topic.

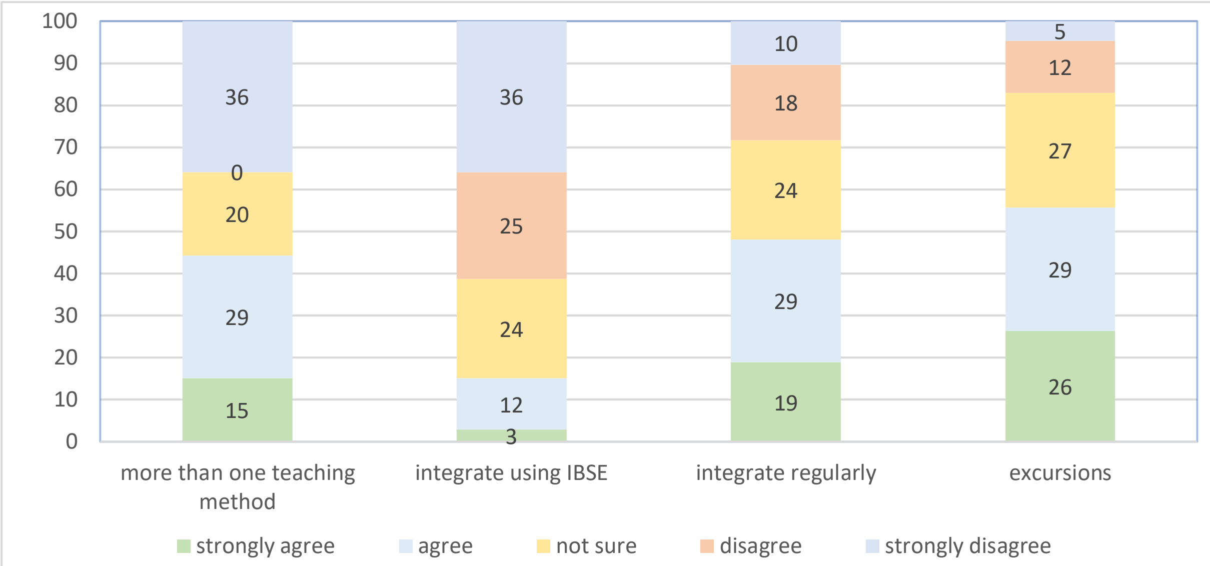

Fig. 2 Attitudes of Respondents to Selected Statements. Numbers are expressed as a percentage. Statements in legend were shorten. For full statements see tab. 1 Selected Attitudinal Statements.

CONCLUSION

The results of this study show that almost two thirds of respondents integrate the topic of returning vertebrate species in their lessons. They do it in different ways ranging from a simple comment made in their lessons through zoological excursions to project days and integrating IBSE in their lessons. However, integrating the topic by means of IBSE is now done in 15% only. There is a potential to increase this number as it is evident that the topic is integrated more by teachers who know and use IBSE in their zoology lessons.

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Influence of the project method on the development of thinking skills in high school students

Małgorzata Nodzyńska

Abstract

The major goals of science education are to improve the cognitive and mental abilities of students. This is due to the assumptions of the EU's policy aimed at supporting the development of a knowledge-based society. The Polish Core Curriculum lists the scientific thinking skills a student should achieve after completing education. It was decided to test the scientific thinking skills of talented students interested in science subjects. And then check whether, after the 3-day workshop where students will work using the project method, their scientific thinking skills will increase. The obtained results show that work using the project method significantly increased the scientific thinking skills of high school students.

Keywords

Project method; scientific thinking; Lawson test

INTRODUCTION

One of the major goals of high school science and mathematics education is to improve the cognitive and mental abilities of students. This is due to the assumptions of the European Union's policy aimed at supporting the development of a knowledge-based society. That is the development of the ability of people to use scientific knowledge to identify and solve problems, as well as formulating conclusions based on their own empirical observations. Reasoning skills fall into three main groups according to their level of complexity (Johnson-Laird, 2006): basic reasoning skills (differently - operational reasoning), Higher-order reasoning skills (which includes: analogical reasoning, inductive reasoning, troubleshooting, critical thinking), and scientific reasoning. The highest of these, 'scientific reasoning', is defined as the use of abstractions and symbols to represent and describe phenomena. It is based on argument. Although scientific reasoning is characteristic of scientific research, it is also necessary for everyday life (e.g. when analyzing leaflets for medicines, cosmetics or food products).

The Polish Core Curriculum (2018) lists the scientific thinking skills a student should achieve after completing each stage of education. Therefore, it is the duty of teachers to practice this skill with pupils from the first year of primary school. Taking this into account, it can be assumed that high school students have trained the ability to think scientifically.

THEORETICAL BACKGROUND

Scientific reasoning is often referred to as the most advanced form of human thinking because it requires the use of abstract concepts and symbols to describe observed phenomena. It requires formulating and verifying hypotheses, designing experiments and analyzing the obtained results (Adey, 1999; Howson & Urbach, 1996; Koerber et. al, 2005; Venville et. al, 2003). Scientific reasoning also includes argumentation that requires the proper organization of numbers, data and facts, performing numerous logical operations, and finding cause-and-effect relationships between the observed changes. Scientific reasoning is based on both inductive and deductive reasoning (Watters & English, 1995). Research (Adey & Shayer, 1994; Chen & Klahr, 1999) shows that the skill of scientific reasoning can be developed through appropriate training and that this skill developed in one field is transferred to the skill of reasoning in other scientific fields. Also, training in students' scientific reasoning skills has a long-term effect on their academic achievement, independent of the science being taught (Adey & Shayer, 1994). As shown e.g. by Tóthová and Rusek (2021), this skill cannot be automatically expected even from prospective science teachers.

One of the first methods used to assess students' formal reasoning was a clinical interview (Piaget). However, this method was time-consuming and thus expensive, therefore it was difficult to apply in training practice (Inhelder & Piaget, 1958; Lawson, 1978). Therefore, many researchers have developed their own tools to assess students' scientific reasoning abilities, such as the group assessment of the Logical Thinking Test (Roadrangka et. al., 1982), the Logical Thinking Test (Tobin & Capie, 1981), and the Lawson Classroom Formal Thinking Test (Lawson, 1978; Lawson, 2000a). The initial version of the test was revised in 2000. The new test consists of 24 multiple-choice questions covering knowledge of biology, chemistry and physics. To properly answer the questions contained in the test, no specialist knowledge of the above-mentioned sciences is required, however, scientific thinking skills are required. (Lawson, 1978, 2000a, 2000b, 2003, 2005; Pyper, 2011).”

HYPOTHESIS

It was assumed that selected, gifted high school students who are interested in natural sciences and math have a high degree of scientific thinking, that is, they will get more points in the Lawson test. Another assumption was that 3 days (25 hours) of work using the project method under the "Summer School for Young Talents" is a very short period and will not raise the level of scientific reasoning of these students to a higher level.

Checking these hypotheses is important from the point of view of the economy of educational activities. Non-formal education is very expensive, so it is important to check which activities of this type bring measurable results.

METHODOLOGY

Ten high school students took part in the project. They were selected, endowed with achievements, students interested in the mathematics and natural sciences. Students to participate in the "Summer Talent School" were selected in two stages. In the first stage, teachers indicated students interested in science subjects who had good grades in these subjects and / or other achievements (e.g. participation in competitions, Olympiads). In the second stage, the achievements of individual students were compared and the best ones were selected. The training lasted 3 days. One of the most important elements of the training was the project method. As part of independent work in the project, students chose the topic of their own research project and developed its plan (including a list of necessary reagents, laboratory equipment, a sequence of actions). They also reviewed the literature on the subject. They independently posed hypotheses and research questions and then verified them experimentally. They also learned the principles of correct measurement as well as the goals and principles of mathematical processing of measurement data and their implementation in spreadsheets. They got acquainted with the principles of presenting scientific results (poster, presentation, infographic) and prepared their own project presentations. The end result was a scientific conference at which individual people or groups presented the obtained results. The obtained results were discussed in the discussion.

The main goal of the workshops was to shape students' scientific thinking and develop their interests in mathematics and science. The expected effect of education was to increase the scientific thinking skills of the participants. After completing the workshop, the student should be able to formulate a research problem and a hypothesis proposal, plan an appropriate experiment for a specific research problem, make careful observations and clear notes on the course of the experiment, process and analyze experimental data and draw conclusions from them. The Lawson test was used to measure the students' scientific thinking skills. At the end of the class, the students also filled in a questionnaire assessing both the activities and their personal involvement in the project.

RESULTS

By answering 24 questions in the pretest, the students, on average, provided 54.6% correct answers.

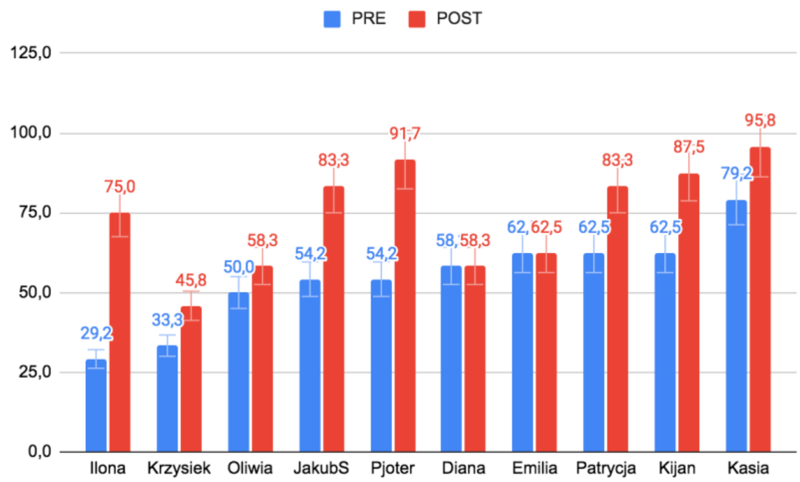

Fig. 1 Percentage of correct answers of individual students in pre-test and post-test.

While the average post-test score is 74.2%. The normalized gain calculated for the whole class is 0.43. It can therefore be seen that working on the project independently increased the students' thinking skills. Individual student responses in the pre- and post-test are shown in Figure 1. The difference between the post-test and the pre-test scores varies greatly from student to student. The biggest changes were achieved by Ilona and Pjoter (45.8% and 37.5%, the normalized gain calculated for them is 0.65 and 0.82). But two people did not improve their scientific thinking skills (Diana and Emilia). The normalized gain calculated for them is 0. Their results strongly contribute to the lower normalized gain of the whole group. Some researchers (Marx & Cummings, 2007) suggest in this case removing such results from calculations.

Tab. 1 Change of response type (correct / incorrect) between pretest and posttest.

	In post-test change of answer ...					
	from wrong to right	**right no change**	**wrong no change**	**from right to wrong**	**no answer to right**	**no answer to wrong**
Pjoter	10	12	1	1	0	0
JakubS	8	12	3	1	0	0
Kijan	7	14	2	1	0	0
Oliwia	7	7	5	5	0	0
Patrycja	6	14	3	1	0	0
Ilona	6	7	3	0	5	3
Kasia	5	18	0	1	0	0
Diana	5	9	5	5	0	0
Krzysiek	6	5	10	3	0	0
Emilia	1	14	8	1	0	0

A detailed analysis of the students' individual answers shows that in most cases students chose the correct answers in the post-test (instead of the incorrect ones as in the pre-test). In Table 1. these results are described as "from wrong to right". Changing the answer from wrong (in the pretest) to correct (in the posttest) shows an increase in the student's scientific thinking skills. However, there are also reverse cases. When the student replaced the correct answer from the pre-test with the incorrect one in the post-test. In the case of 3 students (Oliwia, Diana, Krzysiek) these are not single mistakes. In the post-test, two people repeated most of their incorrect answers (Krzysiek - 10 and Emilia - 8), and another two (Oliwia, Diana) repeated 5 incorrect answers. It can therefore be concluded that although the average posttest results are much higher than the pretest, there are large individual differences in the case of individual students.

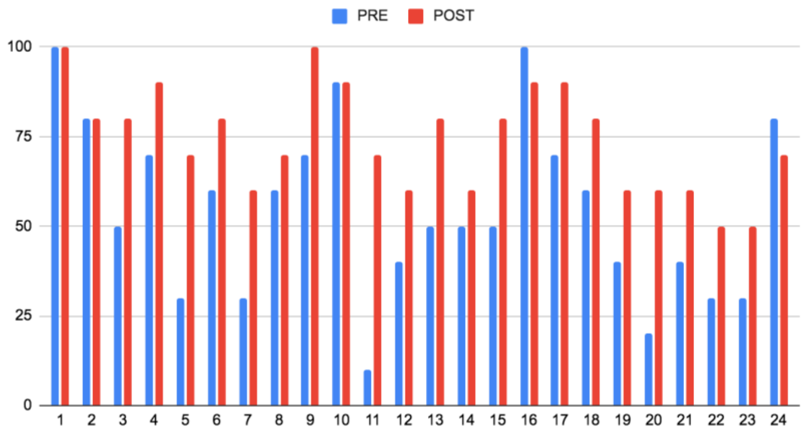

Fig. 2 Percentage of correct answers to particular questions.

The analysis of the students' answers to a particular question (Fig. 2) shows that the difficulty of the questions varied. Five questions (1, 2, 10, 16 and 24) were easy for the students - they obtained over 75% correct answers in the pretest. Only 2 questions (11 and 20) were extremely difficult for students - in the pretest they received less than 25% of correct answers. In the posttest, the lewel of 75% of correct answers was exceeded by 12 questions (1, 2, 3, 4, 6, 9, 10, 13, 15, 16, 17, 18). The fewest correct answers (50%) had two questions (22, 23).

The scoring of the Lawson test has evolved into two forms: one is the individual scoring method, which simply grades each question independently (the results according to this method are described above), and the other is the pair scoring method, which assigns one point when both questions in a pair are answered correctly. Both methods have been frequently used by researchers (Bao, et al., 2009; Colet & Phillips, 2005; Coletta et al., 2007; Lawson, 1978; Lee & She, 2010; Xiao et al., 2018). In a situation where the pair scoring method is used, we can eliminate the so-called "false positives" (Hestenes & Halloun, 1995). This is the case when the student answers the first question correctly without understanding the problem (e.g. by guessing). However, when the student correctly answers the first question and correctly justifies his answer in the second question, we can believe that he can actually solve this problem correctly.

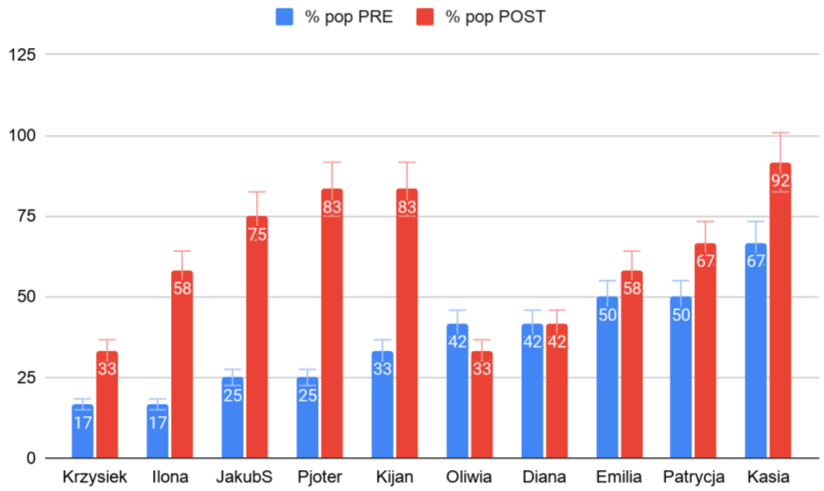

Fig. 3 Percentage of correct answers of individual students in pretest and posttest (both answers are correct in a pair-scoring method).

The use of the pair-scoring method allowed for a different perspective on the test results. On average, the students gave 36.7% correct answers in the pre-test and 62.5% in the post-test. Individual student responses in the pre- and post-test are shown in Figure 3.

Tab. 2 Changing the correctness of students' answers in the post-test in relation to the pre-test.

	Pjoter	Kijan	Patrycja	JakubS	Diana	Kasia	Ilona	Emilia	Oliwia	Krzysiek
changes 0 to 0	0	0	0	1	1	0	1	3	1	5
changes 0 to 1	0	0	2	1	2	0	3	0	2	1
changes 0 to 2	2	1	1	0	0	1	2	0	2	0
changes 1 to 0	0	1	0	0	0	0	0	1	1	1
changes 1 to 1	2	1	1	0	1	1	2	1	1	1
changes 1 to 2	5	5	2	7	3	2	2	1	0	2
changes 2 to 0	0	0	0	0	2	0	0	0	0	0
changes 2 to 1	0	0	1	1	1	0	0	0	3	1
changes 2 to 2	3	4	5	2	2	8	2	6	2	1

When analyzing data from individual students, we can see three groups. In first group, the students' results in the pre-test were low, but they improved significantly in the post-test (Krzysiek, Ilona, JakubS, Pjoter, Kijan). In second group, the scores in the pre-test were medium or high and improved in the post-test (Emilia, Patrycja, Kasia). In third group, the results in the pre-test were average and lowered or did not change in the post-test (Oliwia, Diana).

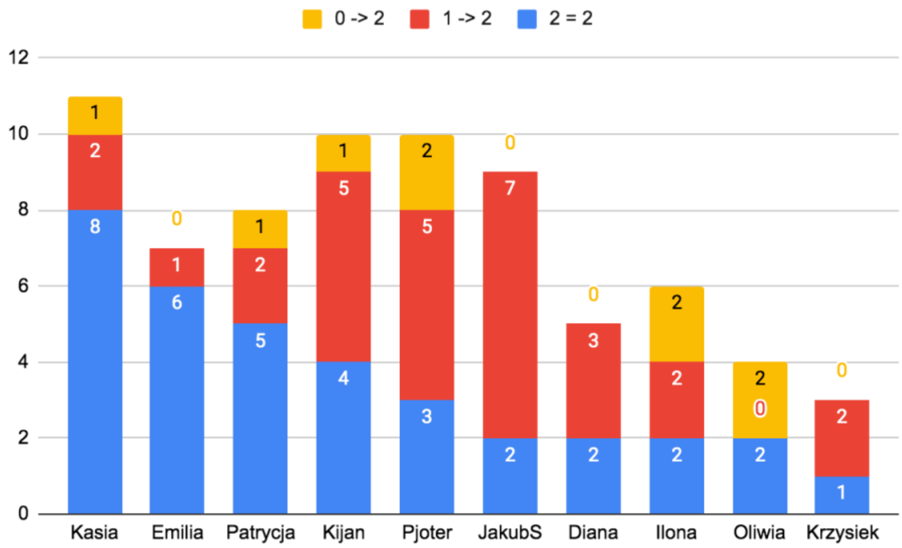

Fig. 4 The number of the answers of the improved correctness of the answers of individual students in the posttest. 0 -> 2 means that in the pre-test the student did not answer correctly to either of the two paired questions, and in the post-test he answered correctly to both questions. 0 -> 1 means that in the pre-test the student has answered correctly only one question and in the posttest - both. 2 = 2 means that the student answered both questions correctly in both the pre- and posttest.

Using the pair-scoring method, we assign points to each pair of questions. If the answers to both questions are correct, we assign two points. If both responses are wrong - 0 points. If one answer is correct and the other one is incorrect one point. As can be seen in Figure 4, the greatest changes in the post-test took place in the case of questions to which the students gave only partially correct answers (for 1 point).

In the case of grouping questions, we can also notice very large discrepancies in the answers to the questions. Almost all students answered correctly to the four pairs of questions (1 & 2; 9 & 10; 15 & 16; 17 & 18). In the last three pairs, we can see a large increase in the number of correct answers in the post-test compared to the pretest. The lowest results were achieved by students and two pairs of questions (21 & 22 and 23 & 24). The highest skill gain occurs in questions 11 and 12 (from 0% correct answers in the pretest to 50% correct in the posttest).

DISCUSSION

The obtained data show that hypothesis 1 has been refuted. Despite 8 years of primary education and 1-2 years of secondary education, students are unable to think scientifically. The mean results in the pre-test are 54.6% correct answers in the individual assessment of each question and 36.7% correct answers in the pair-scoring method. Also, the hypothesis 2 was refuted. For the majority of the students, three-day workshops in which they conducted their own research projects increased the scientific thinking skills. The mean posttest scores are 74.2% correct answers in the individual scoring method for each question and 62.5% correct answers in the pairwise scoring method. Although the students' scientific reasoning skills increased after participating in the project, the results obtained by them are lower than in other studies (cf. Rusek, 2021). For example, studies by Coletta and Pillips (2005) showed that weaker students, whose average score on the knowledge test was 45%, obtained the mean of the Lawson test of 69%, while the more gifted students who obtained an average score of 58% on the knowledge tests, obtained an average score from Lawson's 91% tests. The results presented by Pyper (2011) show that physics students averaged over 80% in the Lawson test. In contrast, the mean students score in the study by Musheno and Lawson (1999) was 88%. However, it should be taken into account that high school students who had 2 years of education before starting their studies attended the present study. The percentage of correct answers to particular questions corresponds to the results obtained by Bao, Xiao, Koenig, Han (2018).

The analysis of the results of individual students was supported by the analysis of questionnaires. In them, the students assessed the activities and made a self-assessment. It turns out that people who did not experience an increase in scientific thinking skills -themselves rated low on their involvement in activities, creativity, conscientiousness, goal-orientation, use of their talents, or substantive contribution to work with the project (3 or 4 points out of 10). On the other hand, people who achieved high results in the Lawson test assessed their commitment very high (10 points).

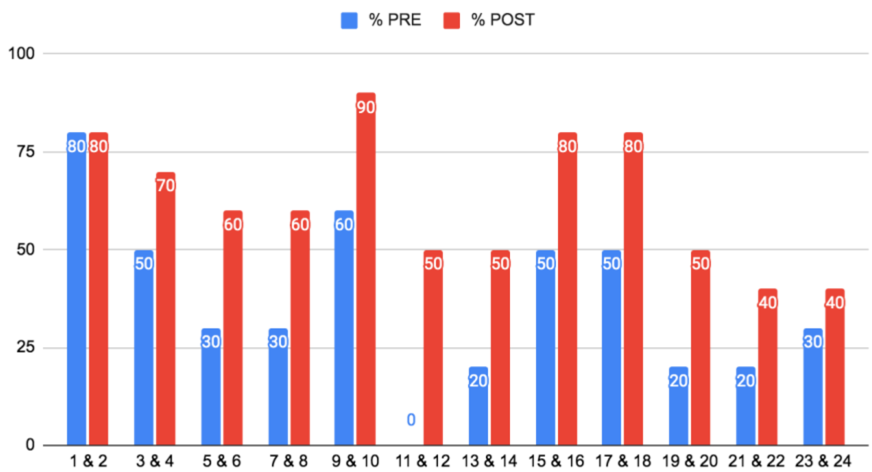

Fig. 5 Percentage of correct answers to particular questions (pair-scoring method).

By analyzing the percentage of correct answers of individual students in the pre-test and post-test (both answers are correct in the pair scoring method - Fig. 3), 3 groups of students can be distinguished. The first group (5 people) were people who scored low in the admission test and high in the posttest. Therefore, it may be assumed that these people have the intellectual ability to conduct scientific reasoning, but they probably were not taught this type of activity in school. In the second group we have 2 people who achieved an average score in the pre-test and did not improve it in the post-test. These people did not show any willingness to work actively during the classes. In the third group, the students obtained average or high results in the pre-test, and after the classes they obtained even higher results.

CONCLUSION

The results obtained are controversial. A positive effect of the three-day project work is a spectacular increase in students' scientific thinking skills (25.8%). However, a question arises about the effectiveness of education in Poland. It turns out that 3 days (25 lessons) of students' independent work under the supervision of a tutor gives a better effect than 8-9 years of education at school (over 900 hours of maths, chemistry, biology, physics and nature)! The project method turned out to be an effective tool for increasing the students' thinking skills and such activities should be permanently available in the educational offer.

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eTwinning project „No stress“

Alena Juřicová & Kateřina Trčková

Abstract

The paper presents the solution and evaluation of an eTwinning project focused on the biochemical nature of stress and depression. The pilot verification of the project involved 18 pupils from school A and 16 pupils from school B. During the project, students were introduced to the schedule, four subtopics, selected mobile applications, poster creation methodology, and citation standard. Students from schools A and B were divided into four groups. Each group dealt with one subtopic. The output of the project were presentations of A2 posters, questionnaires for students and teachers. The items of the questionnaire were classified and the answers of students of schools A and B were compared.

Keywords

ICT enhanced teaching and learning; motivation; peer assessment; project-based learning; peer learning

INTRODUCTION

In times of extraordinary measures, the teacher must operatively address the transition from full-time to distance learning. We consider the optimal solution to this situation to be to give students an interesting project and thus motivate them to cooperate, to communicate with each other in solving a problem situation and work with information sources. Project teaching enables the pupil's involvement according to his individual possibilities and abilities (Zormanová, 2014, p. 117; Turek, 2014, p. 167). The aim of project teaching is to solve a task that is specific, makes sense, is real, based on life and experience (Průcha, 2009, p. 110; Vlčková, 2015). The solution of tasks in the project is based on the initiative and creativity of pupils (Kasíková, 2010, p. 47; Turek, 2004, p. 388), it develops pupils' perseverance, alertness, tolerance, self-criticism and self-confidence (Maňák & Švec, 2003, p. 170).

The project method supports pupil motivation and cooperative learning (Průcha, Walterová & Mareš, 2013, p. 226; Bílek, Machková & Chroustová, 2015). Today, the project method can also be implemented through elearning. The eTwinning platform brings a lot of news and benefits to this teaching method. ETwinning is supported by the European Commission and the Ministrys of Education of European countries. It is essential thanks to its support for the international cooperation of distance schools (Šabatová, 2010). ETwinning attracts users with its secure virtual TwinSpace and the ability to create rich e-learning projects that are fundamentally different from regular teaching projects. A huge benefit of the eTwinning project is the development of ICT skills and support for pupils' language competences, their cooperation in an international group, and the establishment of new friendships. Working in the eTwinning platform motivates teachers to receive an award for a quality project and provides a number of benefits, such as sharing examples of good practice, making friends, and gaining contacts for pupil mobility within the Erasmus project (eTwinning, 2004).

METHODOLOGY

This main goal of our survey was to select an interesting topic, get acquainted with eTwinning, design and implement an eTwinning project for the target group of high school students, compile a project schedule, select appropriate applications, compile and evaluate a questionnaire, publish project results.

Project preparation

Within the preparatory phase of the project, a suitable interesting, motivating, interdisciplinary topic "No stress" was selected, which connects the theoretical knowledge of students with everyday life and at the same time has an overlap with primary prevention. During the implementation of the project, students will learn about the possibilities of mental health care and ways to prevent mental illness. The theme of the project will be divided into four subthemes (‘I'm not feeling well, but it's not flu’; ‘Why does my soul hurt?’; ‘It's falling, like a house of cards’; ‘In a healthy body, a healthy spirit’), each subtopic will be processed by a 4-5 member group of the third and fourth year of grammar school from the Czech Republic and Slovakia. The output of individual groups will be a Power Point poster size A2, who’s formal and content requirements will be specified to students through a sample poster for the 1st online meeting. Students will be introduced to creative applications (Word Cloud, Bitmoji, www.stripcreator.com), whose output will be placed on the poster. Pupils from the Czech Republic and Slovakia will work together on the preparation of posters with the same subtheme. A safe eTwinning TwinSpace environment will be recommended for communicating to pupils by chatting, where pupils will also store their processed posters. Consultations and online meetings will occur via the zoom.us application. Furthermore, the project sponsor will set a precise schedule for the implementation of individual part steps and prepare a questionnaire via Google Form for project evaluation.

To get acquainted with the possibility of implementing an eTwinning project and its smooth progress, reliable partners were selected - teachers with whom we have excellent personal experience. Before entering the project into the TwinSpace, consultation with the relevant teachers occurred via zoom.us. Based on the suggestions of the teachers, adjustments were made to the project assignment.

Project realization

Due to the introduction of emergency measures in schools, the project prepared by us was implemented in online teaching through the eTwinning platform. The project was commissioned as a result of distance learning via the zoom.us application, because the TwinSpace is only ready for class communication through a registered teacher and the assigned role pupil is only allowed to chat in this environment.

A total of 34 pupils were involved in the project, of which 18 pupils of the third year of the Josef Kainar Hlučín Grammar School (school A) and 16 pupils of the fourth year of the T. Ružička Grammar School in Žilina (school B). Pupils in school A were divided into two groups of four and two groups of five. Pupils in school B were divided into four groups of four. During the implementation of the project, three online meetings were planned with the pupils.

The first online meeting

During the first online meeting, pupils were introduced to the project method, the eTwinning platform, the topic and subtopics of the project, the project schedule (it was a medium-term project lasting five weeks), creative applications (WordCloud, Bitmoji, www.stripcreator.com), an example of formal and content processing of the project. This was followed by a short discussion with the pupils about the choice of the project topic. Then the students were divided into groups for which activities were prepared to support cooperation and creativity. During the first brainstorming activity, students generated words related to the project theme and used WordClouds to create the first visual element for the poster - the word cloud. After the introductory activities, the project partners were briefly introduced and the pupils were introduced through the Bitmoji application, with the help of which the pupils created their virtual portraits (avatars), which they placed on the poster. The creation of avatars was also to serve for the drawing of four sub-topics of the project between the teams of the Czech Republic and the Slovak Republic, and after the first meeting, international cooperation was to be established in groups working on the same subtopic. Due to the time-consuming nature of the first online meeting, the teachers of the school assigned individual subtopics. At the end of the first online meeting, students were introduced to four subtopics of the project, with the rules of communication and project solution.

The second online meeting

The main goal of the second online meeting, which occurred in a week, was to provide students with online group work using "breakout rooms" in the zoom.us application. The task of international groups that worked on the same subtopic was to discuss the outputs under development, then to modify and supplement them. The task of the project sponsor and teachers was to control and direct the group work of students in a virtual environment.

The third online meeting

The main goal of the third online meeting, which occurred three weeks after the second meeting, was to present the final products in the form of posters to all project participants, to evaluate the overall implementation of the project and mutual cooperation with national and international teams. Finally, two teachers, 18 pupils of school A and 16 pupils of school B, filled in an online questionnaire, which was used for the overall evaluation of the project.

RESULTS AND DISCUSSIONS

The questionnaire for pupils included 32 items, of which:

- 5 dichotomous questions - the answers to these questions are presented in the graph in Fig. 1. The questions are focused on the implementation of the project, the use of the citation standard, regular communication between classmates and the teacher.
- 3 open questions with short answers
    - What communication tools did you use when solving the project?
    - What did you not learn new when solving the project?
    - What would you do differently the next time?)
- 7 closed questions with a choice of several answers (the results of the survey of four questions are presented in Fig. 2-4), the remaining 3 questions are focused on:
    - What information sources did you use when solving the project?
    - Which application did you use when solving the project?
    - Which application did you like the most?
- 16 questions for the summative evaluation of the project outputs, of which 8 questions for the poster evaluation and 8 questions for the evaluation of the online presentation of posters (Tab. 1) by individual groups of pupils to the remaining researchers of the project. Out of eight questions, there are always four questions of evaluation of output processed by teams A and four questions of evaluation of outputs processed by teams B).
- The last questionnaire item included a space for the project leader's own statement. The results of the school A and B answers obtained from the questionnaire survey are compared.

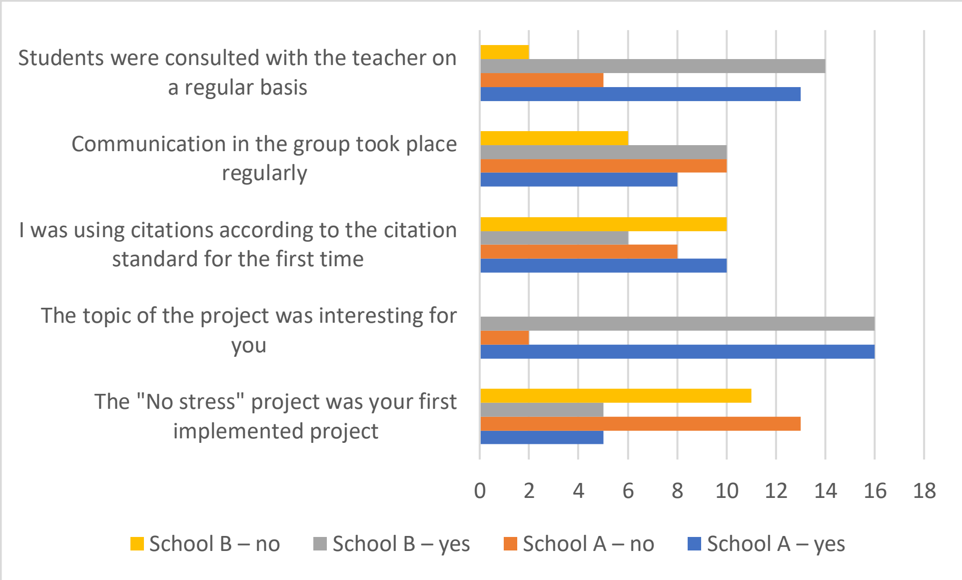

Fig. 1 Answers to dichotomous questions

The graph (Fig. 1) shows that schools A and B have similar experiences and problems with project implementation. The analysis showed that for 31% of pupils it was the first implemented project, for 94% of pupils the topic was interesting, 59% of pupils met the citation standard for the first time, 53% of pupils regularly communicated in a group and 79% of pupils used consultation with a teacher. Prášilová (2016) draws attention to the problems of pupils with cited literature. For this reason, we recommend that teachers pay increased attention to this issue both in teaching and in the implementation of the first projects. A teacher who performs a thorough check and provides continuous feedback prepares his students for the implementation of more complex tasks based on teamwork (Trčková, 2017). We believe that we can call the project method the students' own company only after the student acquires the necessary skills and knowledge about working with information sources, formal and factual editing of the poster.

The following questionnaire items were closed questions with a choice of several answers, which were focused on comparing the length of implementation (Figs 2 and 3) and the difficulty of individual project activities (Figs 4 and 5).

The graph (Fig. 2) shows that students in school A consider simplification and information retrieval to be the most time-consuming, while students in school B consider poster processing. The graph (Fig. 3) shows that students of school A consider the use of applications to be the least time-consuming and students of school B to describe images. The analysis revealed (Fig. 2) that the pupils spent the most time processing the poster (56% of the total number) and working with the text. 44% of pupils consider it time-consuming to search for information in information sources and 29% of pupils choose relevant information and simplify it.

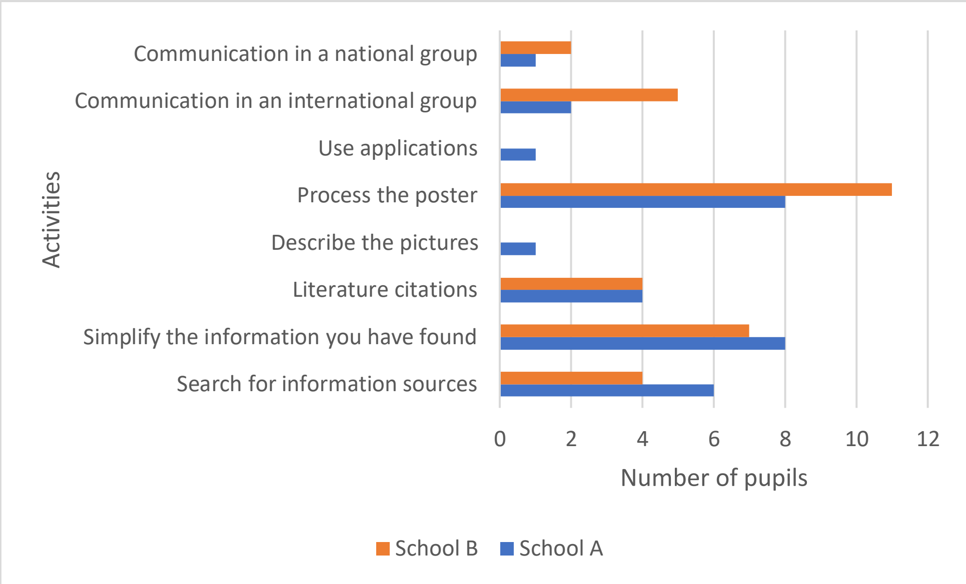

Fig. 2 Answers to questions 'Which part of the project took the most of the time?'

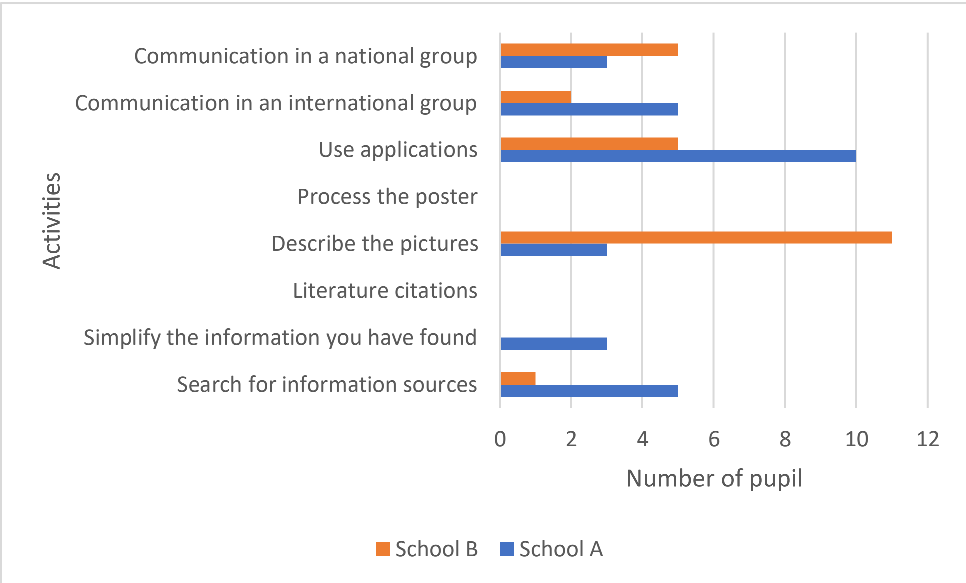

Fig. 3 Answers to questions 'Which part of the project took the least of the time?'

Conversely, the least time-consuming activities (Fig. 3) are considered by pupils to use applications (44% of pupils) and to describe images (41% of pupils). The results of the questionnaire survey are in line with our intention to motivate students through the activities that students perform in their free time. The results of the CZSO research survey (Czech Statistical Office) state that the most frequently performed activities of pupils on the Internet include: participation in social networks (94%), reading online news (87%), searching for information about goods or services (82%) and playing games (67%). Works based on the use of ICT technology, mobile applications, and modern communication technologies, enable interesting and effective teaching of chemistry supporting the motivation of students (Kopek-Putała & Nodzyńska, 2015). The questionnaire survey shows that the use of mobile applications in high school teaching is sporadic. 77% of students say that they are using WordCloud for the first time to create WordClouds. We believe that the inclusion of this mobile application in teaching is very suitable when working with text for writing key concepts and fixing a new curriculum.

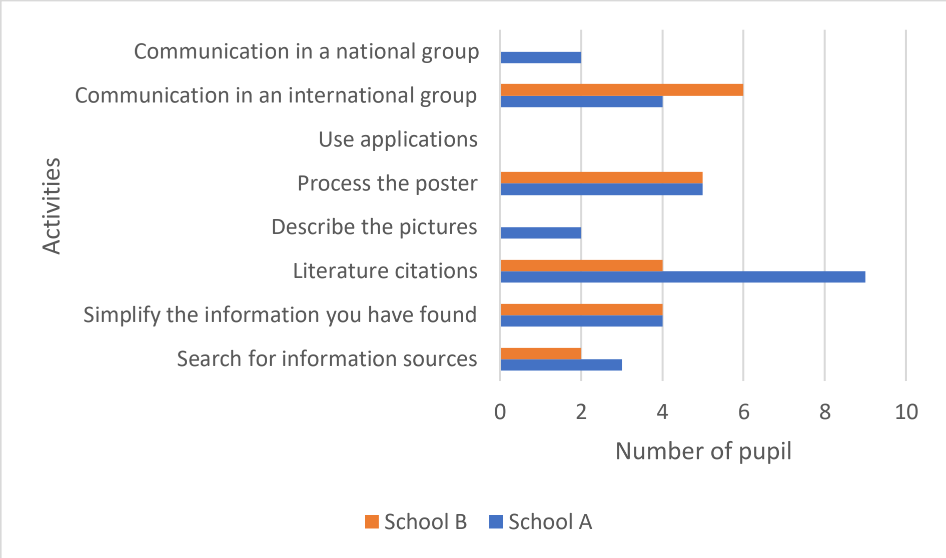

Fig. 4 Answers to questions 'Which part of the project was the most difficult for you?'

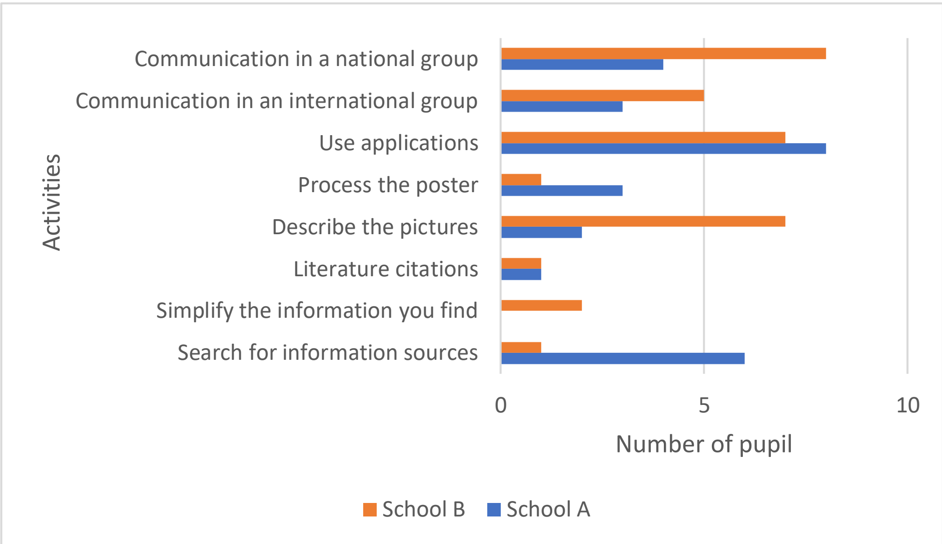

Fig. 5 Answers to questions 'Which part of the project was the easiest for you?'

The graph (Fig. 4) shows that school A students consider it the most difficult to cite sources, while school B students consider communication in an international group. The graph (Fig. 5) shows that school A students consider communication in the national group to be the easiest to use applications and school B students. The analysis (Fig. 4) shows that 38% of pupils cite information sources as the most difficult activity, while 29% of pupils consider poster processing and communication in an international group to be the most difficult. We were interested in what the students learned new during the solution of this project. On this open question with a brief answer, 19 pupils (56%) stated that they have gained new information and learned to work with the text. Nine pupils (27%) learned to work in a team, five pupils (15%) learned to process a poster, and 2 pupils (6%) learned to quote.

Tab. 1 Comparison of poster evaluation results and poster presentations by pupils and teachers

	Poster evaluation								**Evaluation of poster presentations**							
Subtopic	I'm not well, but it's not the flu	I'm not well, but it's not the flu	Why does my soul hurt?	Why does my soul hurt?	It broke down, like a house of cards	It broke down, like a house of cards	In a healthy body, a healthy spirit	In a healthy body, a healthy spirit	I'm not well, but it's not the flu	I'm not well, but it's not the flu	Why does my soul hurt?	Why does my soul hurt?	It breaks down, like a house of cards	It breaks down, like a house of cards	In a healthy body, a healthy spirit	In a healthy body, a healthy spirit
School Evaluator:	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B
Pupils A	1.3	1.3	1.6	1.4	1.7	1.4	1.6	1.6	1.5	1.3	1.4	1.4	1.4	1.2	1.3	1.3
Pupils B	1.1	1.2	1.4	1.4	1.6	1.1	1.3	1.3	1.2	1.2	1.3	1.3	1.3	1.0	1.1	1.1
Teacher A	1.0	1.0	2.0	2.0	2.0	1.0	1.0	2.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Teacher B	1.0	1.0	2.0	2.0	2.0	1.0	1.0	2.0	1.0	1.0	2.0	2.0	2.0	1.0	1.0	2.0
Avarage grade	1.2	1.3	1.5	1.4	1.7	1.3	1.4	1.3	1.3	1.2	1.3	1.3	1.4	1.1	1.2	1.2
Overall average for activity	1.4								1.2							

The following eight items from the questionnaire include a summative evaluation of posters and poster presentations by teachers and pupils in schools A and B (Tab. 1). The results of the survey show that school B was generally more successful in poster processing (average 1.35) and poster presentation (average 1.2) than school A. The results of school B evaluation in poster processing are comparable. School A posters on the topic "Why does my soul hurt" and "It broke down, like a house of cards" were rated the worst. Based on a comparison of the summative evaluation and the completed questionnaires of teachers and students of schools A and B, who worked on these topics, we believe that the main cause of failure is insufficient communication in the international and national team and the problem of finding and sorting information.

CONCLUSION

During the implementation of the project, we noticed enthusiasm and a lot of new ideas from students and teachers, from which we can conclude that the topic was interesting, motivating, and inspiring. Students worked creatively and developed international teamwork. The outputs of the project show that students creatively use the recommended applications. Among the most common shortcomings that we still face in project teaching are noncompliance with the format of posters for professional printing, problems with the citation standard, the description of images. Pupils lack the skills to work with information sources, communication, and organizational skills. From our survey, it is clear that students consider poster processing to be one of the most time-consuming and at the same time difficult activities. Pupils described the use of applications as the least time-consuming and difficult activity.

Nevertheless, it can be assumed that the implemented project contributed to the development of key competencies of students, diversification of online teaching, understanding of the practical significance of the curriculum, and to the expansion of knowledge about civilization mental disorders and their prevention.

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Project versus lower-level student involvement learning activities at summer camp

Petr Šmejkal & Zuzana Míková

Abstract

The contribution is focused on a comparison of teacher-centred learning with active learning with lower student autonomy, project-based learning (PBL) activities (where autonomy of students is higher), camp games and excursions. The comparison was carried out through a qualitative survey among participants of summer science camps (students), where the activities were held. The results of the survey indicate that PBL activities implemented within the camp are perceived the most positively by their participants, but not considerably more positively than active learning activities with lower degree of students´ autonomy. Passive learning showed to be the less favourite activity of the summer camp programme.

Keywords

Science Education; science summer camps; project-based learning; PBL; active learning

INTRODUCTION

Chemistry and Physics are not the favourite subjects among Czech students and repeatedly, they occupy the bottom levels of many subject rankings (Höfer, & Svoboda, 2006; Picková, 2012). In addition to that, interest of students to study science subjects has been constantly decreasing in the Czech Republic recently. With respect to that, and due to principal importance of science subjects for society, support, and implementation of motivational ways of education as well as implementation of wider spectrum of educational methods and approaches, for example PBL (Project-Based Learning), IBSE (Inquiry Based Science Education) and of other ways of active learning is necessary (Rocard et al., 2007). The common denominator of the methods mentioned is that they are "student-centred" approaches as the activity and the learning process is primarily focused on student and his activity. Teacher is a facilitator and a guide (or a mentor) of the teaching process and of the student (McCabe, & O'Connor, 2014). Unfortunately, these modern and innovative approaches to teaching (or education) are not widely used in regular school teaching at primary and secondary schools in the Czech Republic (Česká školní inspekce, 2020). On the other hand, many teachers try to implement some activation elements to their teaching, such as demonstrations as well as laboratory experiments, thematic games, frequent links to common life etc. So, that they still teach in a "teacher-centred" way, nevertheless, they more or less activate their students to attach their attention to make the teaching process more motivating and effective. This approach is in accordance with lower stages of active learning strategy: "*a method of learning in which students are actively or experientially involved in the learning process and where there are different levels of active learning, depending on student involvement*." (Bonwell, & Eison, 1991). However, it is still rather different from the approach of passive learning ("listening") where student just receive the knowledge through teacher's effort (Bonwell, & Eison, 1991). A PBL approach is frequently considered to be a teaching method of active learning approach with high level of student involvement (Vogler et al., 2018). For purposes of this contribution to distinguish both the approaches, the active learning with low level of student involvement, just described above, will be abbreviated "ALLLSI". Obviously, the ALLLSI approach is meaningful teaching approach in the case where it is not possible to implement IBSE or PBL. However, there is a question whether in the case where it is possible to implement PBL or IBSE in teaching, the ALLLSI approach makes sense to use it. Another question is whether students consider both the approaches in a similar way, and from their point of view they are alternatives and prefer one of them, or whether they are distinct procedures, each of which brings its benefits and disadvantages. Accordingly, in this contribution, we focused on a qualitative comparison of both the approaches to teaching and evaluation of their possible contributions to the educational process for a specific case of implementation of PBL and "active" as well as "passive" approaches to teaching in a summer science-oriented camp. We build on a previous study on a similar topic (Chlebounová, & Šmejkal, 2020).

GOALS

In connection with the introductory part, the aim of the research presented in the contribution is to compare students´ opinions and attitudes to PBL, active learning with low student involvement (ALLLSI in this contribution), teacher centred teaching and other camp activities (camp games and excursions). Accordingly, the research question is: "Is, and how much, the PBL approach of teaching/learning preferred by students participating the science camp over ALLLSI approach and other activities performed at the science camp?" Another question is targeted to investigation of factors influencing students´ opinions and attitudes as well as whether the approaches are more competitive or supplementary in their implementation at the science camp: "What are the opinions and attitudes of students/participants of summer camp on the activities with different level of student involvement carried out at the summer camp?"

METHODOLOGY

The comparison of the teaching/learning approaches and other camp activities has been done within science-oriented summer camps for children aged 9-16. During the summer camp programme, students attended several basically different activities, which can be divided into 5 groups, which are summarized in Table 1.

Tab. 1 Types of activities held within the summer camps and examples of topics.

Activity	Topic examples
Teacher centred lecture	Astronomy – the worlds around us; COVID-19; Life of bacteria; Excursion to the world of molecules; Heart; …
ALLLSI	Explosives; Viruses and their behaviour; Human physiology; Botany of the Iron mountains; Hydrobiology; …
Projects and PBL	Periodic table of elements; Fireworks; Rocket fuels; Radioactivity; Food chemistry; Life in a pond; …
Camp games	Formulas; Flags; Smugglers; Pharaoh's stretcher; Bureaucracy (Journey to the scientific conference); …
Excursions	Cowshed and milk production; Quarry; Agricultural museum; Limestone; Lime production and processing; Geology of iron mountains, …

The participants attended "classical" passive lectures, where they more or less only listen to the lecturer's explanation. Another activity is teaching/learning through ALLLSI, where the explanation and lectures are supplemented by a number of experiments, links to everyday life, thematic games, etc. The third type of camp activity is teaching/learning through PBL. In the framework of PBL, the students/participants elaborate a project. Within this project, students should carry out a little research in their area of interest on a given topic. The output of the project is a poster, which students present for 30 minutes at the "scientific" conference organized within the programme of the camp (Šmejkal, & Míková, 2020). The equipment available to all the activities described and used is common, as well as themes are, in average, well comparable with respect to their difficulty, cognitive load and necessary skills of participating students. The only difference is in students´ autonomy and their own activity in the framework of the individual activities. The fourth kind of activity is excursion or a trip. It is mostly focused on visiting interesting places in the wider vicinity of the camp, for example, visiting plants for milk production, animal husbandry, nearby dams, museums (e.g. of lime industry, agriculture etc.). All the excursions are educationally oriented and performed with educational goals and programmes. The mentioned scientifically oriented activities cover broad range of themes combining many didactical, professional, and technical approaches. Regarding chemistry, the themes are oriented, for example, to nanotechnology, oxidation, spectroscopy, water treatment and chemical analysis, forensic, pharmaceutics, etc. (e.g. Hájková et al., 2013; Hájková, & Šmejkal, 2014; Rusek, & Lindner, 2017; Šmejkal et al., 2016a; Štefková et al., 2014). Another integral part of the camp activities is organization of camp games and competitions. These activities are rarely professionally oriented, they are more focused on physical activities and they are mostly based on modifications of well-known camp games (e.g. Sbírka nejen skaurských her). More about the nature and organization of the camps can be found in the article by Šmejkal et al. (2016b).

In order to eliminate the influence of a certain heterogeneity of project topics, quality and leadership of the implemented projects and of the other activities at summer camps as well as the age of participating children, only those students who participated in at least 3 camp years were included in the research of this contribution. With this approach, we tried to average some factors influencing our results as relatively high number of projects (>60), ALLLSI programmes (>70), teacher centred lectures (>20), excursions (>10) and camp games (>70) were evaluated. Thanks to this, it can be assumed that the existence of very high quality and very well managed camp activities (and thus well rated) is balanced by lower quality and less rated camp activities. In this regard, we wanted to further ensure that students evaluate min. 3 completed camp activities, so that their individual evaluation is not too much affected by one successful or unsuccessful activity. Accordingly, a group of 73 respondents was obtained and addressed. Among these, 16 (21.9%) respondents agreed to participate in our research. Due to a limited number of respondents, semi-structured interviews with all the 16 participants (10 males and 6 females) were done and evaluated. The interviews were targeted, according to the goals of the research, to respondents preferences and opinions with respect to individual activities, comparison of their content, their evaluation of the individual activities etc. represented, for example, by questions as "How important the project/experiments/lectures/games are for the camp programme?", What kind of summer camp activities do you prefer and why?", What is the best and the worst experience with the projects/lectures/labs/games/excursions?", "How did you select your project?" etc. A "quantitative" part was also implemented into some questions within the interview, where students, for example, subjectively assessed fun and/or usefulness of individual activities of the science camp on a seven-point Likert scale. This part was introduced to get a rough idea of the views of students to compare different teaching/learning approaches semi-quantitatively, using content analysis (Hendl, 2005). Coding categories were formed based on the answers of participants. All the answers were recorded, categorized by two researchers, and evaluated.

RESULTS AND DISCUSSION

The evaluation of the answers acquired in the semi-structured interviews showed, that PBL approach is the most favourite part of the summer camps programme (Fig. 1). Majority of students evaluated the project as the most fun as well as the camp activity with highest value (mean = 5.7; SD = 0.77; median = 6.0). As expected, students did not like passive lectures without activating parts (mean = 3.2, SD = 1.31; median = 3.0). The difference between their evaluation and the evaluation of the project was considerable. On the other hand, although the ALLLSI approach was rated worse by the students than the PBL (mean = 5.5; SD = 0.87; median = 5.5), the difference was not great (Fig. 1).

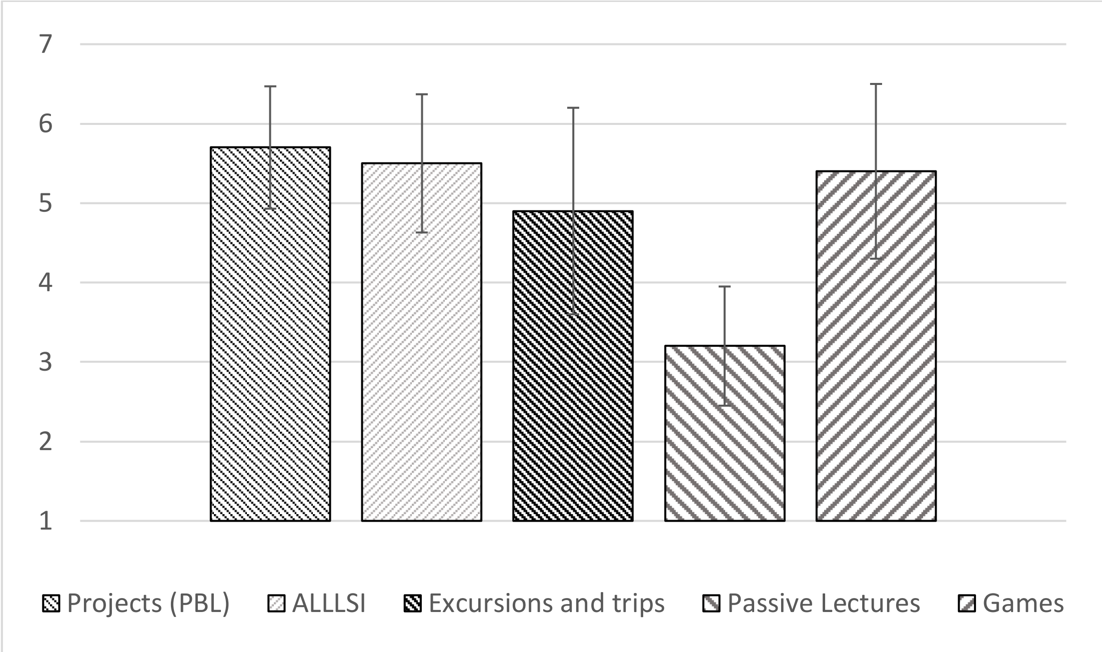

Fig. 1 Respondents´ evaluation of popularity of individual teaching/learning approaches (means and SDs as error bars; PBL – mean = 5.7, SD = 0.77, median = 6.0; ALLLSI - mean = 5.5, SD = 0.87, median = 5.5; Excursions and trips - mean = 4.9, SD = 1.36, median = 4.5; Passive lectures - mean = 3.2, SD = 1.31, median = 3.0; Camp games - mean = 5.4, SD = 1.11, median = 6.0).

Seven students (44%) consider the project and PBL to be the most beneficial activity of the camp, however, six respondents consider both the approaches equal (38%). The ALLLSI approach is considered to be the most beneficial by the rest of the respondents (18%). On the contrary, no one chose passive teaching as the most valuable. The results hence confirm that ALLLSI is still an interesting, beneficial and important camp activity according to the students' point of view. Excursions and trips were also evaluated positively (Fig. 1, mean = 4.9, SD = 1.36; median = 4.5), nevertheless, they were not at the top of the ranking. The respondents were also asked to mention the positives and negatives of all the activities held at the summer camps. The answers (some examples can be found in table 2) showed that students expect something a little different from each of the teaching approaches and evaluate their benefits regarding it.

In the case of the PBL approach, the biggest positive and beneficial effect of this approach appeared to be social aspects (8 answers) such as teamwork, mutual communication or meeting new people. As expected, many respondents also mentioned as an advantage that teaching is active, possibility of their own activity and that practical activity is required (8 answers). Seven respondents also found it very beneficial to be able to explore the topic more deeply and better understand it. Less frequently, factors as the amount of charged knowledge (4 answers), the joy of solving the challenge or intrinsic goal orientation (4 answers) were mentioned. Some respondents also mentioned other aspects of PBL, which were the use of the principles of scientific work (3 answers), poster preparation (3 answers) and its presentation (3 answers). Surprisingly, the preparation of the poster and its presentation were also among the least popular parts of the project (7 answers), although from the point of view of working on the project, all respondents stated that it is a necessary part.

Tab. 2 Examples of categories and answers of camp participants for evaluation of advantages and disadvantages of camp activities.

Activity	Category	Examples of answers
Teacher centered lecture	New knowledge	"We learn a lot of new things, which is great for regular school."
	Active/passive	"Although the topic is interesting, we are just sitting, the attention is disappearing."
	Topic	"Especially in geology, the topics were uninteresting, minerals for example."
ALLSI	New knowledge	"I learned a lot of new things for a few years ahead."
	Topics	"I had no idea that food is actually mainly chemistry. It was fun."
	Active/passive	"I love cross-country walks, I like to test everything and try it in practice."
Projects and PBL	Active/passive	"I like that we do experiments in the project, it is fun and so different in school teaching."
	Social	"I love meeting new people." "We need to agree on how to achieve a common goal." "I hate presenting to people."
	Deeper research	"We can go into the topic in depth, methodically and by what we learn."
	New knowledge	"Since the topic of the project is different from what we learn in school, we learn a lot of new things."
Camp games	Abreaction	"We can have a break from science."
	Social	"We have to cooperate."
Excursions	Abreaction	Let's rest from the routine of the camp.
	Satisfaction of needs.	"We can buy goodies that are not available in the camp."

However, very few negative aspects of the project work were mentioned (approximately 2.5 times less than the positives). Not surprisingly, the importance of the social aspect of working on the project was also emphasized by relatively frequently mentioned negative - a non-functional team and problematic cooperation in a team (6 answers). On the contrary, the wrong choice of the project topic as a negative was mentioned only once, the fear of the failure of the experiment twice. It is obvious that the choice of topic and the content of the project are not as crucial factors from the students' point of view as those connected with the social aspects. Respondents in the interviews also indicated that even a possible inappropriate choice of the project topic, at the start of the project perceived negatively, did not prove to be a problem with the fact that in each project there was interesting information or topics worth exploring. The ALLLSI approach was also perceived positively by students and only few negatives were found. These were mainly uninteresting topics (8 answers) and inappropriate teaching locations (2 answers). On the contrary, respondents appreciated the presence of elements of active teaching and the overall implementation of practical activities and interactivity in lectures (10 answers). The quality choice of topics (9 answers) with frequent links to everyday life (3 answers) and acquired knowledge (8 answers), which, according to the respondents, were very useful for their further school teaching/learning, were important. In this regard, we would like to indicate that the topics of the projects, the lectures, and the laboratory exercises do not differ from the usual school topics, they are only taught in appropriate contexts and using active approaches. From the comments and answers of the respondents it is clear that ALLLSI approach is perceived positively and especially as an opportunity to learn something new, when an important means of teaching and consolidating the knowledge gained. It is also a way of motivation of students and mean of students´ involvement in learning process. For passive lectures, again as expected, a suitable choice of topic is very important. According to the students´ opinions, if the topic is boring, even a quality lecturer will not save the situation (8 answers). On the contrary, an interesting topic and quality lecturers can make the lecture an interesting alternative to other approaches (8 answers). However, the main negative of a passive lecture is still perceived to be low student activity during the lecture, which leads to loss of attention. It follows from the above, again not too surprisingly, that even a passive lecture is desirable to enrich with activating elements.

CONCLUSION

The projects and PBL are the most favourite part of the summer camp programme, nevertheless, excluding passive lectures, the other parts of the programme were also evaluated positively. The reason is that the individual approaches of the active learning bring different kind of experience and development of different competencies at students. While the students participating in the survey see the benefits of PBL mainly in social aspects and mutual cooperation, and the acquired knowledge is rather a secondary product of the whole project work, the ALLLSI approach is considered to be a way for obtaining information through active learning with the necessary motivation. In the case of a lecture, it depends a lot on the choice of topic and if it is not possible to present an interesting topic to most students, it is desirable to choose other approaches to teaching. As can be seen, from the students' point of view, active elements of teaching such as interactivity and practical activity are important. However, even active teaching with lower student autonomy can be perceived by students as fun, interesting and enriching and approaching, regarding pupil assessment, PBL. From the teacher's point of view, it is certainly desirable for him to use different approaches regarding his teaching goals. PBL is obviously suitable for the simultaneous development of more competencies, especially social and communicative competences, while ALLLSI is suitable for strengthening especially learning and work competencies.

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Effectiveness of the methods aimed at the critical thinking development within the topic Viruses

Anežka Blahnová & Lenka Pavlasová

Abstract

Critical thinking is an ability described as a specific type of information processing. It is an ability to analyze and evaluate documents and to use a higher level of cognitive skills in order to solve problems. Here we introduce methods useful within the topic Viruses and aimed at the critical thinking development. We evaluated effectiveness of the methods in teaching high school students (ISCED 3). Jigsaw teaching technique, working with text, working with video and methods based on discussion were examined. The effectiveness of certain method was further evaluated using worksheets and tests submitted to students.

Keywords

Viruses; activation teaching methods; critical thinking; method of working with text

INTRODUCTION

The topic of Viruses is not only a compulsory part of teaching biology (NÚV, 2007), but also a part of everyday life. Today with Covid-19 it shows how current this topic is more than ever. Not only diseases itself but also the life cycle of the virus or vaccination are discussed. It turns out that the knowledge of general population in this field is not sufficient to make a competent decision and that people are likely to get confused by disinformation (Nguyen et al., 2020; Tagliabue et al., 2020). This is associated not only with basic factual knowledge of this topic but also with skills associated with critical thinking - searching for information, evaluation or discussion. Both should be passed on as a part of education. However, it could be debated how well are these two fields connected so that neither of them is neglected.

Critical thinking is an ability whose importance, significance and specifics can be perceived very differently depending on the field of study. It is described as a specific type of thinking (Bailin, 2002), the ability to analyze and evaluate facts to form a judgment (Lai, 2011) and especially for teachers it is an ability to use higher levels of cognitive skills in order to solve problems (Grecmanová et al., 2007).

Within the methods of critical thinking development students acquire basic skills such as cognitive skills, self-regulation, capability of information interpretation and analysis, interference and evaluation (Facione, 1990). Once an individual masters critical thinking they should be to able to make better decisions and solve problems in context regardless of the level of intelligence or the extent of knowledge (Carroll, 2004). Therefore, a goal of this educational area should be to raise an individual capable of reconsidering his own opinion, someone who is inquisitive, open, honest, has a high degree of self-reflection to assess his own bias and last but not least is able to search for information (Facione, 1990).

Within an effort to increase the level of memorization of the transmitted information, we should focus on methods which guide students to think independently and find possible causes and solutions (Lacina et al., 2015). Critical thinking developing methods undoubtedly meet all these requirements. Such methods include the technique of jigsaw learning (Aronson, 2014), which, due to combining of various activities - working with text, discussions, and learning others, can be very effective. Other effective methods could be working with text, discussion, or working with video. Working with video shows high success mainly due to the use of two communication channels - visual and verbal, instead of only one (Brame, 2015). To make our lessons effective in providing students with both transmission of sufficiently deep factual information and development of critical thinking during a single lesson, the methods mentioned above were choose. However, one single lesson is a quite short period of time for such complex methods of teaching. On the other hand, if teacher has enough time for the specific topic, it is more than appropriate to use project-based education or related methods (Tóthová et al., 2018; Vojíř, 2020).

Critical thinking is nowadays a basic skill of each of us as we live in a world full of conflicting information. From childhood we commonly receive information that can more or less seem to have a professional character. However, not always does. It is the critical evaluation of such information that may be a key to our future decisions. Therefore, it is necessary to enable students to improve in this area in the field of education. But how can critical thinking skills be taught to them? And what effectivity can we expect after applying these methods? To these questions the study seeks to answer.

METHODOLOGY

The aim of the research was to verify the effectiveness of methods for critical thinking development using the topic Viruses in high school students. For this purpose, the activities presented to the students were evaluated.

Jigsaw teaching technique, working with text, working with video and discussion were used in the teaching sequence. In order to validate these methods, teaching materials have been developed, covering the topics of *Host Cell Infection*; *Viral diseases and their causative agents, symptoms; Vaccination* and *Vaccination and autism* (see the following overview). Their full text in the Czech language is available in the publication *Viruses in teaching biology at upper secondary school (ISCED 3A)* (Blahnová, 2020).

Host cell infection

A short text consisting of six points was prepared for the implementation of the topic *Host Cell Infection*. These steps describe the sequential steps to infect a host cell with the virus. The students got the task to study the individual points and to draw the whole process according to the text.

Viral diseases and their causative agents, symptoms

The teaching material uses the method of jigsaw teaching technique. It was prepared a set of short texts dealing with a total of 10 diseases and their viral agents (e.g., mumps virus, herpes simplex virus, measles virus, etc.). There can be found an information about the structure of a particular agent (shape, type of genetic information, packaging, etc.), the disease caused by this agent, symptoms, spread and prevention. In the end, the text was always assigned a link for those who are interested, where more information could have been found, including complete resources. With this text students also received prepared tables, which were designed to sort and record the information obtained (structure of the virus, transmission, incubation period of the disease, infectivity, symptoms and prevention).

Vaccination

The teaching material on the topic *Vaccination* used working with video. For students were prepared worksheets containing information from the video Undistorted Science - Vaccination (Czech Academy of Sciences) where some information was omitted. Students were asked to fill the blank spaces in the text while watching the video.

Vaccination and autism

Materials for teaching this topic consist of three different texts. The first was taken from the website of The National Institute of Public Health and is devoted to refuting the link between the MMR vaccine and the development of autism (Vaccination with *MMR vaccine is not associated with an increased risk of autism*). The second article entitled *Editing the article Myths and Facts about Vaccination from the website of the Ministry of Health III.* was taken from the website named Rozalio (Parents for better information and free choice in vaccination). This text makes “a correction” of the report from the Ministry of Health, which provides information on the lack of evidence for a link between autism and vaccines. The author of the article disputes this statement.

The last, third text, presents the results of a study of the relationship between autism and MMR vaccines from 2019 (*Can MMR vaccination trigger autism?*). Teaching was based on working with text and discussion. Students received the prepared materials in triplets, each one studied one article, wrote down the most important information, and informed the two remaining members of the group about its content. The whole group then had to agree on a common position. In the end it was included a discussion with all class members.

Research participants

The research was verified in a total of three groups (designated SA1, SA2, SB) at two grammar schools (SA, SB).

Group SA1 consisted of first-year high school students (15 - 16 years) at school A. In this group, the preparations for topic *Vaccination* (with the participation of 20 students) and *Vaccination and Autism* (with the participation of 18 students) were verified.

There were 18 students in the SA2 group, and it was the first year of a higher grammar school (15-16 years). In this group, the preparation of the topic *Host cell infection* was verified.

The SB group was consisted of 9 students aged 17-18 (the third year of higher grammar school). In this group was verified the complete preparation of topic *Viral diseases and their causative agents, symptoms.*

Evaluation of the effectiveness of teaching materials

The evaluation of the level of remembering the information by the students and the correctness of the solution of the tasks took place in various time intervals on the basis of the solution of the tasks in the worksheets or according to the formulation of the conclusions of the group work (see Tab. 1). Due to the nature of preparations and the organization of teaching at both schools, a pedagogical experiment using the technique of one group was chosen (Chráska, 2006).

Tab. 1 Overview of students' outputs used to evaluate teaching activities

Group	Teaching material	Evaluation
SA1	*Vaccination*	worksheet 1 week after teaching
SA1	*Vaccination and autism*	extracts of each student of the most important of the articles and a common conclusion of the work formulated by the groups immediately after teaching
SA2	*Host cell infection*	worksheet 1 week after teaching
SB	*Viral diseases and their causative agents, symptoms*	worksheet 8 weeks after teaching

The effectiveness of the jigsaw teaching technique used in the topic *Viral diseases and their causative agents, symptoms* was evaluated according to the accuracy of the information that students wrote down based on the interpretation of their classmates in the enrolment tables. This information was evaluated according to the factual accuracy and completeness - whether all the information provided in the original text was wrote down.

In a worksheet submitted at a distance, students added information from a prepared list of terms to a partially completed table. The worksheet had two parts, each containing a table with five diseases. In each line it was necessary to correctly state the cause, symptoms and name of the disease. For each correctly completed term, the student could get 1 point and a maximum of 10 points for the entire table.

The evaluation of the topic *Vaccination* was based on a worksheet, which was presented to students a week after class. In the worksheet, the students performed two tasks. In the first they had to correct four incorrect sentences and in the second they explained what vaccination is. Students could get a maximum of 10 points for the whole worksheet (each correctly corrected sentence meant a gain of 2 points, an explanation of the vaccination also for 2 points).

In the topic of *Vaccination and autism* was the effectiveness of the used methods determined immediately after the teaching. The task of each student was to write out from his text the information that seemed most important to them, and after a joint discussion to write a group conclusion. Both outputs were evaluated according to the content (which information the students consider to be the most important, what they agreed with the other members within the group).

The effectiveness of the method working with text used for the topic *Host Cell Infection* was based on a worksheet submitted 1 week after class. In the worksheet, students had to draw or write down the course of the host cell infection. Students' performance was evaluated in terms of completeness (whether all points were drawn / written) and according to the accuracy of the drawing or description (whether the description is complete, drawing is accurate, whether essential points were omitted, e.g., whether are drawn or described antigen and receptor, etc.).

The results were supplemented by reflective observations in the Discussion and Conclusion.

RESULTS

Jigsaw teaching technique

No false information appeared in the enrolment tables, in which the students wrote down the information according to their classmates' interpretation using the jigsaw puzzle method. However, it should be considered that not all information was transmitted completely. This problem was the most common on the topic of virus construction. The SB group incompletely entered information accounted for 39% of all information. It should be noted that students have encountered this topic for a first time. The success rate of solving tasks in the worksheet, which the group completed 8 weeks after training, reached 76% (group gain 137 points out of 180).

Working with video

In the worksheet focused on the topic of *Vaccination*, the students' success rate was 68% (out of a total of a maximum of 200 points, students received 136 points). The highest error rate occurred in the exercise, where they had to correct incorrect sentences. The aspects in which the students fail the most are supplemented in Discussion.

Working with text and discussion

Data for the topic of *Vaccination and autism* were obtained from the texts of students, which they created during reading the articles and during the subsequent group discussion. 4 of the 6 group conclusions clearly state that vaccination and autism have no connection, one presents the view that "*connection cannot be demonstrated, but rather not*", and one group stated that "*it cannot be said, but rather vaccination reduces the risk*".

As expected, the information that students wrote down from the articles differed according to the article that the students read. The most interesting data came from texts created on the basis of an article from the Rozalio website. Of the together 12 most important information that students wrote, 5 related to Andrew Wakefield (4 students considered the most relevant information about his unrecognized study, only 1 wrote information to defend the study), 3 mentioned the link between autism and intestinal problems, 2 spoke of non-existent relationship between autism and MMR vaccination, and the last 2 noted that this relationship could not be confirmed or refuted.

Drawing a scheme based on text

The success of the worksheet aimed on the topic *Host Cell Infection* was different from one point to another. While the points describing the virus's adhesion to the cell membrane, the replication of genetic information or the completation and release of viruses from the cell were success on average close to 98%, the more difficult points (describing provirus or budding) had higher error rate (on average 75%).

DISCUSSION

Based on the results, we can state that through the method jigsaw teaching technique, which was verified on the topic *Viral diseases, causative agents, symptoms*, students remembered a high percentage of the submitted information. Students were then able to recall this information after a longer period of time (8 weeks).

Similar results were presented in a study focused on the effectiveness of the jigsaw teaching technique for university students (Dat, 2016). In this study, it was shown that puzzle learning inspires students' greater subjective confidence that they understand the topic, and in the short term increases their success in verifying of knowledge (Dat, 2016).

The effectiveness of the working with video method, which was verified on the topic of *Vaccination*, reached 68% in our study. However, in the evaluation it is necessary to consider that the students were significantly less successful in points that were burdened by more complex sentences and more demanding grammar. In the exercise, where their task was to correct a wrong sentence so that it was correct, the success rate for simple sentences reached 71%, in more complex sentences it was already around 50%. Overall, however, this method was effective. The students seem to have memorized the information from the video, but it was more difficult for them to reproduce the information correctly.

Salina et al. (2012) also studied the method of working with video, applying this method to the topic of nursing techniques. In a 33-item test, the video group received an average of 6 points more than the other group (Salina et al., 2012).

In the topic *Vaccination and autism*, all 6 groups stated the correct opinion that MMR vaccination and autism have no relationship (4 out of 6), or that they are rather unrelated (2 out of 6). Taking into account the content of the short notes, which were supposed to be the most important information from each article, it seems that even those who had Rozalio as their primary source (with an effort to „correct" a false report of Ministry of Health) quickly orientated themselves in the text, and as the most relevant information source accepted the report of the Ministry of Health, which was just attached to the article. Such a finding is more than positive, and it shows a potential that remains completely untapped by many students.

The use of working with text for the development of critical thinking is also motivating for the students themselves. After using this method, university students, who were studied in 2017, reported increased motivation and a higher sense of the meaning of words (Stefanova et al., 2017). It is therefore not only a method that develops critical thinking in students but can also develop word bank and improve comprehension of the read text. However, if an individual is supposed to use reading for obtaining new information, their level of reading must reach the so-called „social sustainability of reading" i.e. must be able to read 60 – 70 words in 1 minute. A study in the Czech Republic from 1995 shows, that some students reach this level of reading already in the third grade (8 – 9 years), but others do not reach it even in the eighth grade (13 – 14 years), both when reading a simple and difficult text (Zelinková, 2015).

The method of working with text was connected with drawing in the topic *Host Cell Infection*. From the results it seems that the students were able to repeat the drawing, which they had already drawn, quite accurately, but it is difficult to assess if the students really understood the drawn process. This area can be evaluated only for those students who attached a verbal description to the drawing, or only described the mechanism.

Heideman et al. (2017) also dealt with this area. According to his experiment, it seems that university students who used sketches, drawings, or other forms of visualization during their studies had a 50-80% higher rate of memorization of the studied material than those who did not use these methods (Heideman et al., 2017).

CONCLUSION

The obtained results suggest that the methods developing critical thinking, which were tested in this research, show a relatively high efficiency, in the time horizon from 1 week to 2 months. In addition, the chosen methods were well accepted by the students and they get used to them relatively quickly.

The use of methods for the critical thinking development undoubtedly has its pros and cons. For example, the student´s results can be affected by teamwork with partner, who was not chosen by them. Therefore, these students will not be motivated to cooperate.

However, for topics that resonate in society, they seem to be suitable. The topic Viruses certainly belongs to this area. Nowadays, when the Covid-19 pandemic is moving the world, not only a society's interest in this topic is rapidly increasing, but so is the number of false and misleading information. The more is needed to develop critical thinking in students.

The paper provides examples of ways how to deal with the methods of developing critical thinking and what effectiveness can be expected from them.

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Developing *Key Ideas* to Teach ‘Acids’ & ‘Bases’ in Upper Secondary Schools

Rita Krebs & Anja Lembens

Abstract

According to scientific consensus, one main source of learner confusion in chemistry is having to understand the different levels of the chemistry triangle and their connection. Especially with topics such as ‘acids’ and ‘bases’, using a conceptually coherent model on the submicroscopic level is indispensable in order to prevent learners from confusing the chemistry triangle levels. We aim to construct such a model by delineating *Key Ideas* from the scientific Brønsted-Lowry model and using them as the basis for a learning environment. In this paper, the use of the *Model of Educational Reconstruction* for the subsequent development of *Key Ideas* about ‘acids’ and ‘bases’ is described.

Keywords

Acids and bases; chemistry triangle; design-based research; key ideas

INTRODUCTION

‘Acids’ and ‘bases’ are a central topic in chemistry classes due to their history (Rychtman, 1979). However, acid-base reactions not only have historical value; they are still very relevant both in an everyday context, in the form of acidic and basic solutions, and in the chemistry laboratory, as they constitute one of the four main types of inorganic reactions and are an important example of donor-acceptor reactions (House & House, 2010). Especially in the chemistry classroom, ‘acids’ and ‘bases’ are a pertinent topic as they can be used to connect substances known to most learners to chemical reactions on the submicroscopic level (Taber, 2013).

Due to their rich history and the scientific interest ‘acids’ and ‘bases’ have garnered, numerous studies on (alternative) learner conceptions about ‘acids’ and ‘bases’ have been conducted (e.g. Hoe & Subramaniam, 2016; Pan & Henriques, 2015). In addition, teachers’ (Alvarado et al., 2015; Drechsler & van Driel, 2008) and pre-service teachers’ knowledge and confusion about ‘acids’ and ‘bases’ were researched (Barke & Büchter, 2018; Lembens & Reiter, 2018), and textbooks were analysed with regard to their conceptual coherence (Lembens et al., 2019). However, there is not only demand for knowledge about learner perspectives and conceptions of ‘acids’ and ‘bases’ (Duit et al., 2012), but also about **how to help students learn** about the topic (Johnstone, 2000). Consequently, the overall goal of this doctoral project is to research how to teach the topic ‘acids’ and ‘bases’ in upper secondary schools in a way that is adequate and effective for the learners. A first step in this investigation is to formulate *Key Ideas* based on previous research. According to Haagen-Schützenhöfer (2016, p. 21), *Key Ideas* are the central concepts of a subject or subject branch. These concepts constitute the centre of learning processes for developing an understanding of a concrete target group of learners and are generally set in a particular context (Haagen-Schützenhöfer, 2016). Thus, the research question treated in this paper is the following:

> What aspects of the topic 'acids' and 'bases' should be suited to form *Key Ideas* for learners to develop effective learning environments for learners at upper secondary level?

DESIGN & METHOD

The overall aim of this doctoral project is to design a learning environment (LE) which should support students in constructing an adequate understanding of acid-base reactions by means which will be designed in the course of the project. In other words, the final goal is to construct a design (in this case, an LE), test it and refine it accordingly. Thus, a design-based research approach is deemed appropriate (Bakker, 2018; Herrington et al., 2007).

This paper discusses the first step in the project, namely the development of its basis in the form of so-called *Key Ideas.* Developing *Key Ideas* as central concepts of a topic is a common starting point for design-based research projects (e.g. Wiener et al., 2015; Zloklikovits & Hopf, 2020) using the method of probing acceptance (Jung, 1992). These central concepts of a topic are adapted for a concrete target group of learners and are generally set in a particular context (Haagen-Schützenhöfer, 2016). In our case, the target group consists of students who are in their first year of chemistry in upper secondary schools (year 11, age 16 to 17).

Consequently, the following steps were covered during the development of the *Key Ideas* (see Fig. 1):

Problem analysis: The topic of 'acids' and 'bases' has a high historical value and relevance in the field of modern chemistry (Rychtman, 1979). In addition, it is seen as a central topic in the chemistry classroom (Taber, 2013). However, the literature shows that 'acids' and 'bases' are difficult concepts for learners, as they seem prone to developing alternative conceptions about the topic (Hoe & Subramaniam, 2016; Pan & Henriques, 2015) and are often confused by the different acid-base models (Carr, 1984; Paik, 2015).

Developing solutions: In our study, a first step was to develop *Key Ideas* about the subject, using the *Model of Educational Reconstruction* (Duit et al., 2012). In other words, we constructed a first 'solution' to the problem in the form of learner-appropriate explanations for acid-base reactions. The development of these was informed by existing designs (e.g. Jiménez-Liso et al., 2020), a literature analysis (e.g. Lembens et al., 2019; Sieve & Bittorf, 2016) and known alternative conceptions about the topic (Hoe & Subramaniam, 2016; Pan & Henriques, 2015).

The *Key Ideas* will later on be tested using the method of probing acceptance (Jung, 1992), reflected upon and refined in iterative cycles (see Figure 1) so as to form a final learning environment about 'acids' and 'bases'.

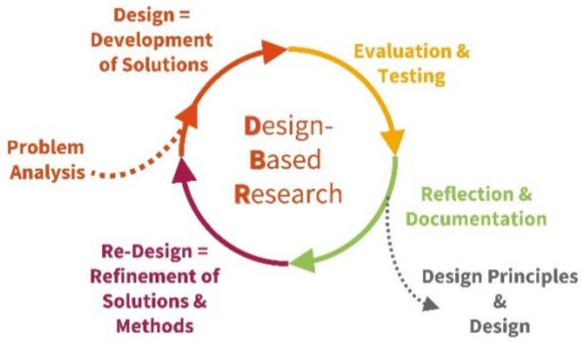

Fig. 1 The design-based research cycle (based on Herrington et al., 2007; Reeves, 2006; Zloklikovits & Hopf, 2018).

PROBLEM ANALYSIS

The *Model of Educational Reconstruction* (see Figure 2) was used to analyse the problem, i.e. how to make knowledge about 'acids' and 'bases' comprehensible in an effective and appropriate manner (Duit et al., 2012), and construct a first 'solution' in the form of *Key Ideas*. The results of the analysis can be found below.

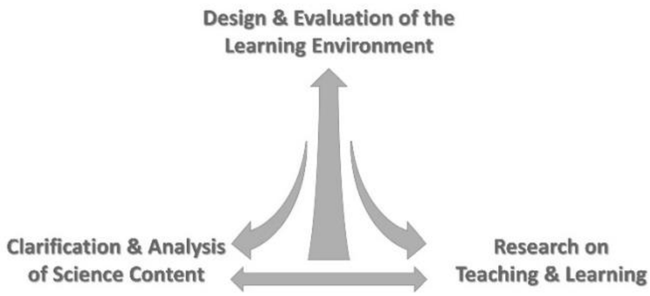

Fig. 2 The Model of Educational Reconstruction (based on Duit et al., 2012).

Research on teaching and learning

As mentioned above, numerous (alternative) learner conceptions about 'acids' and 'bases' are known (Carr, 1984; Garnett et al., 1995; Hoe & Subramaniam, 2016; Pan & Henriques, 2015). Studies primarily focus on the Arrhenius and Brønsted-Lowry models of 'acids' and 'bases', and highlight that Arrhenius "confuses and misleads students" (Hawkes, 1992, p. 542); this might be due to the fact that the different models are not introduced correctly (Lembens et al., 2019) or without an appropriate context (Paik, 2015). However, some authors (e.g. Hawkes, 1992) assert that the Arrhenius model of acid-base reactions as such is confusing for learners and should not be used in the chemistry classroom. In addition to model confusion, the inconsistent use of the terms 'acid' and 'base' to denote both the substance and the particle appears to foster learner confusion (Lembens et al., 2019). Thus, the topic as such is challenging for learners.

Clarification and Analysis of Science Content

Based on the curriculum for Austrian upper secondary schools (BMUK, 2016) and previous analyses of the topic 'acids' and 'bases' (Alvarado et al., 2015; Jiménez-Liso et al., 2020; Lembens et al., 2019), *Key Ideas* on the topic of 'acids' and 'bases' should include the following aspects:

- Acid-base reactions follow the donor-acceptor concept
- Acid-base reactions can take place in protic solvents
- Acid-base reactions can occur in a gaseous state

Due to these requirements, the Brønsted-Lowry model of acids and bases (Brønsted, 1923; Lowry, 1923) is used for our project and refined according to the *Model of Educational Reconstruction* (Duit et al., 2012) to suit the chosen learner group.

DEVELOPING SOLUTIONS

With the *Model of Educational Reconstruction* (Duit et al., 2012), the following *Key Ideas* were developed on the subject:

Key Ideas

1. Acid-base reactions represent one type of inorganic reactions (House & House, 2010).
2. Acid-base reactions are protolysis reactions. In the course of the reaction, one of the particles such as B^- attracts the hydrogen atom of another particle HA with one of its free electron pairs. This leads to the dissolution of the bond between the hydrogen atom and the rest of the particle to form the particle A^-, and the formation of a bond between the hydrogen and the first particle to form the particle HB (Brønsted, 1923; Lembens et al., 2019; Lowry, 1923).
3. Particles such as HA 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). In particular, negatively charged Brønsted bases such as B^- highlight the reaction between acid and base by emphasising the electrostatic interaction between the negative charge of the base and the positive partial charge (δ+) of the hydrogen atom (own work; based on House & House, 2010; Rychtman, 1979).
4. The Electron Pushing Formalism can be used to better comprehend the movement of electron pairs and bond formation in acid-base reactions (based on Sieve & Bittorf, 2016).

5. Acid-base reactions can be reversible, especially if they take place in an aqueous solution (based on House & House, 2010; Jiménez-Liso et al., 2020).
6. Strong and weak acids and bases exist, and their relative strength can be quantified in aqueous solutions (Brønsted, 1923; Lembens et al., 2019).

Especially *Key Ideas 2* and *3* are central to this approach of teaching acid-base reactions: We chose to introduce acid-base reactions first by focusing on the reaction mechanism, and then to define acids and bases as particles. Here, we highlight the electrostatic interaction between particles and the transfer of electrons during the reaction. We believe that this procedure helps students better understand acid-base reactions as a type of reaction and less as an outlier that puts focus mostly on the transfer of protons. In addition, by emphasising that particles reacting as acids or bases can only do so in the course of an acid-base reaction, we strive to explain to learners that acidity and basicity are not intrinsic properties of particles and that not every bound hydrogen atom makes a compound an acid (Hoe & Subramaniam, 2016).

CONCLUSION & OUTLOOK

In conclusion, we gave an overview of the first steps in a larger doctoral project. The overall aim of this project is to design a learning environment (LE) that supports students in constructing an adequate understanding of acid-base reactions. This LE is based on *Key Ideas* presented in this paper and tested, at first, in the form of explanations presented to individual students in teaching experiments, and, finally, in the form of a complete LE in the chemistry classroom.

The main point presented in this paper involves the development of *Key Ideas* with the *Model of Educational Reconstruction* to later form an LE about 'acids' and 'bases' for Austrian upper secondary schools. The process of analysing scientific content and learner perspectives in order to formulate learner-appropriate explanations on the topic is delineated. The *Key Ideas* focus on how acid-base reactions work on the submicroscopic level according to an adapted Brønsted-Lowry model and highlight the bond breaking and forming during the reaction as opposed to the transfer of protons. The *Key Ideas* are subsequently tested in teaching experiments using the method of probing acceptance (Jung, 1992). We expect that this next step in the project, the teaching experiments with students, will show satisfactory preliminary results on the effectiveness of the approach.

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The influence of 3D models and animations on students' motivation in chemistry and biology – The results of the pilot study

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Abstract

The aim of the pilot study and was to find out the influence of using 3D models and animations on students of 8th and 9th grade of elementary school. The pilot study took place in 2019 and overall 66 students participated in it. The following research tools were used: Motivated Strategies for Learning Questionnaire (MSLQ) and Intrinsic Motivation Inventory (IMI). The results of the statistic outcomes show that using 3D models and animations in teaching process led to a significant increase in students' intrinsic motivation in Chemistry and Biology with overall effect size Cohen's $d = 1.37$. The largest effect was found in the increased interest in the topic of the lessons.

Keywords

Animation; motivation; chemistry; biology; education

INTRODUCTION

The lessons of natural sciences (for example Biology and Chemistry) are often taught with the support of various models, schemes, animations, videos and other visual aids which can increase the cognitive process of students Visual aids can be basically divided into three categories: (i) 2D and 3D static models; (ii) 2D and 3D dynamic models (animations); (iii) 2D and 3D multimedia models (Schönborn & Anderson, 2006). Generally, the need for the visual support is evident mainly in fields in which the properties of microscopic objects are introduced and discussed (Herman et al., 2011). Based on the results of previous research, Chemistry as a school subject is perceived as unfavorite subject for pupils (Pavelková et al., 2010). One of the potential causes of low attractiveness of Chemistry is the high level of abstraction required for understanding some of the essential concepts as the crystal structure or an orbital (Chen et al., 2015). The explanation of these concepts can be simplified by using appropriate visual aids helping teachers to explain the abstract topics more effectively. Consequently, better visualization and understanding the abstract models lead not only to a better memorization of the concept, but it also prevents the occurrence of misconceptions (Tarmizi, 2010).

In order to assess the influence of 3D models and animations on pupils, we decided to conduct a pedagogical experiment. Before its implementation, a pilot study was realized in 2019. The aim of the pilot study was to create research tools as well as to measure the influence of application on students' intrinsic motivation, eventually to identify the problematic steps in the suggested pedagogical experiment.

THEORETICAL BACKGROUND

A great amount of studies investigating the influence of 3D models and animations on students were published during last years. Some of them claim the positive effect of using the animations during educational process (e.g. Lin & Atkinson, 2011; Šarboch et al., 2019), while others are not clear in their conclusions (e.g. Boucheix & Schneider, 2009; Bulman & Fairlie, 2016).

A few meta-analysis summing up the results of the existing studies were also published. One of the most actual is a research of Castro-Alonso, Wong, Adesope, Ayres and Paas, whose meta-analysis comprised 82 pair-wise comparisons of animated vs. static graphic visualizations revealed an overall small-sized effect (Hedge's g = 0.23) showing that dynamic visualizations were more effective than static visualizations (Castro-Alonso et al., 2019).

The results of the previous empirical studies investigating the influence of animations point to overall advantage of dynamic visualizations in comparison with static visualizations but do no present uniform outcomes and further investigation is required to find when animations are more effective (Kaushal & Panda, 2019).

RESEARCH QUESTIONS

The goal of our pilot study was to find out the influence of using 3D models and animations on students' motivation. Moreover, we were interested whether this positive influence of using 3D models and animations does not drop significantly with the frequency of its usage. For these reasons, our research questions were:

1. Is there a statistically significant difference between the control and the experimental group regarding intrinsic orientation of students in standard lessons of Natural Sciences (without the usage of 3D models and animations) at the beginning of our pilot study?
2. Is there a statistically significant difference between standard lessons and lessons supported by 3D models and animations regarding intrinsic goal motivation of students?
3. Is there a statistically significant difference in intrinsic orientation of students in experimental group between the beginning and the end of the pilot study?

METODOLOGY OF THE PILOT STUDY

Participants

The pilot study was realized at 8th and 9th grade of elementary school in Biology and Chemistry. In total, 66 students, aged 14-16, participated in it. There were two parallel classes (coded A and B) in each year at this school and all of the classes engaged in this research were taught by the same teacher. The classes were randomly divided into a control group (classes 8A and 9A) and an experimental group (classes 8B and 9B).

The teacher incorporated 3D models and visualizations into the lessons in the experimental group for 2 months, whereas the control group was taught as before the pilot study. The teacher could use visual aids in the control group as well (pictures and schemes, among others), but not 3D models or animations.

Learning environment

As a source of animations and 3D models was used the Corinth application (see Fig. 1). Corinth is a Czech start-up company focusing on development of interactive 3D aids for teaching natural sciences at elementary schools as well as high schools. The purpose of this application is to support the usage of digital support in education at elementary schools as well as high schools. Nowadays, the application contains more than 1 500 different materials for teaching Humans and Nature including 3D models, animations, depth zooms and videos. The purpose of using this app is to help students to understand abstract topics and complicated tasks better. (Corinth s.r.o., 2020) All models were created in a way which allows the students and their teachers to rotate, zoom and work with them simply by the motion of their fingers on the screen of their tablets.

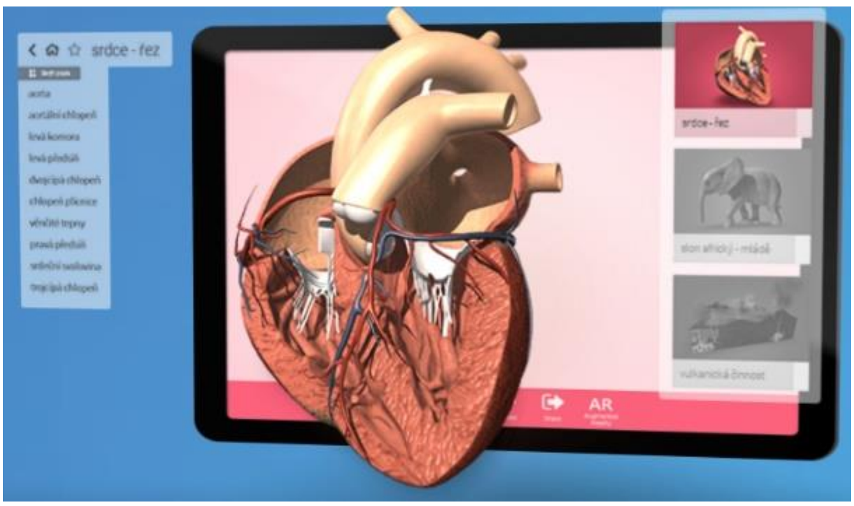

Fig. 1 The Corinth application (Corinth s.r.o., 2020).

Research Tools

The data were collected using standardized questionnaires:

1. Pre-questionnaire (based on Motivated Strategies for Learning Questionnaire (MSLQ), Pintrich et al., 1991)
2. Post-questionnaires (based on Intrinsic Motivation Inventory questionnaire (IMI), Ryan, 1982)

The Pre-Questionnaire was created by selecting sixteen statements from MSLQ in a way that each of the selected statement belong to one of these scales: (i) intrinsic goal motivation, (ii) extrinsic goal motivation, (iii) self-efficacy for learning and (iv) performance and control beliefs.

The Post-Questionnaires were created by selecting twenty-five statements from IMI in a way that each of the statements belong to one of these scales: (i) interest / enjoyment, (ii) effort / importance, (iii) perceived competence and (iv) value / usefulness. All of these scales belong to the area of students' intrinsic motivation. The Post-Questionnaire was created in 2 modifications – one for the control group (focusing on traditional teaching methods in education process – Post-Questionnaire 1) and one for the experimental group (focusing on using the animations and 3D models in education process – Post-Questionnaire 2).

In all of these questionnaires, the 7-point scale was used so that pupils could show their level of agreement with each of the statements in the questionnaires (from "absolutely agree" to "absolutely disagree") (Pintrich et al., 1991; Ryan, 1982).

Pilot Experiment

There were four parallel studies – the influence of the application on the students of 8th grade in Biology (classes 8A and 8B), the influence of the application on the students of 8th grade in Chemistry (the same classes 8A and 8B), the influence of the application on the students of 9th grade in Biology (classes 9A and 9B), the influence of the application on the students of 9th grade in Chemistry (the same classes 9A and 9B).

Each student filled in a Pre-questionnaire at the beginning of the first standard lesson (without the usage of animation and 3D models) and after this lesson each student filled in a Post-questionnaire 1. The students in experimental group filled in Post-questionnaire 2 after second lesson (after the lessons supported by education animations and 3D models in the experimental group, Post-questionnaire 2_1). Furthermore, the students in experimental group filled in Post-questionnaire 2 again after last experimental lesson (after two months) of the pilot study – Post-questionnaire 2_2.

RESULTS AND DISCUSSION

The collected data were statistically processed and then interpreted. The interpretation of its statistical significance was based on a two-sample *T*-test or on a paired *T*-test. Cohen hesitantly defined effect sizes as "small, d = 0.2," "medium, d = 0.5," and "large, d = 0.8". (Cohen, 1988)

The reliability of results was calculated using the Cronbach alpha coefficient for all the scales of assigned questionnaires. All the received values of this reliability reached the required level because the value of the coefficient surpassed generally accepted value of Cronbach alpha 0.7 (Nunnally, 1978). The collected data are internally consistent and reliable and based on the confirmation analysis of verified model (Skoršepa, 2015) new variables were calculated as a mean of individual answers in the post-questionnaires (for pre-questionnaire: *intrinsic goal motivation*, *extrinsic goal motivation*, *self-efficacy for learning and performance*, *control beliefs*; for post-questionnaires: *interest/enjoyment*, *perceived competence*, *effort/importance*, *value/usefulness*).

The influence of standard lessons (without the usage of animation and 3D models) on intrinsic goal motivation of students at the beginning of the pilot study

Using the two-sample *T*-test on data from Pre-questionnaire and Post-questionnaire 1, it was found that there is not any significant difference between the control and the experimental group in any of the tested subscale: for Pre-questionnaire (intrinsic goal motivation: t = 1.451, df = 55, p = 0.153, $M_{control}$ = 3.83, SD = 1.059, M_{exp} = 3.38, SD = 1.26, d = 0.39; extrinsic goal motivation: t = 0.58, df = 55, p = 0.563, M_{cont} = 3.61, SD = 1.23, M_{exp} = 3.41, SD = 1.38, d = 0.15; self-efficacy for learning and performance: t = -0.28, df = 55, p = 0.78, M_{cont} = 4.63, SD = 1.43, M_{exp} = 4.74, SD = 1.42, d = 0.08; control beliefs: t = -0.11, df = 55, p = 0.915, M_{cont} = 3.71, SD = 1.35, M_{exp} = 3.75, SD = 1.16, d = 0.03), for Post-questionnaire 1 (interest/enjoyment: t = -1.72, df = 48, p = 0.092, M_{cont} = 3.37, SD = 1.14, M_{exp} = 3.90, SD = 1.00, d =0.49; perceived competence: t = -1.44, df = 48, p = 0.157, M_{cont} = 3.66, SD = 1.07, M_{exp} = 4.09, SD = 1.05, Cohen's d = 0.41; effort/importance: t = -0.16, df = 48, p = 0.875, M_{cont} = 4.37, SD = 1.03, M_{exp} = 4.42, SD = 1.04, d =0.05; value/usefulness: t = -0.89, df = 48, p = 0.380, M_{cont} = 3.50, SD = 1.13, M_{exp} = 3.76, SD = 0.91, d =0.25).

The influence of the animation and 3D models on intrinsic goal motivation of students

Using the paired *T*-test on data from Post-questionnaire 1 and data gained from Post-questionnaire 2_1, it was found that there is a significant difference in all subscales between the data collected after standard lesson and data collected after the experimental lesson (interest/enjoyment: t = -7.89, df = 14, p = 0.000, M_{cont} = 3.96, SD = 1.02, M_{exp} = 6.36, SD = 0.69, d = 2,77; perceived competence: t = -2.91, df = 14, p = 0.011, M_{cont} = 4.56, SD = 1.19, M_{exp} = 5.73, SD = 1.02, d = 1.06;

effort/importance: $t = -4.02$, $df = 14$, $p = 0.001$, $M_{cont} = 4.03$, $SD = 1.10$, $M_{exp} = 5.22$, $SD = 1.30$, $d = 0.99$; value/usefulness: $t = -8.05$, $df = 14$, $p = 0.000$, $M_{cont} = 3.96$, $SD = 0.94$, $M_{exp} = 6.29$, $SD = 0.70$, $d = 2.82$). Our study concluded that the using of 3D models and animations has a major effect on all aspects of intrinsic goal motivation of students for studying natural sciences. The largest effect was found in the increased interest in the topic of the lessons as well as understanding its importance of their content.

The influence of 3D models and animations on intrinsic goal motivation of students in time

Using the paired *T*-test on the data gained from Post-questionnaire 2 given to students belonging to experimental groups at the beginning (2_1) and the end of the pilot study (2_2), our research tested whether there is a decrease in the positive effects of using this application with frequency of its usage in longer-term period (interest/enjoyment: $t = 1.78$, $df = 11$, $p = 0.102$, $M_{beginning} = 6.49$, $SD = 0.49$, $M_{end} = 5.93$, $SD = 1.23$, $d = 0.60$; perceived competence: $t = 0.74$, $df = 11$, $p = 0.474$, $M_{beginning} = 5.86$, $SD = 0.80$, $M_{end} = 5.65$, $SD = 1.03$, $d = 0.23$; effort/importance: $t = 0.56$, df = 11, p = 0.590, $M_{beginning} = 5.41$, $SD = 1.25$, $M_{end} = 5.18$, $SD = 1.38$, $d = 0.17$; value/usefulness: $t = 1.67$, $df = 11$, $p=0.123$, $M_{beginning} = 6.40$, $SD = 0.57$, $M_{end} = 5.97$, $SD = 0.98$, $d = 0.54$). Despite the fact that there is not any significant decrease in effects of the application on any of the subscales, there is a small effect size proven in each of these changes. The largest decrease was found in the level of interest in the content of the lesson. Comparing the data with the classic teaching style (Post-questionnaire 1), there is a still a significant influence of Corinth application with a large size effect even after two months of intensive support of the application (interest/enjoyment: $p = 0.001$, $d = 1.51$; effort/importance: $p = 0.005$, $d = 1.20$; perceived competence: $p = 0.005$, $d = 1.19$, value/usefulness: $p = 0.001$, $d = 1.60$).

Comparing the obtained results with previous researches, the effect of application is larger than in some of them. The diversity of results can be caused by the low number of participating students, the personality of the teacher as well as the subject matter (see limitations).

LIMITATIONS

This pilot study has specific limitations – the first of which is the sampling, which was not random, but intentional. This procedure is acceptable and appropriate for preliminary researches and pilot studies (Cohen et al., 2007; Hertzog, 2008). Consequently, it is necessary to rely rather on the effect size and its interpretation rather than on statistical significance as it was presented in results (Soukup, 2013). Secondly, another limitation is the choice of the specific topics taught during the pilot study – human anatomy and geological processes in Biology, and atom and chemical bond in Chemistry. Generally, these four topic are abstract and therefore it is vital to visualize the subject matter presented to students so that they can get the picture of the abstract concepts better.

The results of the pilot study cannot be generalized to different grades of elementary school nor to equivalent grades in different types of schools.

CONCLUSION

Based on our pilot study, it was found out that the using animations and 3D models has a positive effect on all investigated aspects of students' intrinsic orientation (interest / enjoyment, perceived competence; effort / importance and value / usefulness) in lessons of Biology and Chemistry. All aspects of intrinsic motivation reached higher ratings compared with standard lessons (without the support of the application). After two months, there was a slight decrease in students' intrinsic orientation for students who had experienced lessons with the support of using animations and 3D models. However, this change did not prove to be significant.

This pilot study was followed by a research conducted in the Czech Republic in 2019 with the sample of 600 students from elementary schools and high schools in total. The same research tools and schedule of the experiment were used as there were not reported any inaccuracies in the pilot study.

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Where are the Barriers for Higher Frequency of Safe Experimental Activities in Secondary Chemistry Education

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Petr A. Skřehot & Zdeněk Hon

Abstract

The contribution presents results of an analysis focused on current state of pedagogical practice in the field of safe chemistry experimental activities in Czechia. The analysis targeted both students' and teachers' experimental activities in schools focusing on valid legislation and the actual observance of safety requirements. A questionnaire was used to gather data. It was filled by 354 lower- and upper-secondary school chemistry teachers. Main results cover problems with appropriate time and place for experimental activities. Unclear legislative conditions and appropriate teacher education were found as barriers for broader range of experimental activities in schools.

Keywords

Safety laboratory work; experimental activity; secondary chemistry education

INTRODUCTION

School chemistry experiment has been broadly discussed as one of the means towards increasing students' interest in chemistry as a school subject (Drozdíková & Prokša, 2016; Rusek et al., 2018; Rusek & Gabriel, 2013). Except for activating aspects, it is a means towards chemistry subject-matter delivery to students on all levels school system as it enables to apply procedures used in chemistry (as a scientific discipline) and by doing so supports scientific literacy's development (Janoušková et al., 2019). Its forming is important not only for chemophobia removal process, but also to understand the sense of chemistry in everyday life as well as entire society's wellbeing.

Another, well-described, benefit of chemistry experiments is in their role of a natural chemistry-triplet's employment (Johnstone, 1991). Introduced by Alex H. Johnstone and later revisited (Taber, 2013) or extended by others (e.g. Talanquer, 2011), its three levels: macro, sub-micro and symbolic allow for students' chemistry learning difficulties explanation (Johnstone, 1991). Johnstone argued, the role of chemistry in this respect was more difficult comparing to physics and biology. In physics, most phenomena involve "macro" with only forces being "symbolic" representations. In biology, "macro" is even more visible, and also relevant to students (Stuckey et al., 2013), with cells representing sub-micro and biochemical processes being on the symbolic level. However, in chemistry, the closest to learners is the sensory (macroscopic level), followed by atoms/molecules (sub-micro), and the formula and equations (symbolic level). Gabel (1993, p. 193) suggested, "using an equilateral triangle with a level at each vertex, any point within the triangle can represent the percentage of time allocated to using a given level in the teaching of chemistry''.

With respect to contemporary knowledge about chemistry lessons preparation (Vojíř & Rusek, 2021), in light of the ideas above, promoting experiments is a way to support the "macro" element of chemistry education "balancing the triangle".

Despite requirements on higher frequency of experimental activities in chemistry education, the long-expected result has not come yet. It is a very slow process usually blamed on insufficient time and low material equipment in schools (Beneš et al., 2015; Rusek et al., 2020). Also for this reason, chemistry stays out of students' interest on lower-secondary (Veselský & Hrubišková, 2009) as well as upper-secondary schools (Kubiatko, 2015; Kubiatko & Balátová, 2016; Rusek, 2014).

There have been several initiatives attempting to improve the situation (Bílek, Kováčiková, & Jenisová, 2011):

- A broad spectrum of chemistry experiment visualizations (projected, video-experiments, on-line experiments, visualizers, web-cameras, virtual labs etc.),
- A turn for everyday-use compounds and experiments with them (food, cleaning compounds, "intelligent" materials etc.).

Experiments are also included in textbooks, however, not in all cases safety and feasibility in schools is taken into account (Vojíř, 2021). A relatively new approach in increasing the frequency of chemistry experiments in schools is a creation of supporting materials which accent safe laboratory practice. The project BEDOX – Evaluation of processes for safe practical chemistry education in schools. The project is supported by the Technological Agency of Czech Republic. The project was established in cooperation of teams from the Faculty of Biomedical Engineering, Czech Technical University in Prague, the Expert Institute of Safety and Health Protection in Prague and the Department of Chemistry and Chemistry Education, Faculty of Education Charles University. The aim of the project is to analyse the current state of pedagogical practice and curricular documents in the field of safe chemistry laboratory practice in the Czech Republic and, based on the results, to prepare an electronic database of videos presenting a selection of safe chemical experiments usable in the school laboratory accompanied with methodical comments from chemistry education point of view.

METHODOLOGY

Aims

The initial aims of the project BEDOX were to analyse the current state of practical teaching of chemistry as a school-subject of a general education nature, with a special focus on students' and teachers' experimental activities in schools. Both the valid legislation and the actual observance of safety requirements in school chemistry laboratories or spaces where they are conducted is taken into account. The research was guided by the following research questions:

What is the frequency of experimental activities in general chemical education?

What affects experiments' inclusion into chemistry education?

Research Sample

The sample and its selection was described in more detail in Rusek et al. (2020).The stratified research sample consisted of 354 teachers teaching chemistry as a general-educating subject in secondary education, which completed the whole questionnaire. The sample contains 302 lower-secondary, 222 grammar school and 21 lyceum chemistry teachers. 79 teachers answered that they teach at two types of school. In this case, their answers were analysed in both teacher categories. A typical respondent for the research is a female teacher (80.7%) with more than 20 years of practice (51.9%) who has a degree in chemistry education (76.2%). With respect to the estimated number of chemistry teachers in lower-secondary schools and a similar recomputation for grammar schools, is the number of participants above the minimal sample, therefore it is possible to generalize the data.

Research Method and Data Collection

For data collection, a questionnaire was used. It consisted of three parts: respondents' identification (chemistry teacher at Czech secondary school with orientation to general education), school experimental activities in teachers' view and safe experimental practice in teachers' view. The draft-version of the questionnaire was piloted among the project team members as well as with 18 chemistry teachers who had previously cooperated with the team members in project "Didactics: Man and Nature A" (Rychtera et al., 2019). The data collection took from June 2019 to March 2020. The answers on scales were assigned numeric values (1 - every lesson, 5 - never). For this reason, the data were treated as ordinal. The questionnaire was created in the 1Ka app. The data were analysed directly in the 1Ka and partly in MS Excel.

RESULTS AND DISCUSSION

Main results describe problems with appropriate time and place for experimental activities in secondary chemistry education. Only a third of the respondents mentioned doing experiments at least once a week. Almost a half of the respondents once a month. An alarming one fifth of the teachers mentioned doing experiment less frequently than once a month or never (see Fig. 1). Considering the fact this time period usually covers one topic, the teachers basically admitted teaching some topics without conducting at least one experiment to accompany their teaching.

Moreover, when asked about students' experiments, a third of the teachers responded they do not do them. Only 14% mentioned doing them on a weekly basis. Almost a half of the respondents said they include students' experiments less than once a month (see Fig. 2). This points to only a theoretical way of chemistry teaching which is in contrast to contemporary conception of chemistry teaching (e.g. Beneš et al., 2015; Bretz, 2019). As far as the development of scientific literacy mentioned above is concerned, such education cannot lead to its development as the epistemic aspects are impossible to show theoretically.

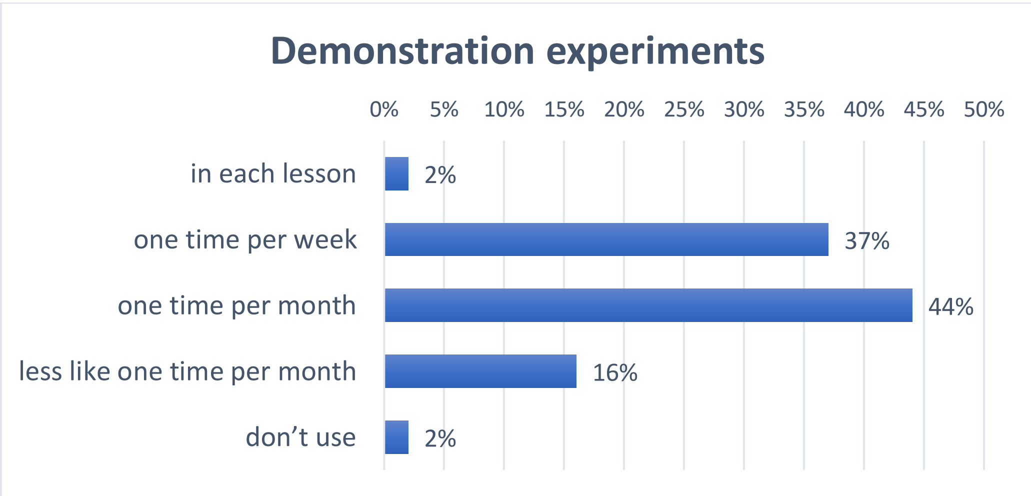

Fig. 1 Answers to the question: How often do you include demonstration experiments (performed by the teacher) in the teaching of chemistry? (N = 354)

Other barriers that emerged from the teachers' responses to the questionnaire were unclear legislative conditions and appropriate teacher education. Only one fifth of the teachers consider their knowledge about safety regulations *good*. Despite almost 75% mentioned they know safety regulations for chemistry teaching in laboratories, only a third mentioned consulting it actively (Fig. 3). Only 40% of the participating teachers mentioned they have elaborated written rules for disposing of chemical compounds. In addition, more than 20% mentioned they do not have anywhere to consult about occupation safety.

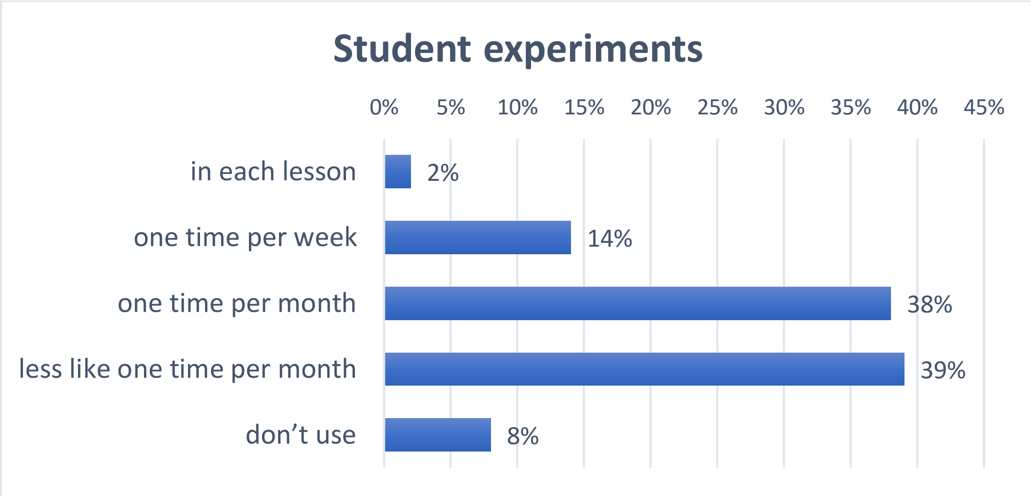

Fig. 2 Answers to the question: How often do you include student experiments in the teaching of chemistry? (N = 354)

More than 70% of the teachers considered their university preparation in this aspect only marginal, almost non-existent or did not remember they had it. Only 17% considered preparation in this respect as extensive (Fig. 4).

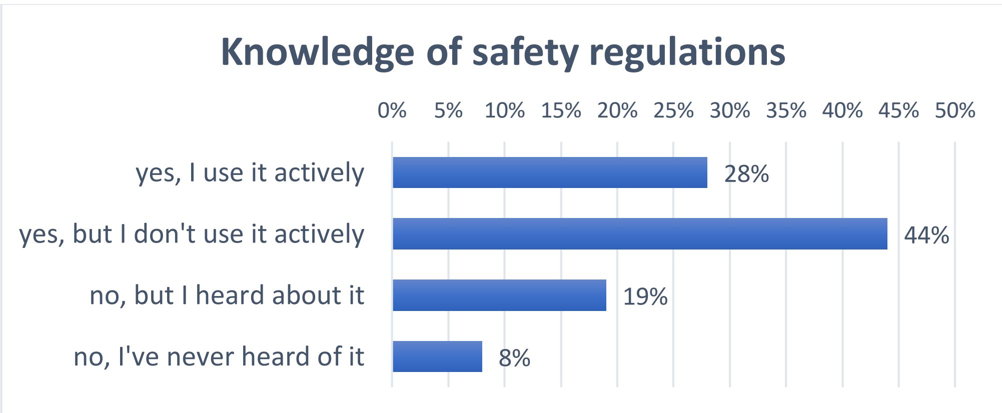

Fig. 3 Answers to the question: Are you familiar with ČSN 01 8003 “Principles of safe work in chemical laboratories“? (N = 354)

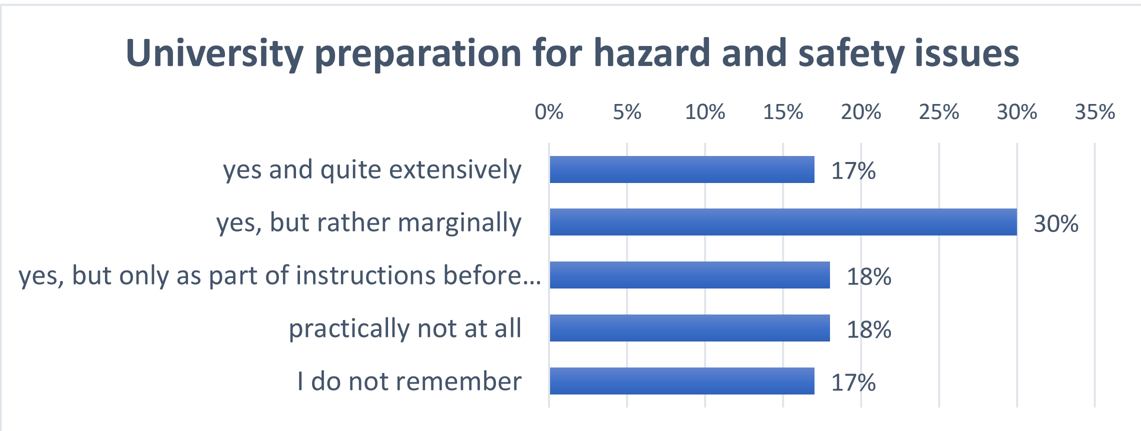

Fig. 4 Answers to the question: Was attention given to occupation hazard and safety issues in chemistry experimental activities during your undergraduate studies? (N = 354)

Almost a half of the teachers (48%) would welcome more activism from universities which offer chemistry education programmes in offering information for school experimental practice. A third of the teachers would prefer this area to be a part of further teacher education (31%) Only 13% teachers consider the activity of universities in this area to be sufficient. The remaining minority of teachers has opinion that it is a matter of practice (4%) or different opinion (4%).

The results show that this area is quite neglected and chemistry teacher education needs to be extended here. Without a sound safety measures, many teachers will remain reluctant to co chemistry experiments. Considering its effect on education, this might be a gamechanger for the field.

As far as pre-service chemistry teacher training is concerned, school experiments are being included only in small proportions as parts of chemistry education training. These are, however, regulated by the Ministry of Education and further hourly extension is not allowed, - teaching study programs for the lower-secondary schools contain only 10–15% courses of both taught fields didactics, i.e. 5–7.5% for the subject didactics for the entire teaching study (bachelor and follow-up master's), in upper-secondary school programmes it is even only 8% for both taught fields didactics, i.e. 4% for the subject didactics (Bilek, 2020, MSMT, 2017).

Due to this paper authors' experience, not even teacher training which is usually mostly focused on content offers a sufficient base for school experimental activities. Conditions for them differ from chemistry labs pre-service teachers work in their training. The results of this research showed, 30% of the teachers do experiments in a normal classroom without special equipment. This limits the range of possible experiments. 42% of teachers (grammar school or lyceum) use a school lab.

Another valuable information about the state of chemical experiment in schools was gathered with the use of open-ended questions on experiments teachers consider worth a special safety measures. The teachers mentioned a broad spectrum of experiment. Several of them were expected: hydrogen preparation, experiments with acids (namely sulfuric acid) and bases, experiments with fire (including manipulation with a burner) and with flammable materials (e.g., ethanol, propane-butane), reaction of sodium with water, ethyne preparation, experiments with gases, halogens, soap preparation etc.

The teachers often mentioned effect-experiments the use to capture students' attention: "hell in a test-tube, Bengal fire, Elephant toothpaste, Pharao's snakes, volcano on a table, ammonium fountain etc. Several teachers mentioned "*all experiments dangerous*" or "*Any experiment – you need to be alert all the time*.". Some teachers, surprisingly also mentioned experiments which usually are not considered dangerous: limewater preparation, distillation etc. Almost half of the respondents used this opportunity to express their attitude towards experiments and to mention concrete examples. These later served as inspiration for selection of the experiments for the database. The teachers' responses on “*What should not be missing in the database?*”, they mentioned also demonstrations of basic lab operations (setting a burner on fire, working with a pipette or burette), but also an overview of safety protective equipment’s overview, reaction products’ disposal, detailed methodology of experiments’ conduct, first-aid and other connections to experiments.

In the final option to add anything to the topic of occupation safety many teachers mentioned their concerns (barriers) teachers are aware of or cause themselves. For instance: “*I think the biggest problem is school lab’s equipment…”, “Students are less skilled from home…, therefore, I must reduce experiments’ difficulty.”, “There is a lack of a list of compounds students are allowed to work with.”, “There is a lack of courses (seminars), information newsletter, focused on occupation safety in chemistry education.”, “Not to be scared to do experiments, because when risks are correctly assessed and students instructed, chemistry can really be fun.”*

Similarly to inclusion of ICT in chemistry education (Rusek et al., 2017) or student-centred approach (cf. Rusek, 2021), also examples of well-functioning experimental activity might persuade more conservative teachers towards their use. Recently, there were such endeavours (Tóthová et al, 2019), yet they still remain isolated.

CONCLUSION

Contemporary state of experimental activities in chemistry as a school subject of general nature, i.e., chemistry at lower-secondary, grammar and non-chemical vocational schools, is, in spite of several examples of good practice, far from ideal. The questionnaire survey’s results provided a considerably complex picture which enables to take further steps in teachers’ complex support. It consists of chemistry experiments video database and related material. Teachers’ opinions and experience about the main barriers for more frequent experiment insertion into chemistry lessons were identified. It is namely insufficient material equipment and legislative obscurity concerning occupation safety. Teachers also mentioned overdesigned curriculum. School experiments, demonstration or namely students’ experiments, require sufficient room for planning, preparation, conduct and evaluation. Chemistry as an independent school subject or a part of an integrated science school subject is not full without experiments and loses its mission. The steps mentioned in this paper have the potential to improve the status quo in Czechia.

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Factors influencing students’ inquiry results

Kateřina Trčková, Petr Bujok & Karolína Farmačková

Abstract

The research focuses on 14-year-old students who, in two-member teams, solve inquiry-based tasks on the separation of a multicomponent mixture and the analysis of substances. Students were divided into two groups: control (25 teams) and experimental (34 teams). During the two inquiry days, students verified tasks with a similar solution algorithm and recorded the obtained results in worksheets, which were evaluated and the obtained data were statistically compared. It was found that the forms of teaching used, the time lag between the inquiry days, the use of graphical representation of a scheme, manual, and communication skills of students affect the results of research.

Keywords

Problem solving; reflective inquiry; scientific competences; worksheets

INTRODUCTION

If we want to contribute to the improvement of students' skills in solving problem tasks, it is necessary to think about which factors influence the inquiry results. Průcha (1996) states that learning outcomes influence the abilities, motivations, and knowledge of students and teachers, educational programs, classroom climate, mutual communication, and mutual teacher-student interaction. The introduction of experiments into teaching helps to develop students' manual skills and supports higher-order thinking. These manual skills focus on more complex cognitive activities: the student formulates inquiry questions, plans experiments, draws conclusions, creates and substantiates arguments (Hugerat & Kortam, 2014; Lunetta et al., 2007; Zohar, & Dori, 2003). Research confirms that if a student actively participates in their knowledge, actively uses their knowledge and skills, does inquiry, discovers and searches for answers to questions: 'Why? On what principle? ', Their knowledge will be easier to transfer to new situations in everyday life (De Jong et al.2013; Lokšová & Lokša, 2003; Tóthová et al., 2019).

Since 2018, the authors of the paper have been dealing with the optimization of assignments and evaluation of inquiry tasks, their verification by 14-year-old students within two inquiry days (ID) organized by the Department of Chemistry of the University of Ostrava. Two-member groups of students are divided according to the schedule into laboratories, where under the guidance of trained instructors from among the students of chemistry teaching, they solve problem tasks. The student of teaching holds the function of a lecturer for the content of the same task verified within the 1st and 2nd inquiry day. In the contributions of Trčková and Kričfaluši (2018) Bartoňová et al. (2019) describe the pilot verification of our inquiry tasks and their evaluation. During the pilot verification, it was found that the students do not have a problem with the practical verification of the inquiry task but with the recording of the individual inquiry steps and the recording of the observation results. Based on the observation of the manual and communication skills of students working in the two-member groups, the results of the evaluation of worksheets according to predetermined criteria, after pilot verification, the thematic focus of the tasks was selected, the assignment and evaluation of inquiry tasks were modified (Trčková & Kričfaluši, 2019a, 2019b). The organization of inquiry days was changed. Tasks focused on solving problems from everyday life were selected, which included a motivational title and an introductory text. The inquiry tasks were focused on the separation of a multicomponent mixture and the analysis of four unknown substances (see Tab. 1).

AIM AND METHODOLOGY

The aim of the authors was to identify factors that may affect the results of the students' inquiry. The research questions were defined as follows: Will the application of a similar algorithm affect the results of solving inquiry tasks? Will the systematization of solving the problem using the diagram affect the results of inquiry? Will providing feedback affect the results of further inquiry? Will the form of teaching in schools affect the results of inquiry between inquiry days? Will the time lag between the inquiry days affect the results of the inquiry? We assumed that the application of a similar solution algorithm, systematization of knowledge, provision of feedback, and a smaller time interval between inquiry days positively affect the results of the research. We were interested in the extension to which of these factors will affect the quality of the recording of the analysis of the research problem, the procedure, and the results of the observations in the worksheets. Whether these factors affect the time of implementation of inquiry tasks.

Organization of the research

In order to define the factors influencing the inquiry results, two different procedures were prepared to verify the assignment of content-identical inquiry tasks in two inquiry days:

I. Verification by a control group of students:

The first inquiry day

a. At the beginning of the first 'ID', implemented in May 2019, instruction was given to students focused on recording and analyzing a problem situation.
b. During the first 'ID', the teams had the opportunity to ask for help in solving the inquiry task.

c. Instructors observe individual teams at work, record data on the time of the task, teamwork (group communication), and manual skills of students in solving the inquiry task.
d. Based on the observations made by the lecturers, the students were provided with feedback immediately after the implementation of the first 'ID'.
e. The evaluator evaluates all worksheets according to the criteria listed in Tab. 2 and 3. After the implementation of the first 'ID', full-time teaching occurs at the relevant school.

The second inquiry day

a. Based on the evaluation of the completed worksheets, feedback was provided before the implementation of the second 'ID' in September 2019.
b. During the second 'ID', the teams independently propose a solution to the problem situation.
c. Instructors observe individual teams at work, record data on the time of the task, teamwork (group communication), and manual skills of students in solving the inquiry task.
d. Based on the observations made by the lecturers, the students were provided with feedback immediately after the implementation of the second 'ID'.
e. The evaluator evaluates all worksheets according to the criteria listed in Tab. 2 and 3.

II. Verification by an experimental group of students:

The first inquiry day

a. During the first 'ID', implemented in February 2020, students work on the assignment of an inquiry task, which contains a diagram with a proposal for solving a problem situation.
b. Instructors observe individual teams at work, record data on the time of the task, teamwork (group communication), and manual skills of students in solving the inquiry task.
c. Based on the observations made by the lecturers, the students were provided with feedback immediately after the implementation of the first 'ID'.
d. The evaluator evaluates all worksheets according to the criteria listed in Tab. 2 and 3. After the implementation of the first 'ID', distance teaching at the relevant school has been taking place since March 2020.

The second inquiry day

a. Based on the evaluation of the completed worksheets, feedback was provided before the implementation of the second 'ID' in September 2020.
b. The next steps for verifying the inquiry tasks are the same as for the control group.

Inquiry-based tasks

In the first 'ID', students verified one task for the separation of a multicomponent mixture (Chemical Disaster) and the other task for the analysis of substances (Forgetful Professor). Within the second 'ID', two tasks requiring a very similar solution algorithm as in the first 'ID' were verified. The inquiry tasks were focused on the separation of a multicomponent mixture (Cinderella's chemical suffering) and the analysis of substances (Save yourself from the wrath of the chemist Horak).

Tab. 1 Characteristics of tested inquiry tasks

Inquiry day	The name of the task	Problem situation
The first day	**Chemical disaster**	A catastrophe of an oil tanker explosion at sea was simulated in the beaker. Oil (cooking oil), sepia ink (blue food coloring) leaked into the salty seawater, and algae (marjoram) swam on the water surface. The task was to solve the problem and separate the individual components.
	A forgetful professor	Labels with the name and formula of the substances were peeled off from four test tubes in the laboratory. The task was to name the substances correctly using the evidence reactions of cations and anions, flame tests, and a table describing the colored precipitates.
The second day	**Cinderella's chemical suffering**	A mixture of sawdust, salt, coconut, sand, and red dye was poured into a Petri dish. The task was to solve the problem and separate the individual components from the mixture.
	Save yourself from the wrath of the chemist Horak	The cleaner wiped the names of colorless nitrate solutions – zinc (II), calcium (II), silver (I), manganese (II) from four storage bottles. Students' task is correctly and as quickly as possible to identify these unknown samples using the evidence reactions of cations and anions, flame tests, and a table describing the colored precipitates.

Two-member groups ('C' and 'E') of students were provided with the necessary aids and a worksheet (W). All worksheets had the same basic structure. They included: a motivational text, a place for formulating the inquiry problem, writing down the necessary tools, the procedure, and the results of the observations. The structure of the worksheet differed for the 'C' and 'E' groups in the first 'ID'. The teams of the 'C' group independently decided on the level of their knowledge and skills, had the opportunity to gradually ask for help first with the inquiry problem in progress, or with the procedure or with the results of observations and work with assignments of different inquiry levels (Tab. 2). The teams of the 'E' group had a diagram in the worksheet (Fig. 1) with a developed solution to the research problem. Students added missing terms to the diagram. The 'E' worked in the first 'ID' in level 3 of inquiry.

Tab. 2 The four levels of inquiry *(Inquiry-Based Science Education)* Banchi and Bell (2008)

The levels of Inquiry-Based Science Education	Points	The questions determined by teacher	Procedure determined by teacher	Results of observations determined by teacher
1. Limited Inquiry	10	+	+	+
2. Structured Inquiry	20	+	+	-
3. Guided Inquiry	30	+	-	-
4. Open Inquiry	40	-	-	-

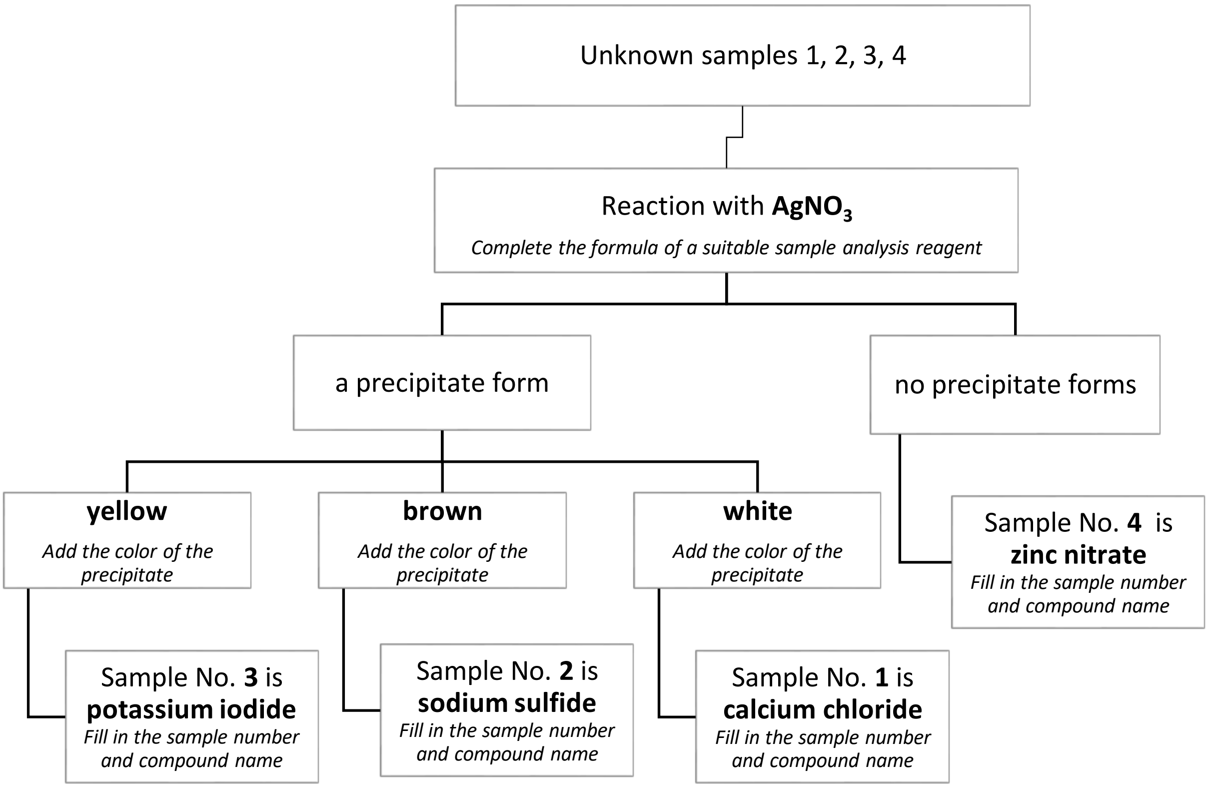

Fig. 1 Diagram – Analysis of the inquiry problem of inquiry task 'A forgetful professor', students fill in the fold text in the worksheet

Research sample

This study includes students in the eighth year of elementary school and the analogous years of multiyear grammar school (N = 118). Students formed two-member teams according to their mutual sympathies. Mini-teams were chosen to increase the performance and even involvement of individual members. Mini-teams were randomly distributed to two groups – control (C) and experimental (E). The division of students into groups randomly occurred according to the participation in the realized inquiry days. The precondition for the selection of students was the same initial knowledge and skills, and the students were randomly selected from the same class. All students had the same theoretical foundations in the curriculum on mixtures and their division and practical skills in basic laboratory operations. The control (C) group included 25 two-member teams (of which eight teams from primary schools and 17 teams from grammar schools) and the experimental (E) group of 34 two-member teams (of which 14 teams from primary schools and 19 teams from grammar schools). The number of groups 'C' and 'E' is different because it is conditioned by the participation of the same teams in two inquiry days.

Task evaluation

The evaluation of research teams in solving tasks was based on the observation and analysis of worksheets. All results of the evaluation of worksheets were filled in the 'Evaluation Card' according to predetermined criteria adjusted on the basis of the complexity of operations (see Tab. 3) and researchs conducted by us (Bartoňová et al., 2019; Trčková & Kričfaluši, 2019a). Points for the research level were allocated according to the degree of elaboration of the worksheet. The evaluation of the time of practical implementation of the task was performed by instructors from the ranks of students of chemistry teaching directly in the laboratory. The evaluation of individual items of the worksheet was based on a comparison of the correct solution and the facts recorded in the worksheet by one evaluator. Completion of worksheet items: aids, procedure and results of observations were assessed as complete, partial, or incorrect. To make it easier to distinguish the scale set by us, the individual items were summarized according to the degree of the exact answer. E.g., the completed items of worksheets were evaluated as complete, if the solution was flawless and it was awarded the grade 'excellent'. A partial solution was considered praiseworthy or good (see Tab. 3).

Tab. 3 Evaluation criteria of worksheets

Items	**Tools**			**Procedure**			**Observation results**		
Solution	**complete**	**partial**	**wrong**	**complete**	**partial**	**wrong**	**complete**	**partial**	**wrong**
Grade	1	2; 3	4; 5	1	2; 3	4; 5	1	2; 3	4; 5
Points	2	1	0	3	2	0	5	3	0

Data processing

The hypothesis was determined and tested:

H_0: There is no significant difference between the evaluation of worksheets of students' inquiry teams in the two inquiry days.

For the statistical evaluation of categorical data (items: aids, work progress, observation results), Pearson's Chi-square independence test and non-categorical data (overall work evaluation) were selected. At the inquiry level, the time of task realization, team cooperation, determination of the inquiry problem, aids, procedure, and results of the solution of the two-sample nonparametric Mann-Whitney test. This test was selected based on the rejected null hypothesis of the Shapiro-Wilk test for the normality of the observed data (Shapiro & Wilk, 1965).

RESULTS AND DISCUSSIONS

During the testing of the 'C' group on the first 'ID', it was found that students do not have a problem with the practical implementation of the task, so they did not ask for help with the analysis of the solved problem, the procedure or the results. The results of the evaluation of the completed worksheets showed that the greatest difficulties for students are to write an analysis of the problem situation, a description of the procedure, and the conclusion of the observation.

Based on these findings, schemes with work-in-progress proposals for the problem solving were inserted into the worksheets verified by an 'E' group in the first 'ID'. The advantage of these schemes is that they facilitate better understanding and interpretation of data (Mokrejšová, 2009). It was confirmed that the graphically developed solution of the problem using a scheme helps students to more successfully solve more complex problem situations in the inquiry process and in the case of the task "Chemical disaster" focused on mixtures leads to more detailed records of observation results. In the 'E' group, it was observed that the better and more detailed the scheme, the better the student process, the procedure, and the results of observations.

During the verification of the influence of the factor of using the scheme with the developed solution, the continuity of our systematic work with the 'E' group was interrupted. Due to the introduction of distance learning in schools, we were unable to confirm our assumption that the practice of systematic analysis of the problem situation in the first 'ID' will lead to improved recording of inquiry results in the worksheet in the second 'ID'. It has been proven (Turek, 2014) that systematic work influences the speed of inquiry, improving the quality and effectiveness of learning. However, this finding was not confirmed in the 'E' group in the second 'ID'. A better result compared to the control group was demonstrated in the item of compiling the problem.

No significant difference was demonstrated for the other monitored items of the worksheet (aids procedure, observation results). We believe that this fact may be influenced by other factors: the introduction of distance learning and extending the time interval between the implementation of the first and second 'ID' by three months compared to the 'C' group. Based on the observation of students in the laboratory and an interview with the teachers of the observed sample of students, we believe that the distance form of education demotivated students. The lecturers, who verified the content of the same tasks on the first and second 'ID', had the impression that they were working on the second 'ID' with a different group of students. This fact could be influenced by the predominance of passive activities (monitoring) and independent activities (study, elaboration) of students in spring distance learning over active and practical group activities (Pavlas et al., 2020).

A very interesting comparison confirming our assumption about the factors influencing the inquiry is given in Tab. 4, from which the comparison of individual items of a worksheet of a given type of inquiry task solved by control and experimental groups is evident. During the inquiry, a difference was observed between the manual and communication skills of the students of the control and experimental groups.

Tab. 4 Comparison of the success of solving inquiry tasks focused on mixtures and analytical evidence by the control and experimental group in the inquiry days

Item from rating card (RC)	*Average point evaluation of items of inquiry tasks solved by two groups of students – control (C) and experimental (E)*							
	Mixture separation tasks				**Tasks for the analysis of substances**			
	Control group $\bar{C}$		Experimental group $\bar{E}$		Control group $\bar{C}$		Experimental group $\bar{E}$	
	1. ID	2. ID	1. ID	2. ID	1. ID	2. ID	1. ID	2. ID
Implementation time	0,96	3,08	1,06	1,26	2,86	4,24	1,85	2,82
Significance of Pearson's test of independence	**< 0,001**		0,356		**0,006**		**0,031**	
Determination of the problem	3	4,6	0	6,18	4,2	1,2	0	4,56
Significance of Pearson's test of independence	**0,040**		**< 0,001**		**< 0,001**		**< 0,001**	
Procedure	1,80	1,76	2,56	2,12	2,32	2,24	2,71	2,11
Significance of Pearson's test of independence	0,121		0,054		0,529		**< 0,001**	
Observation results	1,28	1,68	2,58	0,56	1,80	3,24	2,76	2,74
Significance of Pearson's test of independence	*0,273*		***< 0,001***		***0,034***		*0,879*	
Overall scoring of tasks	47,96	54,96	41,88	55,74	54,64	56,48	43,24	58,18
Significance Mann-Whitney test	**0,001**		**< 0,001**		0,232		**< 0,001**	

The results of the independence test (Tab. 4) show an improvement in the 'C' group for most items of the worksheet in the second 'ID'. Significant differences between the first and second 'ID' are observed in the 'C' group for tasks requiring the same solution algorithm, focused on: on the division of the mixture - in the item time of implementation, a compilation of the problem and overall evaluation of the task, on the analysis of substances - in the item time of implementation, observation results and in the overall evaluation item (including points for the correct entry of aids, procedure and observation results). In the 'E' group, which implemented the second 'ID' with a time interval of seven months, we observed a significant difference in the item time of implementation for the inquiry task focused on the analysis of substances 'Save Chemist Horak'. We can state that in these cases, we reject the set H_0. For other items of worksheets completed by the 'E' group, deterioration was demonstrated in the second 'ID'. The research showed that better inquiry results on the second 'ID' can be influenced by the positive motivation of systematically working students in the traditional form of teaching at school, the shorter time interval between the first and second 'ID' and last but not least by positive feedback, provided by the task evaluator. Research confirms that for achieving better results in the learning process of students, it is necessary to provide students with timely, clear, effective, meaningful, and compatible feedback (Dabell, 2018). It is confirmed that the probability of its use by the student decreases rapidly over time. Well-provided feedback facilitates learning and gives students concrete answers: 'Where am I going?', 'How am I doing?', 'What comes next?' (Hattie & Timperley, 2007).

CONCLUSION

Inquiry-Based Science Education has been shown to be an effective method of teaching chemistry. During the inquiry, the student works actively in a team and participates in the analysis and solution of the problem situation. The results of the research show that the difficulties of students with the proposed solution to the problem situation, recording procedure, and the results of the work can be gradually eliminated using a schematic representation of the solution to the problem. The use of the scheme contributes to the improvement of teamwork and interpretation of results. The use of feedback information and the same solution algorithm contributes to improving manual skills and data interpretation capabilities. The results of our research are influenced by the time lag between the inquiry days and the form of teaching.

In order to obtain more accurate data, we propose to repeat the research in the same time interval and to implement activities supporting inquiry-based education in schools. We believe that it is necessary to change teachers' approach to the learning process by introducing discussion, heuristic, problem-based, and text-based methods.

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Genetics misconceptions of high school students

Vanda Janštová & Kateřina Lišková

Abstract

Genetics belongs to the most difficult biology topics with many misconceptions as it requires active connection of abstract terms on different levels (nucleus – cell – tissue – organism). We preliminarily mapped the most common genetics misconceptions of high school students in Czechia by a questionnaire. A very common misconception was that allele as a specific section of gene. Chromosome was mostly described only by its structure whereas DNA and gene by its function. It was fairly difficult for the students to describe the connection among three terms. We recommend to explicitly link all the different levels of organization, function and structure while teaching genetics.

Keywords

Gene; allele; misconception; genetics; high school

INTRODUCTION

Genetics has increasingly become a part of our daily lives on many levels such as genetically modified organisms and their products, methods of assisted reproduction etc. This is reflected in students' positive attitudes towards GMO (Janštová et al., 2021). They rate it as one of the most important chapters in biology (Ticha, 2019). However, genetics is one of the most difficult branches of biology for both students (Ozcan et al., 2014) and teachers (Bahar et al., 1999;). This is due to i) abstractness, ii) different levels of organization (character, nucleus, chromosome, nucleotide…) (Knippels, 2002) and iii) inability to memorize the content without understanding the context (Vlckova et al., 2016), iv) very specific vocabulary of this field (Woody & Himelblau, 2013). This causes many misconceptions (Osborne & Wittrock, 1983) which persist (Shaw et al., 2008) as the students are not able to combine the genetics concepts into a complex system (Awang-Kanak et al., 2016). Another problem is the extensive content of genetics and limited time (Lewis & Wood-Robinson, 2000). In Czechia, the knowledge about misconceptions in genetics is rather sketchy but showed that the students mostly just memorize the terms and definitions and are unable to combine genetic concepts into a complex hierarchical system, although the understanding of the relationships between concepts has not been examined (Machova, 2020; Vlckova et al., 2016).

Misconceptions

Misconceptions were defined as pre-concepts that differ from scientific knowledge (Osborne & Wittrock, 1983). Misconceptions are erroneous and illogical knowledge. These are a normal part of the learning process (Lucareillo & Naff, 2010). Identifying frequent misconceptions and working towards eliminate them is very important for effective teaching (Osborne & Wittrock, 1983). Vlckova and her colleagues (2016) mention the idea that DNA is made up of amino acids as the most common misconception concerning DNA. Pashley (1994) focused on understanding the relationship between a gene and an allele. He concluded that understanding this relationship is very problematic and at the same time necessary to understand genetics. Pupils often have the misconception that an allele is a section of a gene or a gene is a section of an allele. Very common misconceptions also occur in the area of cell division. This is probably due to the fact that cell division is often taught separately from genetics. Pupils then often do not see the difference between a somatic cell and a germ cell (Lewis et al., 2000) or, on the contrary, think that sex chromosomes are contained only in germ cells (Vlckova et al., 2016). Among the most common misconceptions is the notion that different cell types of an individual have different genetic information (Lewis et al., 2000; Lewis & Wood-Robinson, 2000).

Misconceptions occur in different science fields from zoology (Schubertová et al., 2018) to climate change (Lindner et al., 2014), in students at all school level, including university biology students and pre-service biology teachers. It is therefore very important to explain and use the right relationships between genetic concepts at all levels of education use the terms correctly (Saka et al., 2006).

Terms' definitions

When defining terms gene, DNA and chromosome, the students' answers can be divided into two categories i) functional explanation and ii) structural explanation. For students, functional explanations are highly prevalent in the terms gene and DNA. In particular, the flow of genetic information between generations, not the expression of genetic material in the cell and body. Conversely, the chromosome definition is dominated by structural explanations. However, the correct definition of individual genetic terms should include both functional and structural explanations (Marbach-Ad, 2001).

RESEARCH QUESTIONS

Because as far as we know, the understanding of the relationships between genetics concepts has not been examined among Czech students, we decided to contribute to this knowledge by a pilot study. We wanted to ask the following research questions:

1. Which genetic misconceptions are most common among high school students?
2. Which misconceptions occur in individual terms / concepts (namely gene, DNA, allele, homozygote, heterozygote, chromosome, genotype, phenotype, recessivity, dominance)?
3. How do students understand the connections between the various terms / concepts?

METHODOLOGY

A newly created questionnaire was used after a pilot testing. The questionnaire included three parts: i) demographic; ii) explaining individual concepts (gene, DNA, allele, homozygote, heterozygote, chromosome, genotype, phenotype, recessivity and dominance); iii) connections between triplets of concepts which was based on findings of Knippels (2002) and Awang-Kanak et al. (2016).

Students received a similar questionnaire twice - as a pre-test and a post-test. The tests differed in that the post-test no longer included a demographic part. Between the individual tests, there was a 90minute teaching with an explanation of the concepts and Mendelian genetics. High school students with no preliminary high school experience with genetics took part in the research. The students were from 4 classes from 2 schools (1 class of 21 students from year 12, age approx. 18 years; 3 classes of 71 students in total from year 13, age approx. 19 years).

Only the questionnaires from students who took part in both per-test and post-test were used which resulted in excluding 36 questionnaires out of a total of 220. 184 questionnaires from 92 students were analyzed. The obtained data were rewritten and coded in Excel and the codes were converted to points as follows: i) code 1 (correct and complete) - 3 points; ii) code 2 (correct but incomplete, important part was missing) - 2 points; iii) code 3 (partly correct, but partly incorrect) - 1 point; iv) code 4 (incorrect) was converted to 0 points (as well as the missing answer). Missing answers in definitions of terms and explanations of connections between terms were rated 0 points, as well as incorrect answers. Functional explanation and structural explanation were analyzed in case of definitions of gene, DNA and chromosome.

Subsequently, the frequencies of responses were calculated and the data were evaluated in the program Statistica (ANOVA, t-test). A paired sample t-test was used to compare the points for the definitions of the individual terms in the pre-test and post-test. Whether the average values of the points for the definitions of the individual terms in the pre-test and post-test differed was tested by the ANOVA with repeated measurements. Similarly, for connections between terms paired sample t-test was used to compare the number of points in the pre-test and post-test for the same triplet of terms. ANOVA with repeated measurements was used to compare the number of points among the three triplets. The differences were considered statistically significant when $p < 0.05$.

RESULTS

The concepts “gene” and “DNA” were the easiest to define for the students as they defined these terms most successfully. On the contrary, the term chromosome was more problematic for them in the post-test and they often did not even define it. Overall, students improved significantly in explaining all terms except the term chromosome between pre-test and post-test.

Individual terms

The average points for the definitions of individual terms differed in the pre-test (F = 66.07; p <0.001). The highest average numbers of points were reached for the definitions of the terms gene and DNA which significantly differed from all other definitions of terms (p <0.001). These were followed by the definition of the term chromosome, the average value of which differed from all other terms (p <0.001), and then the definition of other terms whose average values did not differ from each other, Tab. 1.

Tab. 2 Mean scores for terms’ definitions in pre-test

	Mean	Min	Max	SD
Gene	1.78	0	3	1.07
Dna	1.89	0	3	1.04
Allele	0.24	0	3	0.73
Homozygote	0.26	0	3	0.82
Heterozygote	0.28	0	3	0.87
Chromosome	0.97	0	3	0.98
Genotype	0.35	0	3	0.84
Fenotype	0.33	0	3	0.88
Recessivity	0.42	0	3	0.84
Dominance	0.47	0	3	0.76

Note: min – minimum number of points, max – maximum number of points, SD – standard deviation.

The number of points for some definitions differed (F = 16.41; p <0.001) in post-test too. The terms gene and DNA also received significantly more points in the post-test than the other terms, with the exception of the term heterozygote (respectively homozygous and heterozygous in the case of the term gene), Tab. 2.

The average number of points did not differ between pre-test and post-test only for the term chromosome (t = -0.80; p = 0.42). For the other terms, students obtained significantly (p <0.001) more points in the post-test than in the pre-test (gene (t = -3.59), DNA (t = -3.87), allele (t = -3.87), homozygous (t = -10.84), heterozygous (t = -11.22), genotype (t = -5.94), phenotype (t = -6.57), recessivity (t = -5.01) and dominance (t = -6.97)). Gene and DNA were defined mostly by their function rather than structure. Chromosome was defined mostly by its structure, Tab. 3.

Tab. 2 Mean scores for terms definitions in post-test

	Mean	Min	Max	SD
Gene	2.26	0	3	0.92
Dna	2.32	0	3	0.85
Allele	1.71	0	3	1.31
Homozygote	1.78	0	3	1.33
Heterozygote	1.84	0	3	1.29
Chromosome	1.07	0	3	1.06
Genotype	1.28	0	3	1.37
Fenotype	1.33	0	3	1.39
Recessivity	1.18	0	3	1.27
Dominance	1.36	0	3	1.21

Note: min – minimal points, max - maximal points, SD – standard deviation.

Tab. 3 Frequencies of functional and structural explanations of the terms gene, DNA and chromosome

		Functional explanation	Structural explanation
Gene	pre-test	35	13
	post-test	31	7
Dna	pre-test	32	15
	post-test	31	9
Chromosome	pre-test	11	36
	post-test	11	31

Misconceptions occurred in almost all terms - except for *chromosome*, which was often undefined and seldom definitions were lacking the functional part. The most common misconceptions repeated in the pre-test, the replacement of a gene with DNA, definition of gene as "the smallest part of DNA", were almost non-existent in the post-test. In the case of DNA, the students often confused different acids and typically wrote that DNA was made of amino acids. Allele was commonly perceived as a specific part of a gene instead of a specific variant of gene. This was one of the most common misconceptions at all and also persisted in post-test. The students stated homozygote has a gene with only one allele, or two alleles respectively. These misconceptions appeared only in the post-test.

Connections among concepts

The mean scores obtained for explaining the connections between the three concepts did not reach 1 of 3 possible (in contrast to the averages of points obtained for the definitions of individual terms which were always higher than 1 sometimes exceeded 2 points out of 3 possible). The best explained links were among gene, genotype and DNA; triplet alela, genotyp, fenotyp was explained significantly worse ($F = 3.20$, $p = 0.03$). Triplet chromosome, gene, allele did not differ from the others. Students scored significantly higher in the post-test than in the pre-test ($p < 0.001$) and the triplets did not differ among themselves in post-test.

DISCUSSION

The Czech context of genetics knowledge and misconceptions seems to be similar to international one. The comparison of functional and structural explanations favours the functional explanation in case of gene and DNA and structural explanation in case of chromozome, like in the Marbach-Ad (2001) study. The predominant structural explanation of the term chromosome may be due to greater emphasis on teacher explanation of its structure and also to the fact that students often do not associate genetics teaching with meiosis, which is usually taught separately (Machova, 2020; Awang-Kanak et al., 2016). Very frequent was misconception of allele as part of gene, similarly to Pashley et al. (1994). It was difficult for the students to explain the relationships between concepts, probably due to the need to link different levels, which was also pointed out by Abraham et al. (2014). Unfortunately, the different terms and levels are seldom linked even in genetics textbooks (Machova, 2020; Heemann & Hammann, 2020). Only the term chromosome was not defined better in the post-test, probably due to the fact it was used marginally. This stresses the need to place every new term in the correct context of other terms and definitions which was demonstrated also by the fact that some misconceptions were caused by teaching genetics as they appeared only in the post-test. For example a frequent confusion of the terms "gene" and "trait" among students and teachers in other studies led to student misconceptions and create a barrier to the understanding the mechanisms of genetics (Saka et al., 2006; Thörne et al., 2013).

CONCLUSION

Misconceptions in genetics were found among Czech high school students in this study. The most common misconceptions are international, but the misconception that DNA is made up of amino acids, which is mentioned abroad, was not common in this Czech study. It was more difficult for students to explain the connections among concepts than to simply define individual concepts. In teaching practice, it is essential to purposefully connect individual organizational levels, actively discover the most common misconceptions and prevent them.

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Did students reach the periodic table related curricular objectives after leaving from lower-secondary education?

Martin Rusek & Martina Tóthová

Abstract

In this paper, another step towards students' attained curriculum evaluation is described. Earlier piloted tasks (think-aloud and eye-tracking) were transformed into a three-tier task shape. First, the tasks were piloted to check for the understandableness of the multiple choice second tier. Later, they were evaluated in order to optimize the distractors as well as to check students' success-rate on the tests. The students (N = 92) provided adequate feedback. The success rate decreased considerably from 48% to 15% when the second tier (explanation) was considered. Based on the result, two distractors were replaced. This process produced a final test ready to be used on a broader sample.

Keywords

Three-tier tasks; chemistry education; education effectiveness; pilot study

INTRODUCTION

There are several ways to evaluate basic schools' effectiveness: students' success in entrance exams to upper-secondary schools, students' attitudes towards school (education) or school subjects, students' knowledge and skills, level of students' literacies' development and/or quality of their competences (cf. Burušić et al., 2016).

This research was built on the premise, that the key factor of the school effectiveness is embedded in national curricula. Although it only represents the intended curriculum (van den Akker, 2013) and is further affected by teachers' conception of education (cf. Elmas et al., 2020), it represents a cornerstone for school curricula. Educational goals in the Czech national curriculum for lower-secondary education are oriented on students' performance (*Rámcový vzdělávací program pro základní vzdělávání*, 2017). Field-specific curricular objectives are introduced in the form of so-called *expected outcomes* which are set to several node points. With respect to chemistry, only the last - the 9th grade - matters. The curriculum, thereby, sets the attained curriculum by defining what Czech students are supposed to achieve. However, the state of their skills and knowledge is being tested only on a school level (depends on each teacher). For this reason, with several exceptions (mostly selective inquiries of the Czech School Inspectorate), and random researchers' interest. These were for example the 9th graders' conception about the nature of chemistry (Rusek, Chytrý, et al., 2019), effect inquiry-based (Škoda et al., 2016) or project-based education (Rusek, 2021; Vonášek & Rusek, 2013) on students' learning. Yet, there is only limited evidence of the shape Czech students leave the compulsory (lower-secondary) education in.

Nevertheless, this knowledge is crucial in the ongoing curricular reform debate. The instruction coming to the teams responsible for curricular reform suggest the educational content needs to be reduced. This study therefore focused on mapping selected students' expected outcomes achievement after graduating from lower-secondary education. As classic tests can be influenced with so called false positive results (see e.g. Rusek, Koreneková, et al., 2019), this research used a three-tier multiple-choice test. These tests found a broad use also in science education, for example to assess high school students' understanding of acids and bases (Cetin-Dindar & Geban, 2011) or students' misconceptions about carbohydrates (Milenković et al., 2016). A three-tier task includes the content tier (content knowledge), the reason tier (explanatory knowledge) and confidence tier (strength of conceptual understanding) (Caleon & Subramaniam, 2010).

To test the possibility to transform the curriculum standards tasks into the three-tier task form, a triplet of periodic table related tasks was chosen. This contribution brings data of its piloting.

GOALS AND METHODS

Research goal

The goal of the presented research was to evaluate *to what extent students mastered the knowledge and skills as translated in the lower-secondary school chemistry curriculum's expected outcomes*.

In this study, the following objective was targeted: "the student orientates himself in the periodic table of elements, distinguishes chosen metals and nonmetals presumes their possible characteristics" (*Rámcový vzdělávací program pro základní vzdělávání*, 2017, p. 69).

Naturally, an all-embracing test would be impossible to construct. The research was therefore focused on one part. With respect to its importance for chemistry education, periodic table related curricular objectives were chosen. This contribution presents the instrument's design and pilot study.

Sample selection

In regard to the curricular objective orientation - the end of compulsory school attendance (9th grade), 1st grade upper-secondary students at the beginning of their studies were included (15-16year olds). In the Czech education upper-secondary school system, about 22% of students attend grammar schools - schools of general focus, 42% attend vocational and 36% apprentice schools (Vojtěch & Štěpánek, 2020). General chemistry education is provided only at grammar school and specific fields of vocational and apprentice schools (Rusek, 2013). With respect to the sample selection, the average current of schools - non-chemical vocational schools were chosen. Grammar schools are considered more prestigious and chemistry-focused students would bias the sample. As this paper presents a pilot study results. The sample consisted of students from 3 classes in the Economic lyceum study programme of one commercial Academy in Prague (N = 93).

Research instrument

For the testing's purpose, chemistry tasks (Holec & Rusek, 2016) adjoined to the Czech educational Standards for lower-secondary education - Chemistry (*Standardy pro základní vzdělávání - Chemie*, 2013) were used. The tasks' behaviour was well-known (Vojíř et al., 2017). For this research, the same three tasks the authors of this paper dealt with in their previous eye-tracking backed up study (Tóthová & Rusek, 2020) were chosen. However, more quantitative information about the students' work with them was needed.

Tab. 1 Task used in the test

	Task 1	**Task 2**	**Task 3**
Cognitive difficulty (Holec & Rusek, 2016)	Minimal	Optimal	Excellent
Students' task	Reading instructions and find elements' proton number in the periodic table.	Reading instructions, the use of the periodic table to categorize elements (metals, non-metals), finding electronegativity in the periodic table.	Reading of the instructions, application of information in learning text (context) about the atomic radius size trend.
Knowledge required	Identifying elements' proton number with the use of the periodic table.	Properties of metals and non-metals (electricity and heat conductivity).	Trends in the periodic table (reactivity), concept of group and period).

The tasks' cognitive difficulty was increasing (see Tab.1). The original tasks were transformed to the three-tier task shape (Caleon & Subramaniam, 2010; Milenković et al., 2016) - see above. The tasks' design followed the steps shown in Fig. 1).

Data analysis

The tasks provide three sources of information: the answer itself, multiple-choice explanation of the reason behind the answer and students' perceived certainty of the answer's correctness (confidence). The first two are binary – correct or incorrect, the third used a scale. The test, thus, enabled evaluation of the following confidence ratings (see Caleon & Subramaniam, 2010): CF (general students' confidence), CFC (mean students' confidence when they answered correctly), CFW (mean students' confidence when they answered incorrectly), CAQ (mean confidence accuracy quotient) and CB (confidence bias).

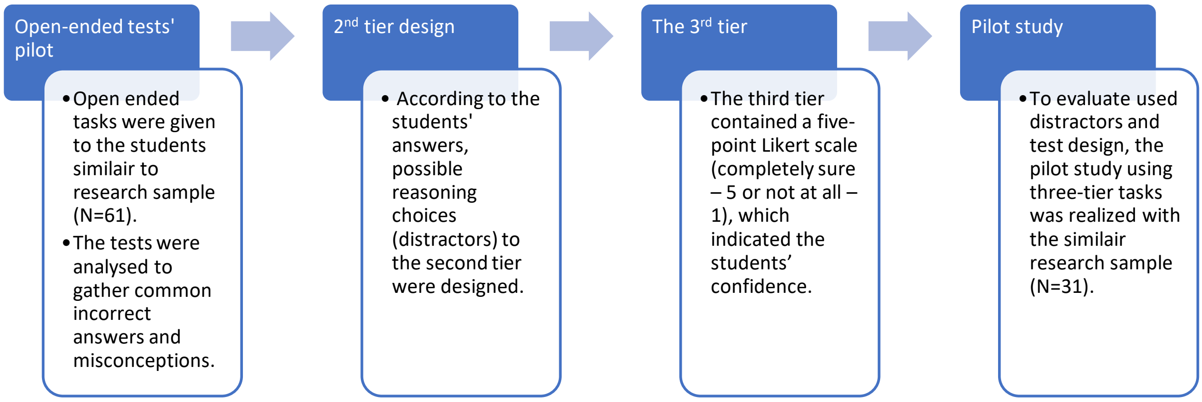

Fig. 1 Design of the process

RESULTS AND DISCUSSION

The results (see Tab. 3) suggest the students did not achieve the lower-secondary school chemistry curricular objective concerning the periodic table. The used tasks seemed very difficult for them despite being considered appropriate after their piloting (Vojíř et al., 2017). The results also showed that with increasing cognitive level, the difficulty of items also increased. It varied from low (0.76, Q1) to high (0.03, Q7). The second and third tiers provided extra information about the students' results. However, the second tier's effect on the students' success needs to be checked.

Tab. 2 Tasks' results

		PROPORTION CORRECT		**CONFIDENCE**				
Task	**Question**	**Content**	**Both tiers**	**CF**	**CFC**	**CFW**	**CAQ**	**CB**
TASK 1	Q1	0.79	0.76	3.07	3.18	2.67	0.46	-0.24
TASK 2	Q2	0.62	0.41	2.71	3.08	2.44	1.02	0.01
	Q3	0.38	0.38	2.70	2.60	2.94	0.09	0.05
	Q4	0.76	0.24	2.50	3,00	2.81	-0.04	0.13
TASK 3	Q5	0.45	0.21	2.78	3.17	2.67	1.03	0.24
	Q6	0.17	0.07	2.13	3.50	1.94	1.90	0.24
	Q7	0.17	0.03	2.57	4.00	2.52	1.90	0.36

Note: To measure the confidence bias, the confidence data were converted to a 0-1 scale (Stankov & Crawford, 1997).

The difference between the first (content) tier score and both (content and reasoning) tiers scores which is supposed to eliminate the luck effect (Caleon & Subramaniam, 2010; Cetin-Dindar & Geban, 2011) is considerable. All students' mean success ratio in the content tier was 48% whilst only 15% when both tiers were considered. The task difficulty increased when analysing both tiers. This suggest that the students could have guessed the answer (see Rusek, Koreneková, et al., 2019), or they simply did not know the correct reasoning of their choice. It seems that the use of the second tier makes the already difficult items (0.17, Q7), almost impossible to solve for these students (0.03). This raises the question of real usability of three-tier tasks in case the tasks are complex.

The students' confidence varied from 2.13 to 3.07. The difference between the correct and incorrect solvers (CAQ) was found in the last task (Q7, Q8). In the second task (Q4), unsuccessful students were even more confident than the successful ones. The confidence bias showed the students' "underconfidence" in the first task, whereas they were overconfident in all the other tasks (positive values). This is in contradiction e.g. with Chytrý et al. (2020) who found a correlation between students' success and confidence. In the second task (Q1, Q2), the students seemed to have evaluated their skills correctly (CB is closely to zero) - cf. Chytrý et al. (2020).

As suggested above, the pilot study showed possible problems with used answer choices for the second tier. Some of the used distractors were not attractive enough for the students. The results suggested distractors A and B in task 1 (Tab. 2) needed to be revised. The reason why the students did not choose one of these distractors could be the cognitive difficulty of the task (see Holec & Rusek, 2016), difficulty of the test item (p = .76)[1], or different formulation of the correct answer. These formulations were revised based on this pilot's results. All distractors were formulated in the same way (the same order of words, etc.) not to deviate from the others and to be more plausible.

Tab. 3 Second tier answer choices

	Task 1	Task 2			Task 3		
Tasks'questions Answer	Q1	Q2	Q3	Q4	Q5	Q6	Q7
A	0%*	**42%**	**35%**	10%	13%*	**35%**	16%
B	0%*	13%	39%	**29%**	26%*	6%	61%
C	3%	13%	10%	10%	26%*	29%	6%
D	**87%**	19%	10%	42%	**26%***	10%	**10%**

Note: *unsuitable distractors, **correct answers**, if the sum of % is less than 100, some students did not answer

Another problem was found in task 3 (Q5). A lot of students did not answer it at all. This was probably caused by its character - the students were supposed to connect two words. They often circled one of them, probably used for this sort of exercise. For the final test's purpose, the question was divided into two parts to avoid this misunderstanding (see Fig. 2).

[1] The *p*-value (item difficulty) was counted as a quotient of the number of students answering the item correctly and the total number of students (Matlock-Hetzel, 1997).

Circle the next element in the group and the state in which it occurs. 1) Astatus a) liquid 2) Tellur b) gaseous 3) Xenon c) solid	Circle which other element belongs to the group: a) astatine b) tellurium c) xenon In which state does this element normally occur: a) liquid b) gaseous c) solid

Fig. 2 An original first tier (left) and the revised first tier (right) in the task 3

CONCLUSION

In this paper, a pilot of a three-tier task test was presented. It represents another step in the authors' continuous work on feedback tools' perfection, i.e. usual pilot, use of eye-tracking, use of three-tier tasks. The results confirmed the previous conclusions of the plain tasks' lower usability due to a considerable difficulty and a high risk of students' answer guessing. As eye-tracking allows only smaller student samples, three-tier tasks offer an acceptable alternative when prepared carefully. After the pilot, several distractors from the added second tier were changed for the final test to be as precise as possible. These results then can be used by a teacher in the intervention phase, in which they target problematic areas ascertained by the test and ideally with the use of a supplementary method (eye-tracking, think-aloud or interview).

The test has already been given to students and the results will be published soon.

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Popularity of biology and selected topics from the perspective of Czech and Finnish students

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Abstract

The paper presents the results of quantitative research solved by a questionnaire survey in Oulu, Finland and Prague. A total of 195 ninth graders from Prague and 178 ninth graders from Oulu took part in the survey. Results show that biology is significantly more popular with Finnish students than with Czech ones. The effect of some biology topics on students' interest in biology was also examined. According to statistical results, all topics contributed more to the interest of Finnish students in biology than to the interest of Czech students. Students enjoy biology the most thanks to the theme of the human body. Topics concerning ecology enhance students' interest in biology the least.

Keywords

Popularity of biology; elementary school students; biology topics; questionnaire survey

INTRODUCTION

Finnish students have repeatedly been at the forefront of success not only in scientific literacy compared to students from other countries that have participated in the TIMSS and PISA surveys in recent years. For this reason, Finnish education is perceived as one of the best in the world. Finnish students have always achieved better results in scientific literacy in international comparative studies than Czech students (Blažek et al., 2019; Blažek & Příhodová, 2016; Palečková et al., 2014).

The literature shows that Czech and Finnish students prefer biology to other science subjects (Kubiatko, 2012; Uitto, 2014), are interested in it and perceive its importance (Kubiatko, 2012; Uitto, 2014). Czech lower secondary school students have a neutral attitude towards biology itself (Kubiatko & Vlčková, 2011; Vlckova et al., 2019). Finnish students have a slightly positive attitude towards biology (Uitto & Kärnä, 2014).

THEORETICAL BACKGROUND

According to the characteristics of the educational area Man and Nature, to which biology, whose popularity we observe in the presented paper, belongs, nature should be explored in context so that students understand the importance of balance in nature, the development of open thinking and logical thinking through activity and research teaching (FEP EE, 2017). Furthermore, students should gain a positive approach to nature and environmental protection, as the Czech and Finnish curriculum emphasizes that students prefer a sustainable lifestyle, behave with respect in nature, perceive the value of biodiversity and ecological balance and realize the impact of human behavior on environment (FEP EE, 2017; FNBE, 2016; Wang et al., 2019).

Key areas of biology content in the Finnish curriculum are not prescribed according to the fields of biology (FNBE, 2016), in contrast to the Czech curriculum (FEP EE, 2017). They are prescribed and complements each other with the target focus and criteria of the final evaluation (Hollins & Reiss, 2016). Teachers should select content according to predetermined topics, local conditions (FNBE, 2016; Hollins & Reiss, 2016; Wang et al., 2019) and so that through these topics the target focus of the subject of biology is fulfilled (FNBE, 2016).

Teachers in both countries thus gain a degree of autonomy in choosing a particular curriculum, the subject matter (Hollins & Reiss, 2016; Wang et al., 2019). In addition to what has just been said, multidisciplinary learning plays an important role in the Finnish national basic curriculum, which is not explicitly defined in the Czech curriculum (FEP EE, 2017; FNBE, 2016; Lindell et al, 2018). For this reason, in our research we present to students the topics of biology, not the specific biological areas described in the Framework Educational Programme for Elementary Education (FEP EE, 2007).

The literature shows that students who generally like science subjects also have a more positive approach to biology than students who do not like science subjects (Kubiatko & Vlčková, 2011). Czech and Finnish students prefer biology to other science subjects (Kubiatko, 2012; Uitto, 2014), are interested in it and perceive its importance (Kubiatko, 2012; Uitto, 2014). However, Czech lower secondary school students have a neutral attitude towards biology itself (Kubiatko & Vlčková, 2011; Vlckova et al., 2019). Finnish students have a slightly positive attitude towards biology (Uitto & Kärnä, 2014).

RESEARCH METHODOLOGY AND RESEARCH QUESTIONS

Two research questions were examined in the paper:

- Is there a difference between the interest of Czech and Finnish students to biology?
- Which biology topics attract the attention of Czech ad Finnish students to biology?

Ninth graders of Czech and Finnish primary schools took part in the research. A questionnaire was picked as the research tool. The questionnaire survey was conducted in Oulu in Finland (n = 178) and in the Czech Republic in Prague (n = 195). Through research, we monitored and compared the Finnish and Czech students' relationship to biology. The questionnaire was thematically focused on the students' relationship to biology, as a school subject in terms of why and what makes biology lessons attractive to students (e.g. I enjoy biology lessons because biology is my favourite school subject, I enjoy biology lessons because biology is easy for me), the use of biology knowledge during their leisure time (e.g. I enjoy biology lessons because I can identify the organisms we have learnt about, I enjoy biology lessons because I can apply biological knowledge in everyday life), for their future career and also their relationship to selected biology topics was examined (e.g. I enjoy biology lessons because I will apply biological knowledge in my future career, I enjoy biology lessons because I learn more about the human body). Instead of selected biological disciplines we evaluated thematic units typical for biology, as teachers of both countries have a certain degree of autonomy in the choice of the content they teach (FEP EE, 2017; FNBE, 2016). The content of textbooks is also compiled differently in both countries, and therefore the questionnaire is not limited to specific biological disciplines as to thematic units. Likert's five-point scale was used in the questionnaire.

To verify the understandability of the questionnaire items designed for students in the ninth grade of primary schools, a preliminary survey was carried out in 2018, in which Czech students aged 13–16 participated ($n = 7$). After modifications of the first version of the questionnaire based on the results of the preliminary research, the questionnaire was translated from the Czech language to the Finnish language by Mgr. Jan Dlask, Ph.D. and Lasse Suominen, M.A.

In the autumn of 2018, data collection took place in the Finnish city of Oulu. In the spring of 2019, data collection was conducted in the Czech Republic in Prague. Questionnaires were always distributed by the author, who also explained the instructions and answered the questions. The author was present throughout the whole data collection process. The author gave instructions in the English language in Finnish schools, and if necessary, the Finnish teacher translated the information into Finnish.

Cronbach's alpha coefficient ($\alpha = 0.904$) was used to measure the reliability of the questionnaire. Then, the factor analysis with Varimax rotation with a threshold value of 0.4 was used. The suitability of using factor analysis was verified by calculating the Kaiser-Meyer-Olkin coefficient (KMO = 0.85) and the Bartlett sphericity test ($\chi2 = 6974.5$).

For the further procedure of statistical data analysis, the evaluation was made at the level of significance $\alpha = 0.05$. The data were further evaluated according to whether it was an evaluation of individual items or the evaluation of the whole scale. Mann and Whitney's U-test was used for the data, which were evaluated as individual items. If the scale was evaluated as a whole, then t-test was used. The magnitude of the effect size was determined by calculating Cohen's d, which is used after the t-test, and by calculating r, which is used after the U-test.

RESULTS

The first research question is concerning the difference between the interest of Czech and Finnish students in biology. After comparing the data from the Czech Republic and Finland, see Fig. 1, it is evident that Finnish students (M = 3.35) are more interested in biology than Czech students (M = 2.79).

The results indicate that the relationship of Finnish students to biology is slightly positive, while the relationship of Czech students to biology is slightly negative. In addition, after performing the t-test, the difference between the relationship of examined Czech and Finnish students turned out to be statistically significant. Thus, the survey shows that Finnish students are significantly more interested in biology than Czech students (t = -3.70; p = 0.0003; d = 0.44), see Tab. 1.

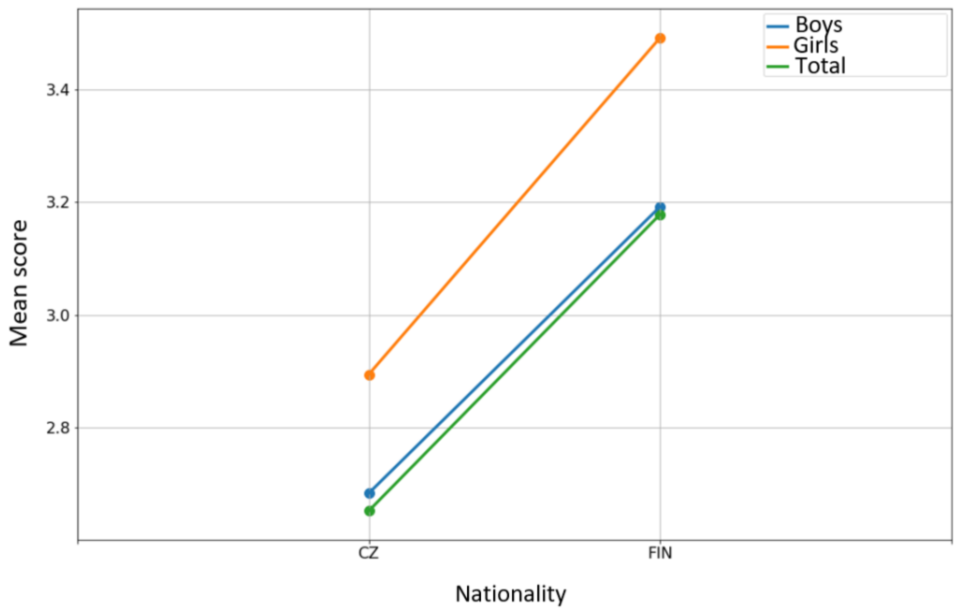

Fig. 1 Average score of items determining the relationship of Czech and Finnish students to biology.

Tab. 4 Results of t-test that examined the difference between the effect of nationalities of students on their relationship to biology.

Compared nationalities	Mean	T-test	P-value	Effect size (d)
CZ	2,79	-3,70	0,0003	0,44
FIN	3,35			

The second research question is focused on the effect of some biology topics on Czech and Finnish students' interest in biology. The influence of Czech and Finnish nationality on students' interest in these biology topics was examined: living nature, inanimate nature, the human body, health and a healthy lifestyle, ecology. According to statistical results, see Fig. 2 and Tab. 2, all topics contributed more to the interest of Finnish students in biology than to the interest of Czech students, although the effect size is low. Only for topics about inanimate nature no statistically significant difference was found ($U = 16422.5$, $p = 0.133$).

Czech and Finnish students are most interested in topics related to the human body ($M_{CZ} = 3.86$; $M_{FIN} = 4.08$). Czech students are also interested in living nature ($M_{CZ} = 3.50$) and in health and a healthy lifestyle ($M_{CZ} = 3.47$). Finnish students are also interested in health and a healthy lifestyle ($M_{FIN} = 3.82$) and living nature ($M_{FIN} = 3.79$). Topics related to ecology contributed the least to the interest of Czech and Finnish students in biology ($M_{CZ} = 3.14$; $M_{FIN} = 3.48$).

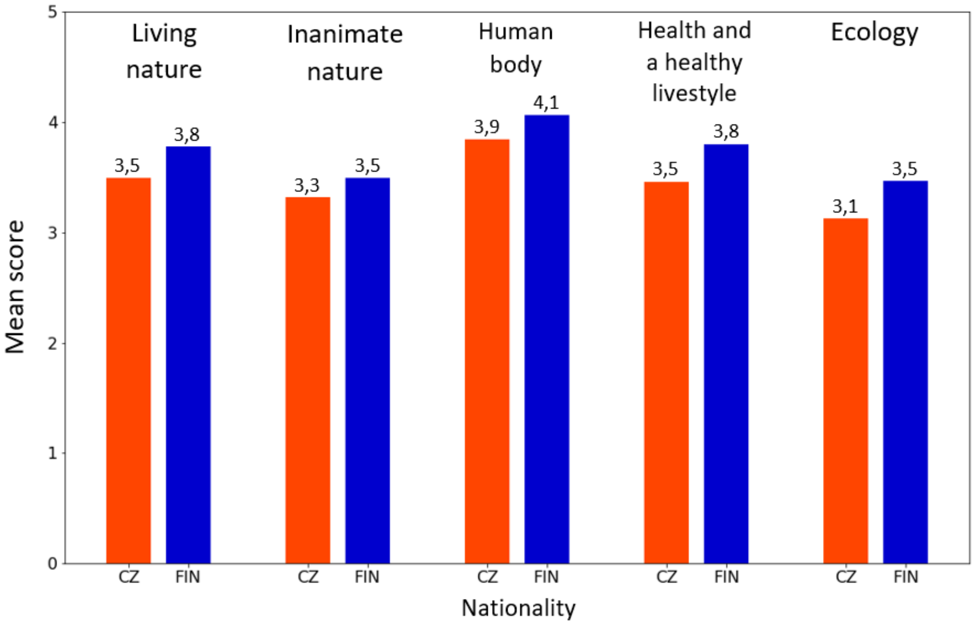

Fig. 2 Comparison of the effect of selected biology topics on the interest of Czech and Finnish students in biology.

Tab. 5 Results of the U-test that compared which given topics of biology contribute to the fact that Czech and Finnish students enjoy biology.

	Nationality	Median	Mode	U-test	P-value	Effect size (r)
Living nature	CZ	4	4	14964,5	0,005	0,14
	FIN	4	4			
Inanimate nature	CZ	3	3	16422,5	0,133	-
	FIN	3	3			
The human body	CZ	4	4	15672,5	0,03	0,11
	FIN	4	4			
Health and a healthy lifestyle	CZ	4	4	14917,5	0,004	0,18
	FIN	4	4			
Ecology	CZ	3	3	14618,5	0,002	0,17
	FIN	3	3			

DISCUSSION

From the results of this work and also from the research of Vlckova et al. (2019) is revealed that Czech students have a neutral (or slightly negative) relationship to science. The relationship of Finnish students is also neutral, resp. slightly positive, as shown by the results of this work and the work of Uitto and Kärnä (2014). Vlckova et al. (2019) explain that students' neutral attitude towards biology is probably because biology consists of many disciplines, some of which are more interesting for students, others are not, so as a result the student has a neutral attitude towards biology.

The results presented in this article and the work by Uitto (2014) show that the relationship of Czech and Finnish students to biology most positively influences the discussion of topics about the human body and also that topics including health and a healthy lifestyle further contribute to students' interest. Kubiatko and Vlčková (2011), Uitto and Kärnä (2014) and Blažek and Příhodová (2016) point out that the connection of the curriculum with its practical use in the daily life of students contributes to improving the attitude of primary school students to biology. The body and health thrive because they directly concern the students, who, thanks to them, learn not only to know themselves. Even the Finnish (FNBE, 2016) and Czech curriculum (FEP EE, 2017) recommend connecting the curriculum with everyday life. Both documents mention that the teaching of science subjects, resp. biology, should lead students to understand how to apply the acquired curriculum to practical life (FEP EE, 2017; FNBE, 2016). The results of this work show that topics that are closely related to the daily lives of students, contribute to the interest in biology.

However, the results of this work and work by Uitto (2014) show that topics related to ecology contribute less to students' interest in science than other selected topics, even though ecology and environmental science are currently widely discussed and also reflected in everyday students' lives. It is possible that students' attitudes towards ecology will increase slightly in the coming years, as students currently in lower grades reach the ninth grade, where surveys are often conducted on their attitudes to the subject, as they have already gone through all the lessons and prescribed topics which are taught in biology.

CONCLUSION

In the presented research, a neutral relationship of Czech and Finnish students of the ninth grade of primary schools to biology was found. Nevertheless, Finnish students have a more positive attitude towards biology than Czech students. Student nationality had a statistically significant effect on students' relationship to biology.

The interest of Czech and Finnish students in biology is most positively influenced by topics concerning the human body. Topics about living organisms also contribute to the interest of Czech students in biology. It was found in this work that topics including health and a healthy lifestyle contribute to the interest of Finnish students. Topics related to ecology have the least positive effect on the interest of Czech and Finnish students in biology. No difference was found between the contribution of the inanimate nature to the interest of Czech and Finnish students in biology.

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Attitudes of high school students toward genetically modified organisms and their knowledge about this topic

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Abstract

We investigated attitudes of Czech high school students' toward genetically modified organisms (GMOs) and their knowledge about GMOs and looked for correlation between them. In this pilot study, 185 Czech students from 6 different high schools completed a survey using a translated and modified questionnaire. The mean attitude of students toward GMOs was positive. Free-time activities, teachers and the frequency of purchase of organic food had an influence on students' attitudes toward GMOs. An influence of father's education planned studies' focus, and students' attitudes toward biology on knowledge about GMOs was found. Students' attitudes toward and knowledge about GMOs did not correlate.

Keywords

GM; GMO; genetic modification; family influence; school influence; attitudes; knowledge

INTRODUCTION

Nearly all of us encounter genetically modified organisms (GMO) or more likely products made of them like food, dietary supplements, or pharmaceutical products. Because the lack of information about the methods behind genetic modification can lead to stopping research focusing on these technologies which may prove to be very useful (Hudson et al., 2015), it is crucial to educate the students and possibly all citizens to be able to assess their position on the GMOs as qualified as possible. Citizens should have a basic knowledge and understanding of what are GMOs, how are they prepared and what are the risks and benefits. The GMO is not covered by the Czech high school biology curriculum and as far as we know there is no study mapping Czech students' attitudes toward and knowledge about GMOs. Therefore, we wanted to preliminarily map the Czech situation.

ATTITUDES TOWARD AND KNOWLEDGE ABOUT GMOS

Not all GMOs nor their usages are perceived by students the same way, GM plants and microorganisms are perceived as useful, however, only if they are not intended for consumption GMO as food or for fun are more likely rejected in Slovenia. Pre-service teachers were undecided about GMOs used in research and medicine (Šorgo & Ambrožič-Dolinšek, 2010). The attitudes toward GMOs are influenced by factors among which family is the most important (Hudson et al., 2015). The level and focus of parents' education are among the most influential factors. Respondents with a father who is educated in science have more positive attitudes toward GMOs. Interestingly this influence was not found in the case of mother educated in science (Hudson et al., 2015; Prokop et al., 2007; Šorgo & Ambrožič-Dolinšek, 2010). If the respondents themselves study science they also tend to perceive GMO more positively. This can be caused by a more detailed education in science and therefore more knowledge about GM (Gaskell et al., 2000; Hursti & Magnusson, 2003). Another hypothesis claims this fact can be explained by a different type of mind with scientists being more rational and fact based rather than emotional (Saher et al., 2006).

The attitudes toward GMO correlate weakly with knowledge about GMO in the case of pre-service teachers (Šorgo & Ambrožič-Dolinšek, 2010). The knowledge about GMO is low, as confirmed in different countries (Aleksejeva, 2014; Jurkiewicz et al., 2014; Türker et al., 2013) which allows the respondents to think that e.g. normal tomatoes do not have DNA, the genetic modification is painful for animals or that genes from GM food can transfer to human eggs and sperm and become part of genetics information of an offspring (Aleksejeva, 2014). At the same time, the respondents themselves feel their knowledge about GMO is rather low (Aleksejeva, 2014; Jurkiewicz et al., 2014; Türker et al., 2013). Although school is seldom ranked among the main sources of information about biotechnology and GMOs in general (Rzymski & Królczyk, 2016), some schools modify their curriculum and include this topic in teaching. For example, at a high school in the Netherlands, they found that a newly introduced GMO module significantly influenced the attitudes of all students, mainly towards the more positive pole (Klop et al., 2010).

The acceptance of GMO is different between genders with women accepting GMO less than men (Hudson et al., 2015; Hursti & Magnusson, 2003; Jurkiewicz et al., 2014; Prokop et al., 2007; Saher et al., 2006; Šorgo & Ambrožič-Dolinšek, 2010). This might be caused by their evolutionary role in history which included the care about the family and caution against new things (Hudson et al., 2015). Also, younger people are more likely to buy bread made of GM wheat compared to older respondents (Grimsrud et al., 2004).

RESEARCH QUESTIONS

In order to map the high school students' attitudes toward GMO and knowledge about GMO in Czechia, we were looking for answers to the following questions:

1. What are the attitudes of Czech high school students toward GMO?
2. What is the knowledge of Czech high school students about GMO?
3. Is there a correlation between attitudes toward and knowledge about GMO?

4. Does family and school background influence the attitudes of Czech high school students toward GMO?

METHODOLOGY

We used a validated questionnaire by Šorgo & Ambrožič-Dolinšek (2010) which was translated into Czech language and modified for this pilot study. After two testings in two different classes, we excluded one knowledge question which most of the students marked as too unlikely („cat can fertilize a female rabbit; the resulting young rabbits have shorter ears"), shortened the whole questionnaire. The original questionnaire by Šorgo & Ambrožič-Dolinšek (2010) consists of attitude, knowledge and acceptance. Due to the length of the questionnaire, only attitude and knowledge parts (28 statements each), except for demographics, were used like in other studies e.g. Aleksejeva (2014), Prokop et al. (2007) and Usak et al. (2009). The attitude part consists of statements and a 5-point Likert scale to indicate the degree of consent. The knowledge part contained true or false statements and the students were asked to mark "yes", "no" or "don't know". The validity of the Czech version was ensured by consultation with two experts, one in genetics modifications and one in biology education, Cronbach alpha of the attitude part was 0.71 which shows acceptable internal consistency (e.g. Tavakol & Dennick, 2011).

The final questionnaire was used to collect data from 199 pupils from 6 high schools. The data were manually transcribed to Excel 2016 and Statistica 12 was used to analyze the data. Only completely filled-in forms were analyzed. Answers to negatively formulated questions were reversely coded. This resulted in "the lower the score the better the attitude" results. To be able to compare the values to the original Šorgo & Ambrožič-Dolinšek (2010) study who used "the higher the score the better the attitude" were reversely coded all the attitude scores. The knowledge answers were coded as follows: 1 point for a correct answer, 0 points for "don't know" answer and -1 point for an incorrect answer.

Due to the relatively high number of respondents (Heeren & D'Agostino, 1987; Norman, 2010; Rasch et al., 2007), Student's t-test, ANOVA, and Pearson's correlation coefficient were used although the data did not have a normal distribution. The differences were considered statistically significant when $p < 0.05$.

RESULTS

After excluding questionnaires with missing data 185 questionnaires from 74 men and 111 women aged between 16 and 20 years were analyzed.

The attitudes toward GMOs were rather positive (mean 96.59 points out of 148) and not influenced by gender, interest in biology nor parents' education. On the other hand, they were influenced by the teacher with one teacher having students with much lower attitudes ($F = 4.92$; $p < 0.001$) and frequency of purchasing organic food: the students who purchased organic food frequently had worse attitudes toward GMO ($F = 2.65$; $p = 0.02$). The students who enjoy sports in their free time had better attitudes compared to students who felt neutral with sports ($F = 2.93$; $p = 0.02$).

In the knowledge part, the students reached 8.95 points out of 28. If coding only correct answers and not subtracting the incorrect, the score would be 12.73. Gender did not influence the total score, but girls marked more correct and more incorrect answers that boys who marked "don't know" more often ($F = -2.27$; $p = 0.02$). An influence of father's education, planned studies focus, and students' attitudes toward biology on knowledge about GMOs was found. In case the father studied science, the pupils had better knowledge about GMOs compared to students with father educated in humanities ($F = 3.71$; $p = 0.03$). Students with a better attitude toward biology had better knowledge than their schoolmates with a worse attitude ($F = 9.42$; $p < 0.001$). Students who planned to study science had better knowledge than their schoolmates who planned to study humanities ($F = 3.99$; $p < 0.01$).

Students' attitudes toward and knowledge about GMOs did not correlate.

DISCUSSION

The attitudes of Czech pupils are different from the original expectations based on the conducted literary research. The average value of 96.59 out of 148 possible alone shows that the attitudes of Czech pupils can be considered rather positive. There was no statistically significant difference in attitudes between the genders contrary to other studies (Hudson et al., 2015; Jurkiewicz et al., 2014; Šorgo & Ambrožič-Dolinšek, 2010). This can be a bias as most of the students had a positive attitude towards biology and almost a third of all pupils wanted to continue their studies in science or medicine in their follow-up university studies and they were all young which probably led to better knowledge about GMO. Unlike in the study made by Šorgo & Ambrožič-Dolinšek (2010), attitudes and knowledge did not correlate in the case of Czech students. In concordance with Saher et al. (2006), those who were buying organic products more often had worse attitudes toward GMO. Interestingly, only the father's field of education influenced students' knowledge about GMO, not mothers'. The influence of parents' education on knowledge about GMO was also found in studies of Hudson et al. (2015) and Prokop et al. (2007). Unfortunately, we did not ask about the source of information about GMO which is one of the weaknesses of the study. Because the topic is not covered by Czech curriculum, we presume, in concordance with literature (Aleksejeva, 2014; Rzymski & Królczyk, 2016; Türker et al., 2013), it is mostly media. The danger of the media comes mainly from the point of view of possible distorting the available information. Despite not having the GMO topic in curriculum and that the teachers told us they did not teach about GMO, we found a significant influence of teachers on students' attitudes toward GMO. We assume that this could be explained by that the teachers with strong attitudes toward GMO are likely to include at least something connected to the GMO topic and share their attitude toward it with their students.

CONCLUSION

The pilot study exploring high school students' attitudes toward and knowledge of GMO in Czechia brings several findings that are in concordance with the international situation like the fact students with a closer relationship to biology have better knowledge about GMO as well as those whose father is educated in science. Students who buy organic products frequently have a worse attitude toward GMO compared to their schoolmates. Interestingly, the teacher seemed to influence students' attitudes toward GMO but not their knowledge about GMO although GMO topic is not covered by the Czech curriculum. We suggest this actual topic should be included in the curriculum so all citizens are educated in it.

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Preferences of the atomic model in drawings by prospective chemistry teachers

Dominika Koperová & Ľubomír Held

Abstract

The present study investigated how future chemistry teachers imagine the atomic model. Drawing from various representations, student teachers gradually form a mental model of the atom and its structure, which they then apply in practice. In the present study, we investigated the preferences of 69 pedagogical students for different models of the atom presented to them. Next, the participants drew their own models, which we then categorized based on several characteristics based on multiple open coding. We found that students could clearly identify models that did not correspond with their beliefs. Their depiction of a model that did clearly correlate with their beliefs was inconsistent, as the model they choose as the most suitable for atom representation did not match to their drawings.

Keywords

Atom; atomic model; science education; chemistry preservice teachers; mental models

INTRODUCTION

Books and internet resources contain various atomic models, from little balls to structures described by complex equations. Chemistry preservice teachers draw from the available models to gradually form their own, individual conceptions of the atom. It is likely that students will apply these mental models in their future pedagogical practice.

Individual conceptions, models, modelling and their limitations

Since the 1990s, several researchers have investigated the individual conceptions of teachers on teaching (Mareš & Gavora, 2004). These studies found that teachers can be understood in terms of their beliefs, personal traits, and experiences, all of which result from their individual, subjective evolution and are stable and resistant to change, just as misconceptions are (Tomkuliaková, 2015).

Models and modelling are important means of communication in science education, even though they are often misunderstood (Akaygun, 2016; Gilbert, 2005). Chemistry presents a good working platform on which to investigate the utility of modelling because the subject is largely based on a single central model—the atomic model, which is a key for explaining all other chemical phenomena (Abraham et al., 1992; Othman et al., 2008). The models used in chemistry education can be categorised as either material (including physical and symbolic) or mental (conceptual) (Chamizo, 2011; Coll & Lajium, 2011).

Pupils can use material models to check certain facts or characteristics, whereas they carry mental models with them as ideas. Mental models have an advantage over material models because they are not fixed, but can be changed and perfected (Gilbert, 2004 in Akaygun, 2016). Material and mental models are not detached from the real world, but rather are connected with it (Chamizo, 2011) in a way that resembles Johnstone's triangle (Johnstone, 2010), which describes the relationships and interactions between three levels of the world. In the context of education, the atomic model is most often depicted using words, images, or schematics. In any given situation, any one of these approaches can represent the key facts about atomic structure very well, but the levels (microscopic, macroscopic, and symbolic) ale not properly (if ever) connected. Modelling of the atom has been closely linked to various misconceptions, even in university environments (Derman, Kocak & Eilks, 2019). Haverlíková (2013), found that the most common misconception is that the atomic model perfectly depicts the form of the atom. Analysis of textbooks has found a similar situation. Justi & Gilbert (2000) analysed chemistry textbooks in order to identify the theoretical background for nature of models to develop atomic models. Their analysis showed that only one of three British textbooks stated the definition of their models, and four of nine Brazilian ones say something about models, but only two of them also defined the models. Similarly, we turned to Slovak textbooks and curricula to find definitions of models, and definitions and depictions of the atomic model. Current and older chemistry curricula (ŠPÚ, 2009; ŠPÚ, 2016) do not present any definition of the model and atomic model, and the limitations of the models are not mentioned in either currently used or decade-old chemistry textbooks. Slovak textbooks contain various atomic models, most of which are good quality illustrations with varying levels of scientific value. Fig. 1 shows the depictions of the atom in the four analysed Slovak textbooks. The problem is that models in textbooks are not presented as just an analogy, but rather as facts, which the student subsequently internalises (Gokdere, & Calik, 2010). Mental models acquired from drawings may not be correct. For example, Nodzynska (2005) pointed out that it is inappropriate to draw an atom with borders, because atoms have no borders.

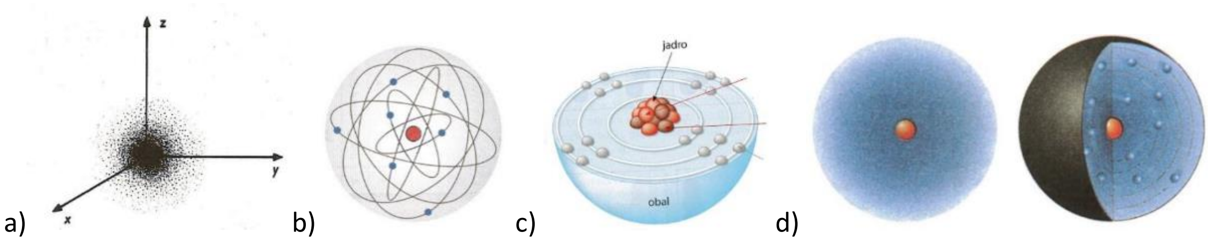

Fig. 1 Models of the atom in textbooks (a) Adamkovič & Šimeková, 2005; (b) Kmeťová et al., 2010; (c) Vicenová, 2011; (d) Vacík et al., 2003.

Harrison & Treagust (1996) and Al-Balushi et al. (2012) investigated students' preferred atomic models. Their results conflicted, perhaps because the preferred atomic model depends on the particular textbook the students used. Cokelez & Dumon (2005) also researched drawings of atoms. Based on pupils' answers, they identified six mental models of the atom (solar system model, confusion atom-molecule, group of atoms, composition atom model, ball model, electron cloud model); in 2012, Cokelez added a seventh (particle model). In 2016, Akaygun used drawing on a computer program or with a pencil to investigate atomic models. She distinguished three separate models (symbolic model, Bohr´s model, modern integrated model).

RESEARCH PROBLEM AND METHODOLOGY

The aim of the research question is to find the dominant preference of the atomic model by perspective chemistry teachers. When researching students' individual conceptions, we sought to ascertain their dominant didactic formulation of the atomic model. To this end, we asked the students about their preferences regarding the atomic model. Specifically, we presented four models similar to atomic models commonly used in textbooks (see Fig. 1): (1) a circular model with a nucleus and circular electron paths marked; (2) a ball model in which the atom has no inner structure; (3) a probabilistic model showing the electron cloud; (4) an elliptical model with a nucleus and elliptical electron paths. The illustrations were chosen from the images used by Harrison and Treagust (1996) and represented the most common models depicted in textbooks (see Fig. 2). The test was appraised by three independent experts in science education and modified based on their recommendations. The questions about the participants' preferences had a three-tier character: First, the students specified their preferred model; next, they gave reasons for that preference; finally, they stated their level of confidence in their knowledge in the answer.

Fig. 2 Models of the atom used in test (Harrison & Treagust, 1996)

We then had the students draw the atomic model for themselves and explain it with a description and labels, as appropriate. We assumed that any models drawn by the participants would be the dominant form used in their future pedagogical practice. The data were obtained from 69 chemistry preservice students (year 1- 5) (58 women, 11 men). The atom and its structure are addressed under General Chemistry in the first year of the chemistry teaching study program.

RESULTS

Among the 69 students, 63 (91.3%) marked Dalton's 'little ball' as their least favoured model of the atom (Fig. 3). Some of the reasons given for this decision were as follows: 'The electrons are not distinguished from the nucleus, so the model doesn't show which trajectory the electrons move along, and we cannot judge the size or volume ratio of the electrons to the nucleus' (Student #11); 'The image does not show any difference in density between the nucleus and the electron shells, although there is a huge difference' (Student #61). All the participants agreed that the 'little ball' model of the atom gave an inadequate impression of the atomic structure, and they tended to favour the other models.

However, the results did not confirm which model was most favoured by the students. Options (a), (c), and (d) were marked as most favourable by 20, 18, and 31 of the students, respectively. Those who marked option (a) as the most favourable atomic model gave the following reasons: 'Because the nucleus and orbitals are nicely shown' (Student #8); 'This is how the atom is depicted in all textbooks' (Student #48). Those who marked option (c) gave the following reasons: 'Because we cannot know exactly where the electrons are at any given moment' (Student #25); 'It provides the most realistic representation of the electron cloud around the nucleus—the quantum mechanical model' (Student #69). Those who marked option (d) gave the following reasons: 'The most precise theories state that electrons move in elliptical paths around a central nucleus' (Student #1); 'This image best depicts the movement of the electrons in their orbits' (Student #59).

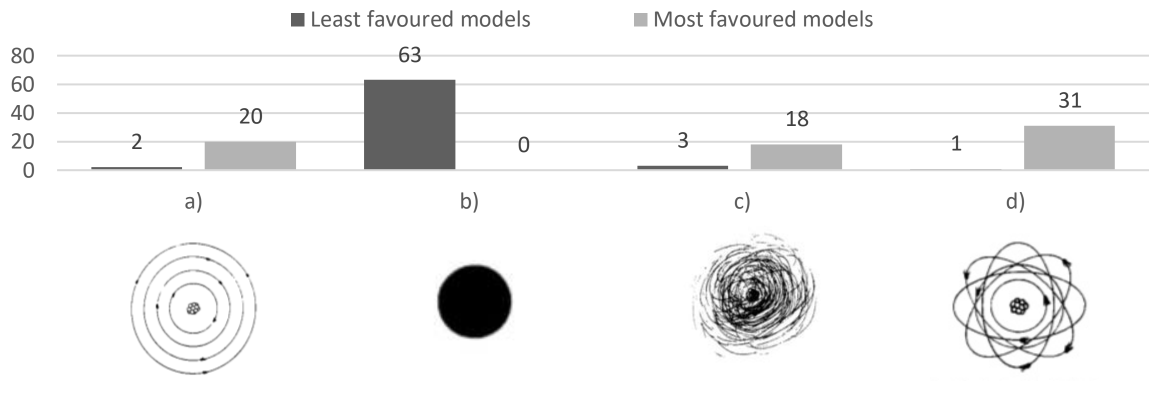

Fig. 3 Preferred models of the atom

With regards to students' level of confidence (Fig. 4), the data showed that most students were sure of their choice, even though they gave different answers. When choosing their least favoured model, ¾ of the students were sure of their choice, while 15 of them were unsure, and two were only guessing. When choosing the best model, around 70% of the students were sure, while 14 of them were unsure and five were guessing.

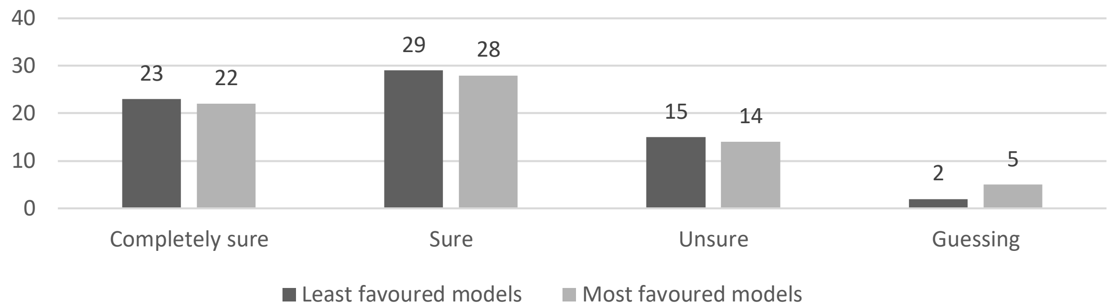

Fig. 4 Students' level of confidence about their answers

When the students drew the atomic model for themselves, we categorised the models based on various characteristics using multiple open coding. Presented results are a consensus of several discussions, comparisons, especially with the regard to the complexity and content of the atomic topic. Specifically, we identified eleven categories into which the characteristics of the atomic models could be sorted. These various aspects of the models are listed in Table 1, along with the number of students who depicted them, and some examples of atomic models are given in Fig. 5. Sixty-eight of the participants distinguished the nucleus from the electrons, although 22 of these provided no detailed nuclear structure, and only three showed the correct proportions of the nucleus and the electrons. Forty-three of the participants detailed the paths of the electrons within the shells (circular, ellipsoid, or a combination of both), but only four drew the various orbitals. Seventeen of the images showed the dynamic character of the atomic shell and the probabilistic locations of the electrons by use of scattered dots, and only three showed the wave-like movement of the electrons. Among all the images, only six showed the electron configuration in terms of completing different electron levels, and only four participants depicted electrostatic balance between the electrons and protons.

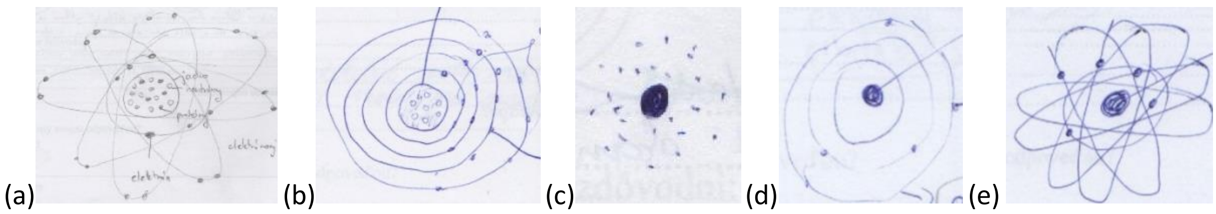

Fig. 5 Examples of preservice teachers' atomic models with some chosen criteria - (a) distinct nucleus and electrons, nucleus structured as particles, atom without borders, combination of circular and ellipsoid paths, (b) distinct nucleus and electrons, circular paths, nucleus partly structured as particles, (c) distinct nucleus and electrons, unstructured nucleus, probabilistic character of the electron´s location, atom without border, (d) distinct nucleus and electrons, unstructured nucleus, circular orbits, (e) distinct nucleus and electrons, unstructured nucleus, a combination of circular and ellipsoid paths

Tab. 3 Criteria for categorising the atomic models

The atom as a whole	Distinct nucleus and electrons	68	**Structure of the atom**	Nucleus as a whole ball	22
	Indistinguishable nucleus and electrons	1		Nucleus with particulate structure clearly marked	47
	Atom without a border	3		Electron shells showing both particles and their paths	36
External form of the atom	The atom as a bordered ball	16		Electron shells with particles only	16
	The atom without borders	53		Electron shells with paths only	12
Movement within the atom	Circular paths	28		Electron shells with another structure depicted	6
	Ellipsoid paths	12	**Structure of the nucleus**	Structured as particles	14
	A combination of circular and ellipsoid paths	3		Partly structured as particles	32
	No paths marked	22		Unstructured	23
	Orbitals marked	4	**Electron configurations shown**	Yes	6
Dynamic character of the shells	Dynamic with the moving particle depicted	32		No	40
	Dynamic without the moving particle depicted	10	**Structural laws**	Particles placed appropriately	45
	Only the moving particle depicted	6		Particles placed inappropriately	1
	Wave-like movement depicted (without the moving particle)	3	**Terminology**	Basic terminology	38
	Probabilistic character of the electron's location	17		Adequate university-level terminology	1
Electrostatic laws	Electrostatic balance	5		Correct terminology in the incorrect context	11

EVALUATION AND DISCUSSION

The results showed that the least favoured model was the depiction of the atom as a little ball, indicating that students have moved beyond Dalton's image of the atom. The most common reason was inability to distinguish between the core and shell. When the students' chose their most favoured atomic model, the results were somewhat equal among the three remaining options. The option favoured by the highest number of students was the model with a combination of circular and ellipsoid paths, which was depicted in a high school textbook (Kmeťová et al., 2010; Fig. 2b). The students' preferences for atomic models in the present study corroborated the findings of Al-Balushi et al. (2012), who stated that the choice of model depended on external circumstances and individual interests. All but one of the students' drawings of the atom rejected Dalton's model of a whole ball with no internal structure, but only a small number of the students accounted in their models for the difference in density and volume between the nucleus and shells. The model with firmly drawn borders is the prevailing image of the atom, even among university students, who should know that atoms have no borders (Nodzynska, 2005). Some of the models correctly depicted the electron cloud, but we also found the terms ‘layer’ and ‘electron layer’ among the students’ answers. In the context of the drawings, these layers represented the moments of probability, but at the same time indicate a confusion between the electrons’ paths and their orbitals. Similarly, in many of the students’ models, the term ‘orbital’ is incorrectly used to refer to the paths of the electrons, rather than the probabilistic location of the electrons. In this way, the term is used in an inappropriate context, confirming the findings of Unlu (2010), who showed that students preferred other models over the quantum mechanical. Similarly, Allred & Bretz (2019) stated that students described atoms using terminology that was inappropriate to the model they were referring to. To a large degree, students still accept the model of the nucleus and shells, with the electrons orbiting in circular or ellipsoid paths. They also tend to describe this model using terminology which, although correct, is inappropriately applied. We suggest that these persistent incorrect models arise from textbooks, which present the models in their historical context, but are understood by students as representing the currently accepted model (Justi & Gilbert, 2000; Ozmen, 2004; Kiray, 2016; Derman et al., 2019). Therefore, it may be safer to omit such models from textbooks to allow students to build a mental model of the atom themselves. The participants drawings in the present study, just as in the research of Justi and Gilbert (2000), showed that students confuse various representations of the atomic model and their associated terminology. They modify abstract information to create simpler, more concrete, but scientifically unacceptable models (Unall & Zollman, 1999). As a result, they use hybrid or confused models that contain misconceptions and outdated notions of the atom (Taber, 2003).

CONCLUSION

Research into prospective chemistry teachers’ individual conceptions of the atomic model provides insight into how the model will be portrayed in future classrooms. One positive finding of the present study was that almost all the students rejected Dalton’s model of the atom. However, the results also showed that students of chemistry teaching presented hybrid conceptions that contained elements of various models. Furthermore, they mixed terminology, and few of them accounted for the probabilistic and wave-like character of the atom. The students’ models replicated images from primary and high school textbooks, which depicted outdated ideas of the atomic model. As such, the atomic model remains in a vicious cycle of incorrect concepts.

Acknowledgement

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An analysis of pre-service chemistry teachers' progress when solving multicomponent tasks

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Abstract

The OECD sees problem-solving as a key aspect of education. Teachers' active role is crucial for these skills to be developed in their students. This contribution presents a pilot research focused on chemistry pre-service teachers' problem-solving skills. Students (N=38) were tested with the use of PISA and chemistry tasks. Based on the results, three students were selected for the qualitative study using eye-tracking (ET). The students were significantly more successful in scientific (PISA) tasks than in chemistry tasks. ET results showed the students' lack of problem-solving abilities, mainly regarding reading, using available information and understanding the assignment.

Keywords

Problem-solving; pre-service chemistry teachers; eye-tracking

INTRODUCTION

The more education focuses on students' independent work, the more their readiness to take over responsibility for their own learning affects the result. Considering project-based education the most open for students, several authors questioned its effect (see Rusek, 2015; Vonášek & Rusek, 2013). These concerns were well-founded as students need to be equipped with appropriate skills (at least on some level) to fully benefit from project-based education, as found in a recent review (Rusek, 2021). Students' problem-solving skills investigation became the aim of this study.

According to the PISA results, Czech students' ability to solve problems has been declining (OECD, 2016, 2019). This can be a problem as this ability is one of the 21^{st} century competencies (Bellanca, 2010). The possible cause of Czech students' result is the lack of attention to these abilities in schools (Tóthová & Rusek, 2020). Teachers' active role in this area is crucial. However, if a teacher is the one responsible for students' problem-solving skills' development, they must be a good solver (Krulik & Rudnick, 1982) themselves. Also, there is only a limited research on students' mastering intended curriculum (cf. Rusek & Tóthová, 2021).

Research on teachers' problem-solving is mainly focused on problems related to knowledge. To gain more insight, only quantitative research (e.g. Barba & Rubba, 1992) is not sufficient and qualitative information is needed. Cheung (2009) realized a misconception-related research of students' problem-solving ability with chemistry teachers. The research used a think-aloud method and results showed that in-service teachers also hold misconceptions, mainly caused by memorizing lessons (Le Chatelier‘s principle in this case). These misconceptions influenced the problem-solving process. Another research showed the importance of the think-aloud method for false-positive problem tasks results’ identification (Rusek et al., 2019).

With availability of modern equipment, the use of eye-tracking (ET) has also been expanding in education as shown by a review by Lai et al. (2013). It is widely used in chemistry research, e.g. types of representations (Slapničar et al., 2020), models (Hinze et al., 2013) or students’ ability to use the periodic table (Tóthová et al., 2021). Eye-tracking also appears to be a suitable method even in problem-solving research (see e.g. Tsai et al., 2012). For this reason, it was used in this research too.

The presented research is a pilot of a project aiming to map pre-service chemistry teachers’ ability to solve scientific and chemistry problems. The research followed these research questions:

What difference, if any, is there between students’ problem-solving skills at the beginning of their university studies and at the end?

What difference, if any, is there between students’ performance in PISA-task compared to a chemistry-related task?

What are the pre-service chemistry teachers’ critical points in problem-solving?

METHODOLOGY

Research methods and design

Mixed methods (see e.g. Hinze et al., 2013) were used in this research. A quantitative part consisted of a PISA and chemistry pre-tests. Based on the results, three respondents were selected for the qualitative part based on eye-tracking (ET). A GazePoint eye-tracker GP3 was used for this purpose with a free software OGAMA 5.0.

Research sample

The research sample consisted of 38 chemistry teacher students. All the students from the first year of bachelor (Bc, N = 27) and master (Ms, N = 11) studies in the academic year 2019/2020 were included. Based on their pre-test score, three students (successful, partially successful and unsuccessful) were selected for the qualitative part.

Materials

Two types of tasks (both aiming at 15-year-olds) were used. To assess the chemistry part, the tasks from Czech curriculum Standards (Vojíř et al., 2017) (CHE tasks) were used. For general scientific part, tasks released from PISA (PISA tasks) were used (see Frýzková & Palečková, 2007; Tomášek & Potužníková, 2004).

Quantitative part

Three CHE and three PISA tasks were used. All three CHE tasks were on the same ("optimal") level of cognitive difficulty (Vojíř et al., 2017). The first chemistry task aimed at elements' properties where students are supposed to work with the periodic table. The second task aimed at progress of chemical reaction and included working with a graph. The last chemistry task was focused on the organic chemicals' state change.

The first of the PISA tasks aimed at scientific reasoning, as well as text-reading. For the correct answer in the second task, students were supposed to use information about climate changes presented in graphs. In the third task, students were supposed to answer questions about a pressure pot using information in graphs, text, and pictures.

Qualitative part

One CHE and a one PISA task were used to identify students' problems and strategies. The CHE task aimed at element properties using information from a text and the periodic table. In the PISA tasks, students were supposed to propose a science experiment regarding to environment pollution, based on information from a map and a table.

Data analysis

In the *quantitative part*, the pre-test's correctness was evaluated according to the attached key from both PISA and Chemistry tasks. The achieved score was converted to the score in percent (each tests' maximum points differed). Non-parametric tests were used to analyse the data. For differences between CHE and PISA tasks' evaluation, the Wilcoxon test was used. The difference between the bachelor and master students was evaluated with the use of the Mann-Whitney test.

In the *qualitative part*, the analysis included the percentage fixation time in particular Areas of Interest (AoIs) related to total fixation duration in all AoIs. Relative transitions (%) between individual AoI were counted to analyse the students' process. For the sake of the students' anonymity, their pseudonyms are used in this contribution.

RESULTS AND DISCUSSION

Tests

The students' success in the pre-tests is shown in the graphs (Fig 1 and 2). As the number of students as well as the maximum point of each (PISA and CHE) test differed, the data are shown in percentage.

Chemistry tasks' results showed the students' (mainly Bc) low ability to solve chemistry problems (see Fig. 1). Nearly 75% of them achieved 50% or less in the test. Considering it was designed for 15-year olds, this result is alarming. The Ms students performed significantly ($p = .018$; $r = .384$) better. The effect-size shows a *small* effect, even though nearly 55% of them did not outreach score 50%.

All the students performed significantly better ($p < .001$; $r = .508$) in PISA tasks compared to chemistry tasks (see Fig. 2). The effect of the difference was *medium*.

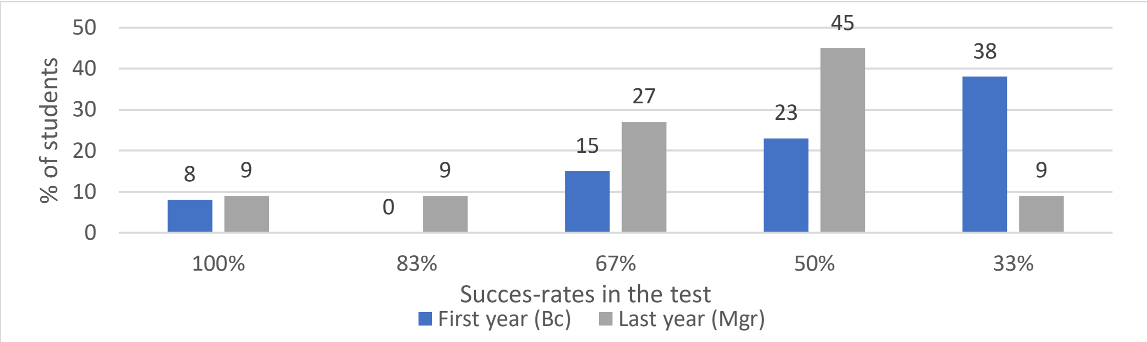

Fig. 3 Students' results in the CHE test

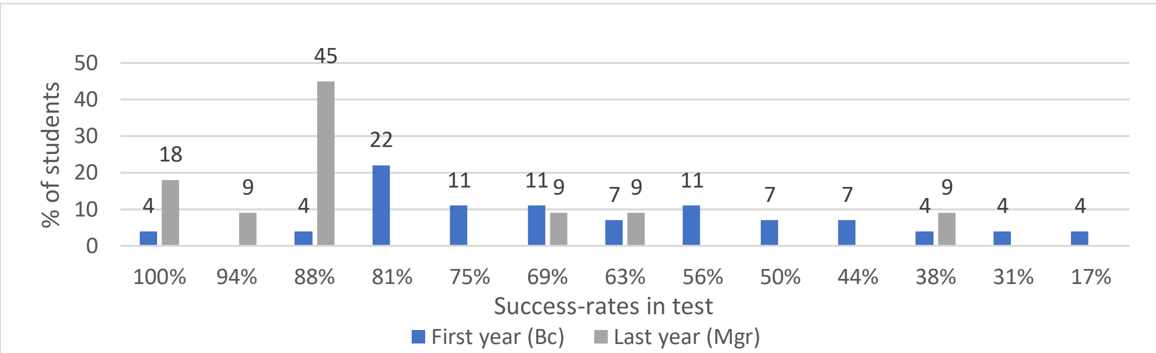

Fig. 4 Students' PISA test results

The chemistry pre-service teachers were less successful in solving the CHE tasks compared to the PISA tasks. They performed better compared to the non-chemical secondary (vocational) school students` (15-year-old students) who took the same test (Tóthová & Rusek, 2020). Yet, their success rate was low. The secondary school students' results can be explained by their attitudes towards chemistry (Rusek, 2011). However, the reason for such a low chemistry teacher students' success rate, i.e. students who chose chemistry as one of their majors, as well as their ability to solve problem tasks when they transfer to their teaching service, is unclear. It seems more support is needed in this part of pre-service teacher training.

In the PISA tasks, chemistry teacher students (compared to the average results of 15-year-old students in the Czechia) achieved a higher success-rate (Tomášek & Potužníková, 2004).

ET study

The students' success in the qualitative part of the study corresponded with their pre-test (see Fig. 3). The most successful (Jack) answered all but one of the task-parts correctly. Kate (partially successful) reached 50% of the points in the PISA and 17% in CHE test. The least successful Claire completely failed in the CHE test and answered only one task-part of the PISA test correctly.

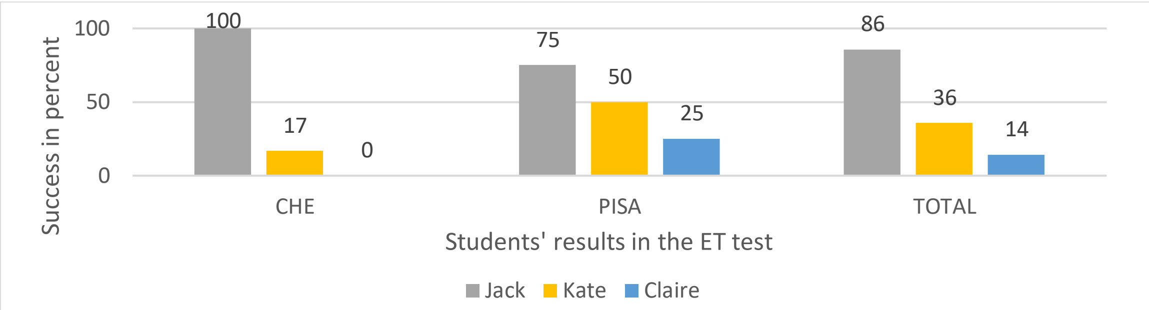

Fig. 5 Qualitative test results

To explain these students' results, an eye-tracking method with the special focus on the transition between the tasks' parts (areas of interest – AoIs) was used.

CHE task

The chemistry tasks consisted of three parts. To answer each part, students were supposed to read the task and use the periodic table or task's context. Fig. 4 shows percentage of the time-fixations on particular AoIs. There was no clear trend in TFD among students. Kate and Claire observed the periodic table longer than Jack. Most fixations in this area were, however, expected from the successful student, as it was the key to solve CHE task (see Holec & Rusek, 2016). Nevertheless, Jack spent the shortest time on the periodic table. This finding supports the results, that even novices can spend time on relevant parts of the task, but they cannot gain the information they need (cf. Kastens et al., 2016). To analyse the reason of their success, another look into students' problem-solving process is needed. The students' progress can be indicated by transitions between the AoIs. Fig. 5 and 6 show relative transitions of eye-movements between particular AoIs. In the first part of the task, only Jack was successful. He did not use the periodic table at all (Fig 5, green line), which suggests, he remembered the state of each halogen instead of deducting it from the text.

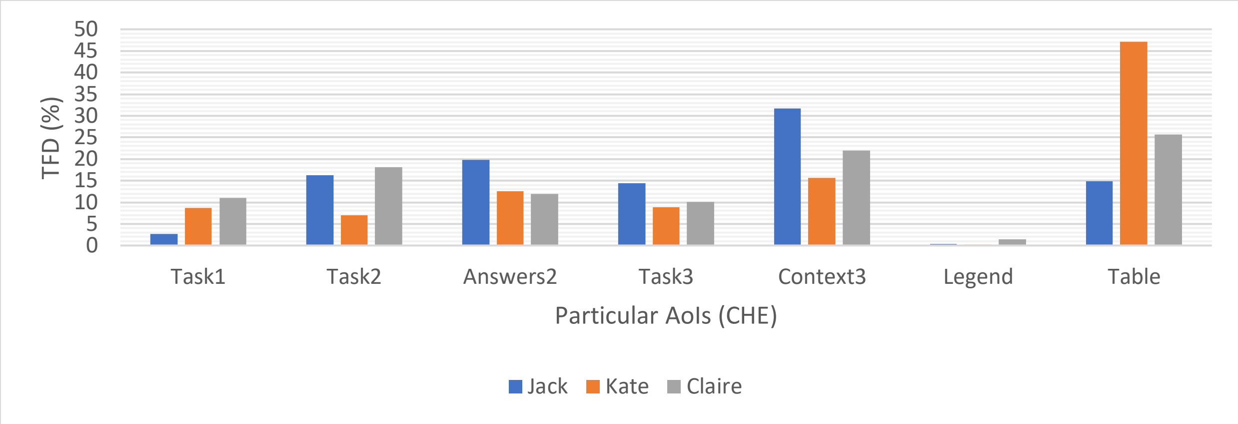

Fig. 6 Percentage of time fixated in particular AoIs related to all fixations in all AoIs in the CHE task

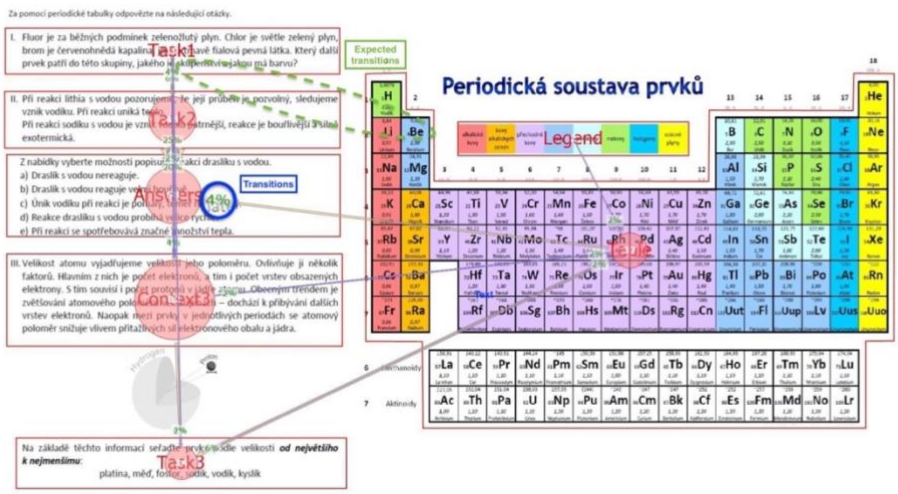

Fig. 7 Jack's eye-movement transition. Green – expected transitions between the periodic table AoI and Task 1 AoI blue – transitions between periodic table AoI and Task 2 AoI.

Kate (partially successful) used the periodic table for solving the first part of the task (see Fig 6, green line). She recognized trends in the periodic table and answered the state of the halogen but failed to answer the other part of the task. These results support the conclusion, that students are not taught to use the periodic table as an inductive tool (cf. Ben-Zvi & Genut, 1998), but tend to remember information instead of gaining them from the given material.

Focusing on the second part of the task, Jack used the periodic table while solving it. He looked to the table to search the trend in the alkali metals' reactions with water. The relative transition between the answer choice AoI (Task 2) and the periodic table AoI is 4%. On the contrary, Kate (similarly to Claire) did not use the periodic table. Their ET record showed only 1% of transitions between Task 2 and the periodic table. Their answers were incorrect. The transitions between the table and the task can imply its use for the question's answer.

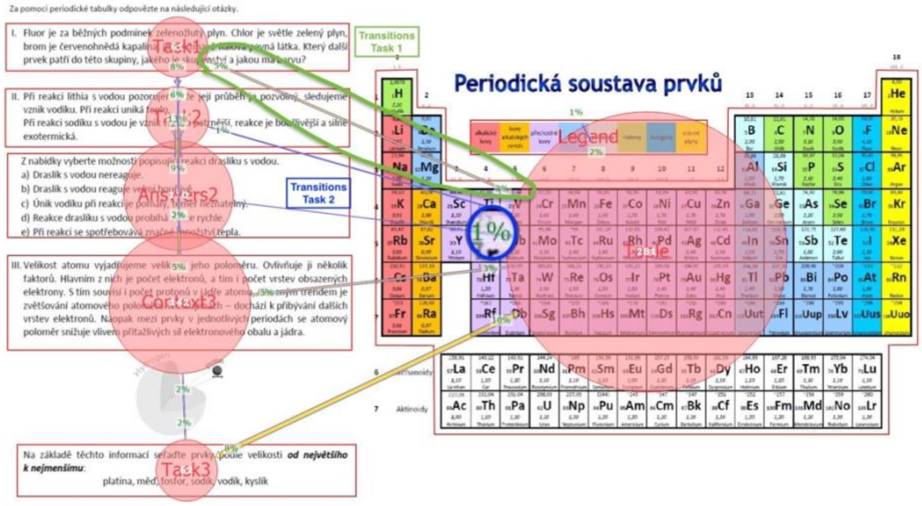

Fig. 8 Kate's eye-movement transition. Green – transitions between the periodic table AoI and Task 1 AoI blue – transitions between periodic table AoI and Task 2 AoI.

More information, however, needs to be gained by a think-aloud method (cp. Hansen, 1991). In the third part of the task, transitions between the context AoI and the periodic table AoI were expected. The successful student's (Jack) transitions between these AoIs were 4% of all while partially successful (Kate) had 2% of transitions between these AoIs and unsuccessful student (Claire) did not have any transitions between those areas. The lack of transitions implies that the students did not use the context (hint) to answer the task. Clare's eye-movement transitions explain her answer in which she ordered the elements according to the increasing proton number instead of their position in the table (as instructed in the context). The other two students' failure was clearly caused by them not using the table. The results show the lack of reading ability and proves its importance even in chemistry courses (cp. Wilson & Chalmers Neubauer, 1988).

PISA task

In the PISA task, the students were supposed to use a map to answer two out of four parts of the task. The percentage of time fixated in particular AoIs (Fig. 7) shows that students read each task, considered both the table and the map. Still, no student answered completely correctly.

Their eye-movement transitions between task AoIs and the map reveal the possible reason (Fig. 8). The use of the map was necessary for solving parts 3 and 4. Despite that fact, students were using it even in the other parts. Its use in relevant and irrelevant phases of their solving process is shown in Tab. 1.

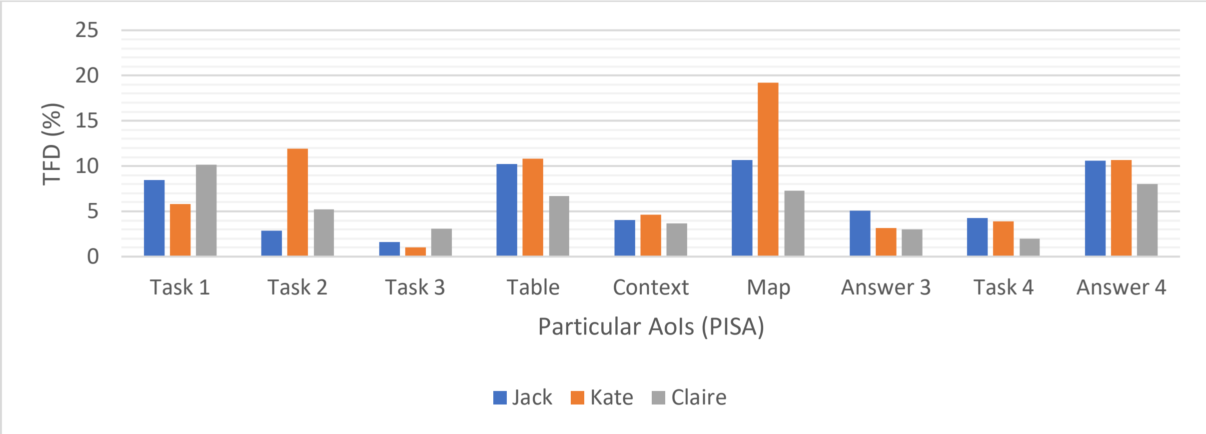

Fig. 7 Percentage of time fixated in particular AoIs related to all fixations in all AoIs in the PISA task

Tab. 3 Relevant and irrelevant transitions between map and other task's AoIs

	Relevant map transitions	**Irrelevant map transitions**
Jack	28%	9%
Kate	16%	15%
Claire	15%	10%

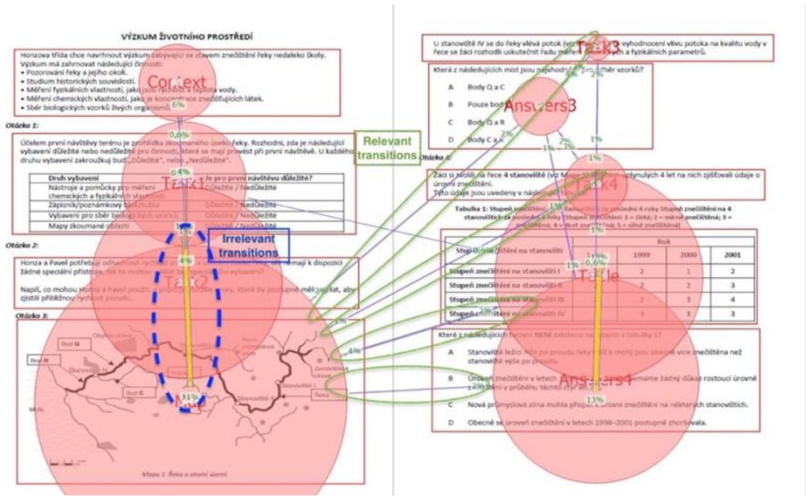

Fig. 8 Claire's eye-movement transitions between AoIs. Blue - irrelevant transitions, green - relevant transitions

The irrelevant transitions seem to be a predictor of students' failure even in the PISA tasks. In addition to transitions, the critical point was the students' reading ability. Kate did not take into account the conditions written in the first part of the task. Claire did not understand the text correctly and did not answer the third task (she considered it the same task as the third one). These results prove that understanding the task can represent a problem even for pre-service teachers. Considering the composition of pre-service teacher training programmes, this preliminary finding indicates a potential crucial point in teacher training. There is a need to focus on the individual steps of students' (Tóthová et al., 2021) even at the university level (Johnstone, 2001) problem solving as well as reasoning (Nodzynska, 2021). Learning problem-solving mechanisms (re-reading, careful reading, searching for information in a text), which in the past proved to be functional in upper secondary students (Tóthová & Rusek, 2020), seems to be a promising way.

Limits

In this pilot, only a limited student sample was used. In future research, in addition to enlarging the research sample, students' think-aloud and interview will be analysed for a more detailed identification of the students' success and failure in solving problems. Also, the use of interviews to complete particular questions needs to be considered. Yet, the results brought several useful information about students, and indicated several methodological issues which will be taken care of in future research.

CONCLUSION

The presented research was focused on the chemistry pre-service teachers' ability to solve scientific and chemistry problems. Tasks from the Czech curriculum standards and scientific tasks released from PISA (both designed for 15year olds) were used to determine their problem-solving abilities. The results showed that chemistry pre-service teachers' ability to solve the problems is not well-developed (as far as the sample was concerned). Freshman students scored significantly worse than students from the final year. At the same time, chemistry problems seem to be more difficult for these students compared to general scientific problems. The eye movement transitions between individual areas of interest show that the students fail because of their inability to understand the assignment and no or incorrect use of available information. Students are often unable to select information relevant to a particular task. Mainly, when solving chemistry problems, it seems that students tend to recall the learning content rather than use available information and tools which could suggest the way they learnt to approach chemistry problems during their studies. Future research also needs be expanded on students' think-aloud analysis to provide more information about the problem-solving process.

Acknowledgement

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Short Term Exchange Supports Students Professional Development: International PBE Course in Prague 2019

Leena Mattila & Elina Laurila

Abstract

The study focuses on the intensive PBE course organized in Prague by University of Jyväskylä, Finland and Charles University, Czech (11/2019). Teacher students participated in the international course. The focus of the current research was on experience and professional development. Participants filled out eight online questionnaires during the course. Data was analyzed both qualitatively and quantitatively. Students were asked to define their learning outcomes. These were compared with the ones teachers specified. Students evaluated and described their learning daily. Even though students rated learning high, the description of learning was challenging.

Keywords

Short term exchange; intensive international course; professional development

INTRODUCTION

An intensive international Project Based Education (PBE) course was organized autumn 2019 (3rd - 10th, November) in Prague in collaboration with University of Jyväskylä (Department of Chemistry and Department of Teacher Education) and Charles University (Department of Chemistry and Chemistry Education). Masters and Bachelor students (15 JYU and 8 CUNI, n=23) took part into the course. All participants were studying to become teachers (subject, primary school, special education). The PBE course was mandatory for primary school teachers (JYU). However, they could have taken a similar course at JYU. For other students the course was optional. The structure of the international course is presented in Fig 1.

The course consisted of lectures (8 h) of Project Based Education (PBE), activating teaching approaches and Inquiry Based Science Education (IBSE) in the morning. In addition, the course contained group work (9 h) during the afternoons. Students created a project under one theme of UN's sustainable development goals (https://sdgs.un.org). Students also presented the project to others. During the two last days, students participated into the PBE conference (12 h). Students got 2-3 ECTS depending on the amount of individual reflective written assignments.

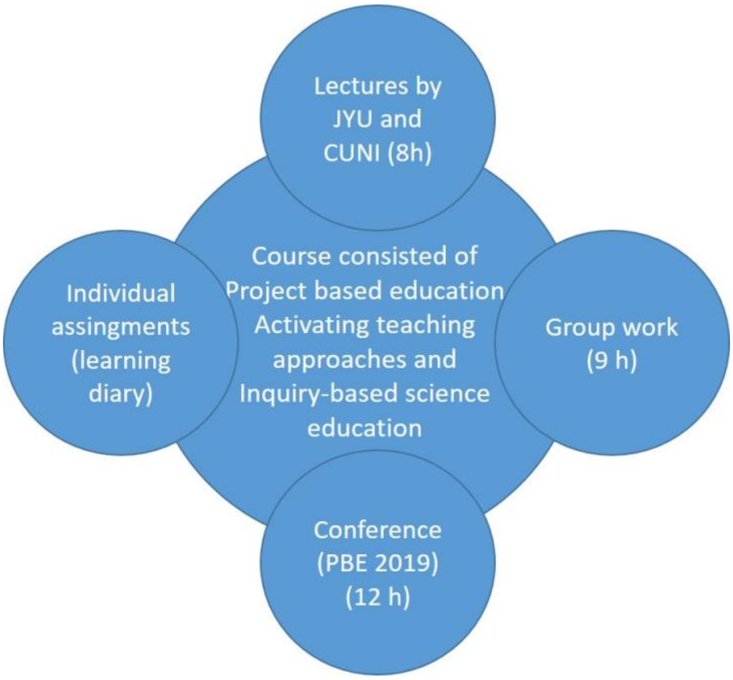

Fig. 1 The course structure.

THEORETICAL BACKGROUND

Exchange has reported to develop cultural, personal and career skills (Roy at al 2019, p. 1641). OECD (2017, p. 31) has stated the importance of global skills, competences and values on Global development. OECD (2017, p. 13) sees the co-operation of the development of the internationalization of the education of different countries beneficial. In addition, OECD (2017, p. 27) noticed that the international integration of working life depends on the cognitive skills and the readiness to learn. Unesco (2015, p. 5) has categorized transversal competencies: critical and innovative thinking, inter- and intra-personal skills, global citizenship and optional domains (physical and psychological health).

Erasmus skills research (https://assessment.erasmusskills.eu/) has defined skills that could develop during exchange. The research is set to find out students' idea of skills development. Certain pedagogical methods can support development of skills as Virtanen and Tynjälä (2019, p. 890) has noticed. Their research has focused on learning skills in general and pedagogical methods to teach them. General skills are repeatedly taught during teacher studies in higher education institutions (HEI). Aarto-Pesonen (2017, p. 3341) mentioned the spiral of learning and deepening of learning each round in the spiral.

Tynjälä´s (2008, p. 130) research pointed that HEI students´ idea of learning is connected to formal teaching. Tynjälä observed (2008, p. 150) that emotions are challenging to separate from learning and growing. Ursin et al (2018, p. 313) described how personal emotions effects individual reactions, learning and perceptions. Tynjälä noticed (2008, p. 150) that emotions seem to empower students.

RESEARCH QUESTIONS

The current research was made to find out the reasons of the students for taking the course and expectations for the international course. In addition, students' perceptions of learning and experiences of internationality were investigated. Research questions were the following:

1. Why students participated in international course?
2. What learning outcomes students had?
3. What students described they learned and where?
4. How students experienced the international course?

METHOTOLOGY

Data was collected anonymously during the course in Prague 2019 in a form of eight online questionnaires (O365 Forms and Webropol (Q8), Tab 1.). Response rate varied from 47% to 100% (n_{max} = 15 Q1, Q2 and Q5-Q7, n_{max} = 23 Q3, Q4 and Q8). The questionnaire included both open questions and a 5-point Likert scale questions (1 = strongly disagree, 5 = strongly agree). All survey data was coded using the following format (Questionnaire abbreviation, student running number): Q1, S1; Q1 S2 etc. Data was analyzed both qualitatively and quantitatively. Quantitative data analysis was done calculating averages, standard deviations and medians.

Content analysis was used to examine the answers of the open questions. The qualitative content interpretations were done stepwise. First, the concepts/words were analyzed. Secondly categorization of concepts/words was performed. Both authors worked first individually. They reached a consensus after discussion.

Tab. 1 Questionnaires of the course.

Abbreviation	Participants	Response rate (%)	Topic
Q1	15 (JYU)	100	Goals of the course and reasons for participation
Q2	14 (JYU)	93	First course day feedback
Q3	20 (JYU+CUNI)	83	Second course day feedback
Q4	19 (JYU+CUNI)	79	Third course day feedback
Q5	14 (JYU)	58	Conference days feedback
Q6	13 (JYU)	87	Excursion day feedback
Q7	7 (JYU)	47	Travel day feedbacks
Q8	17 (JYU+CUNI)	74	Experience of the course

RESULTS AND DISCUSSION

At the beginning of the course, students defined their own learning outcomes (Q1). These learning outcomes are presented together with the ones defined earlier by teachers on Table 2. Students´ and teachers´ descriptions of the learning outcomes are basically similar. However, teachers are more focused on the topics. Students describe general learning and take international context into consideration.

Tab. 2 Learning outcomes defined by students and teachers in the beginning of the course.

	Students	**Teachers**
1	How to work with language barrier and learning difficulties	To be able to learn in international context
2	Peer-learning: experiences, habits	To be acquainted with project-based education: pros and cons
3	Get to know other cultures	Basics of inquiry as a method of teaching and learning science
4	Practical applications on phenomenon-based education	Phenomena-based teaching: a path to understanding
5	How to create a project, how to induce learning, driving questions	Sustainability development goals: for us, by us, but what about learning?
6	The mystery of abbreviations	
7	Relations to subjects	

At the end of the course, students were asked the reasons for signing up for the course (Q8). The motives for taking the course were diverse (Fig 2a). Majority of the students mentioned traveling to be the reason. Other points were for instance interesting topic of course, learning something new and curriculum-based reasons. The reasons to participate in the short international course were similar as reasons for the long exchange abroad. Students were interested in traveling/international experience (Erdei 2020 p. 15).

In addition, students were asked about their goals and expectations (Q8). The goals of the students were similar to the outcomes they defined at the beginning (Q1) (Fig 2 b). Learning of the subject was the main aim (Tab. 2, students 4-7). In addition, students stated that they wanted to practice methods in action. Networking, communicating in English and study abroad were also mentioned (Tab. 2, students 1&3). Majority of the students (Q8, 71%) felt that they achieved their goals. 18% of the students were not completely sure or they were partly content.

"I got way more from the course than expected. I also got some new inspiration to my studies." Q8, S17

Students were asked multiple times (Q2-Q8) to evaluate a statement about their learning. Students experienced that they have learned a lot/new things (avg 3.4 – 4.1). When students described their learning, they were focused on the subjects of the lectures. They were unable to describe or realize their learning outside classroom. Learning can be analysed in multiple ways and on several levels as Tynjälä (2008, p. 132) describes. The current research contained general questions about learning. However, the meaning of learning was not defined. On the other hand, the target group of the current research, teacher students, could be assumed to be aware of the theoretical definition. At middle of the course learning got the lowest rating (Q3, avg ± SD 3.5 ± 1.1; Q4, avg ± SD 3.4 ± 1.0). Same time students described that they felt tired and frustrated. Therefore, communicating in English was demanding. *"I was little bit tired. I think it was because the day was fully in English and that is harder for brain."* Q2, S15

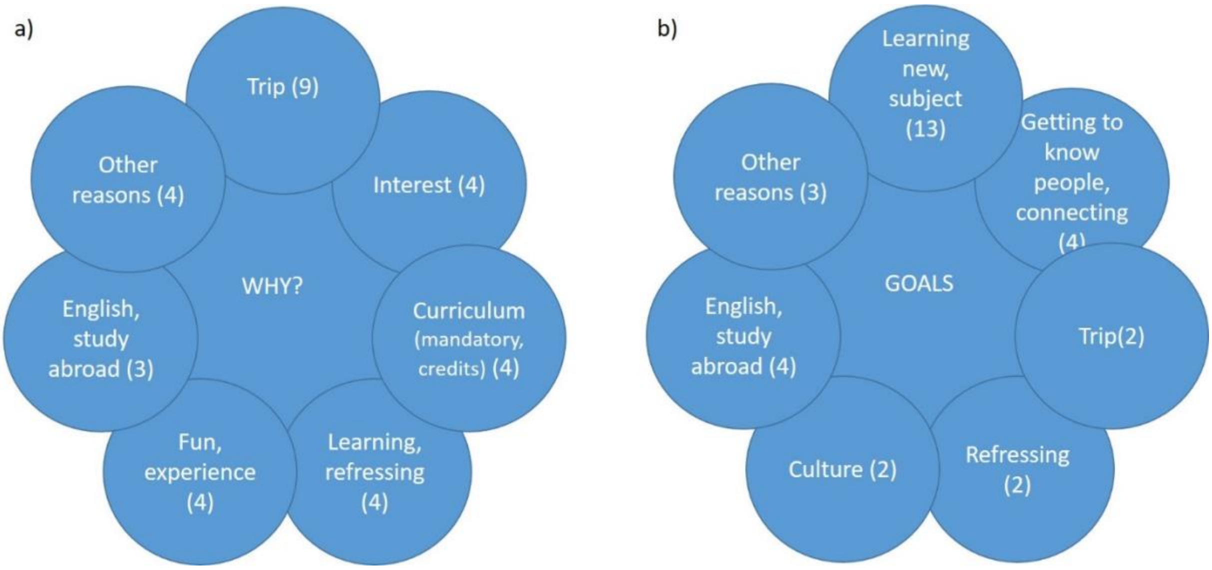

Fig. 2 a) The reasons of the students for taking the course and b) the goals of the students for the course (Q8).

The expected skills that students could have obtained during the course are presented in Table 3. The skills are categorized according to the Erasmus skills research (https://assessment.erasmusskills.eu/). Skills that are connected to internationalization and to the course topic are European identity and global citizenship, cultural knowledge, social skills, communication in different languages, adaptability to change, teamwork in diverse environment and discipline awareness. General skill includes planning & organizing and curiosity. On the international short course European identity and different school systems were discussed during lectures and multicultural group work. Changes of timetable of the course taught students the adaptability, creativity, planning and organizing. Communicating in different languages, teamwork in diverse environments were constantly present during the whole course week. Students could choose several aspects concerning internationalization, when they were provided with options on questionnaires. They felt that they developed their English language skills (Q8, avg ± SD 4.0 ± 1.0) and they got international contacts (Q8, avg ± SD 3.8 ± 1.2). The multicultural group was stated positive.

Tab. 3 Erasmus skills developed during the course.

Erasmus skills	During the course	During the conference	Other program (free time, travel days)	Students mentioned
European identity and global citizenship	Lectures	Presentation	All the time	Not identified
Cultural knowledge	Lectures	Coffee brakes	All the time	During discussion
Social skills	Discussions	Coffee brakes	All the time	New friends
Curiosity/ openness attitudes	Groupwork	Coffee break, Social activity	All the time	Only towards applying methods
Discipline awareness	Lectures	Presentation	Depending on program	On formal teaching
Communication in different languages	All the time	All the time	All the time	Group work
Adaptability to change	Groupwork	Presentation	All the time	Not identified
Teamwork in diverse environment	Groupwork	Coffee brakes	Depending on program	Group work
Planning & organising	Groupwork	Parallel sessions	All the time	Not identified
Creativity	Groupwork	All the time	All the time	Not identified

"Well I think now I have much better overall view of the topics and I can try to actually apply and combine different ideas in practice. I can possibly try to apply ideas based on the conference as well and I think I have a better capability to start co-working with fellow teachers and also set a start on projects or brainstorming about different methods in teaching. Also talking and sharing ideas, views and different methods and cultures with other students and staff broadened my horizons and the way of thinking." Q5, S14

CONCLUSION

The current research focused on the experiences and professional development of students of one-week international PBE course (11/2019). Students defined their own learning outcomes realizing the multicultural context. Teachers should pay attention to that when planning the course and the learning outcomes. They should take cultural awareness and international environment into consideration. In addition, teachers should underline the importance of informal learning on international course. Perspectives of learning of students were strongly concentrated on the topic of the course and formal situations. Even though they were teacher students, they were unable to understand the learning in informal situations such as free time activities and conference.

Acknowledgement

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The shift in chemistry teacher students' self-efficacy with respect to their ability to notice: Observation Practice Course's effect

Linda Honskusová & Martin Rusek

Abstract

The aim of the study was to evaluate an Observation Practice Course's effect on pre-service teachers' self-efficacy. The course focused on forming chemistry teacher students' professional vision was run in the winter semester of 2019/20. A self-efficacy questionnaire containing items oriented on general aspects of lesson observations as well as concrete aspects (perceived ability to describe teaching methods, analyse subject matter or suggest changes to the lesson plan) was given to the students (N = 12) at the beginning and at the end of the course. The results show a significant shift with a medium effect in the students' self-efficacy. Therefore, the course can be considered effective in this respect.

Keywords

Initial teacher education (pre-service); professional vision; self-efficacy

INTRODUCTION

Professional development can be a critical factor for (pre-service) teachers' growth as well as for their students' results (Lowden, 2005). Furthermore, a teacher's ability to reflect on their teaching is one of the fundamental factors that enhance quality of teaching. According to Švec (1999), a teacher cannot change their teaching activity only by studying literature but also by examining this activity. *Pedagogical-content knowledge* (Shulman, 1986) and educational reality assessment belong to the essential categories of pedagogical pre-service teacher (PST) training and play an important part in teacher professional competences (Švec, 2006). However, it cannot be assumed that teacher students will be equipped with these competences unless they are actively developed during their pre-service training. A good and experienced teacher is able to pay attention to many factors during teaching and also perceives the teaching as a set of individual learning activities and their monitoring. Teachers' ability to pay attention to students' involvement in the lesson is the key for effective teaching activation strategies application. For this reason, during the pre-service teacher training, it is important to find and monitor ways, how to focus on individual activities and evaluate their activation potential (Janštová & Rusek, 2015). From the authors' experience with pre-service teacher training, providing them just with theories of activation methods or several examples does not suffice. Work on their ability to notice these aspects of teaching and classroom management, if necessary, altering them so that they actually prove to be functional, is one of many teacher training goals (Harris & Sass, 2011).

THEORETICAL BACKGROUND

Nowadays, the professional community pays considerable attention to reflection on teaching (e.g. Stockero, 2008). One of the strategies to support pre-service teachers is to design courses focused on the concept of *(teachers') professional vision* Goodwin (1994) in (Sherin & Van Es, 2009) which appears in pedagogical literature in the sense of students' ability to reflect on teaching (Lefstein & Snell, 2011). (Sherin, 2007) further developed Goodwin's (1994) concept and presented two components of *teachers' professional vision*: a) identification of professionally relevant events based on the knowledge process (selective attention), b) thinking about identified situations and recognizing their context (knowledge-based reasoning) – see Sherin and Van Es (2009). Additionally, Minaříková and Janík (2014), among others, present further related concepts (e.g. competent perception of educational process, ability to notice, productive reflection) conceptually leading to *3A methodology* (Janík et al., 2019). This methodology uses the skills of teachers with a certain degree of professional understanding to develop their ability to recognize moments that require improvement. The reflective process thus consists of three basic parts – annotation, analysis and alteration of the teaching situation.

Another key component of the teaching process is the *teacher self-efficacy*. (Bandura, 1997) anchors self-efficacy in the theoretical framework of social cognitive theory that emphasizes the development and transformation of how people influence their activities in some way, i.e. how they are organized, how proactive they are, their self-regulation and also self-reflection. It seems that if a teacher perceives their personal efficacy realistically and positively, it can be easier to achieve the desired goal (Zee & Koomen, 2016). Teacher self-efficacy plays an important role in how teachers choose teaching methods and also augments their efforts to overcome obstacles. It furthermore affects emotional responses when teachers face difficult situations. In combination with other variables, it affects the success of the action itself: teachers with a high self-efficacy level are more open to new ideas and more enthusiastic about them as well as more satisfied with their teaching (Bamburg, 1994; Tschannen-Moran & Hoy, 2007). It is clear from the above-mentioned that measures leading to the development of professional vision also support perceived teacher self-efficacy and at the same time interact with each other. For this reason, it is valuable to monitor this area of pre-service (chemistry) teacher development.

As this has not been mapped yet, at least in the central-European context, this study aims at this unattended area. The present study is a part of a more extensive inquiry into the effectiveness of the Observation Practice Course (OPC). The OPC's effectiveness, namely its role in developing the students' professional vision by nurturing their ability to notice key aspects of educational process as well as the ability to assess their quality and suggest possible improvements, is evaluated according to several factors: the quality of the students' lesson reflections (the difference between the quality of the initial and final reflection on the same video-recorded lesson), shift in students' self-efficacy assessment and, last but not least, according to interviews with students. This part of the project deals with evaluation of the effectiveness during the second academic year of a modified Observation Practice Course aimed at students' self-efficacy. The results are also compared with data acquired in the previous academic year. As the Observation Practice Course is gradually modified according to the theoretical framework of design-based research (Reeves, 2000; Trna, 2011), a sequence of such research reports creates a solid ground for evaluation of its effectiveness.

RESEARCH GOALS

The main goal of the wider project is to determine the effect of field didactics-oriented pre-service teacher training in the first year of the follow-up master's study (the first-year students are exposed to actual teacher training) on the pre-service chemistry teachers' self-efficacy as well as the level of their professional vision. This paper is focused only on a small fraction, leading to the following research questions: **RQ1:** What is the initial level of pre-service chemistry teachers' self-efficacy with respect to their ability to notice? **RQ2:** To what extent does the Observation Practice Course affect pre-service chemistry teachers' self-efficacy with respect to their ability to notice? **RQ3:** What changes can be observed in terms of students' teacher self-efficacy shift after adjusting Observation Practice Course in comparison with the previous academic year?

METHODOLOGY

The research sample

Twelve pre-service chemistry teacher students (2 male, 10 female) for lower- and upper-secondary school attended the course in the first year of their master's studies. Prior to joining the master's degree program, all the students completed pedagogical-psychological training as well as several chemistry education oriented university courses.

The study design and Observation Practice Course (OPC)

To answer the research questions, this study was designed based on the course plan. It consisted of several consecutive parts were carried out - see Fig. 1. The study consisted of an input and output teacher self-efficacy questionnaire assessments (essential for this paper) and a model lesson reflection. In the original design of the OPC (2018/19), based on a pilot study (Honskusová et al., 2018), students filled out the self-efficacy questionnaire, watched one video-lesson and then wrote their own reflection at the beginning of the course. Next, the 3A Methodology was explained, followed by several lesson observations led by either course educator or by the students (in tandem). Each lesson included submitting a reflection in writing. At the end of the OPC, the students were asked to fill out the self-efficacy questionnaire again and write another reflection on the same video-lesson. The course ended with semi-structured interviews.

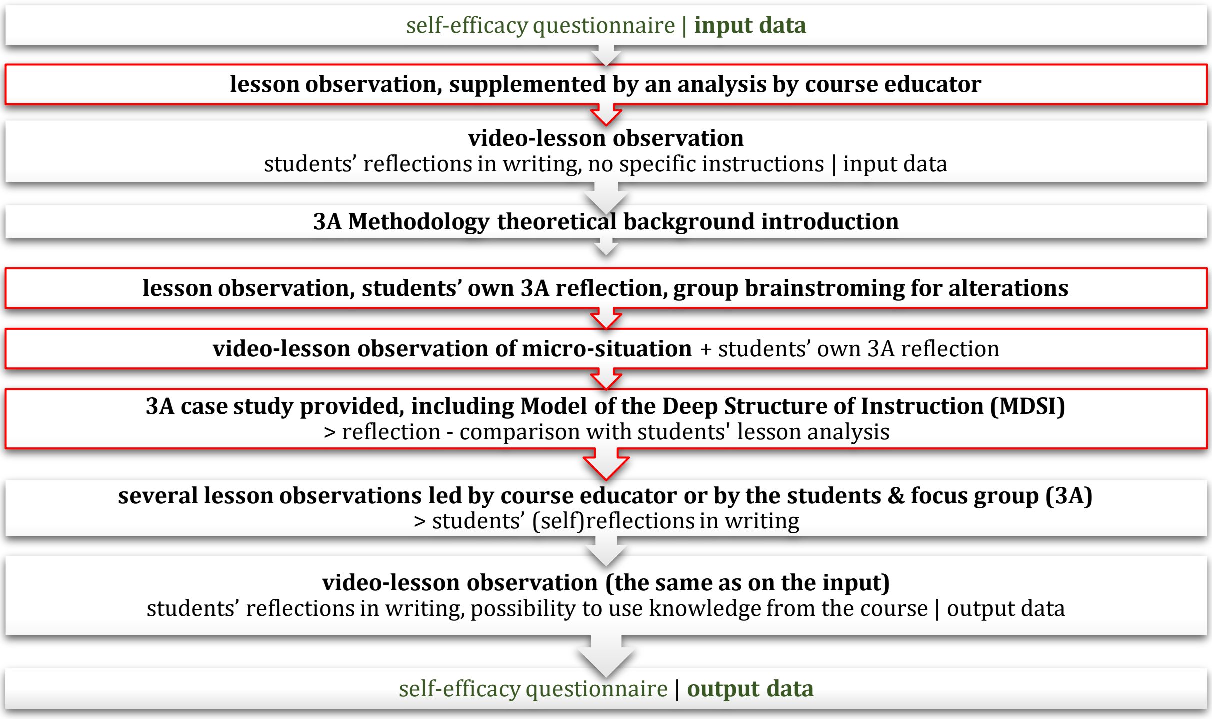

Fig. 1 Diagram of the study and the Observation Practice Course plan. The red boxes indicate changes made for the 2019/20 academic year, the black boxes the original Observation Practice Course (the 2018/19 academic year); the green text highlights which outputs were included for data collection and analysis.

The adjustments of the OPC for the 2019/20 academic year were based on the analysis of data from the previous academic year and on the outcomes of the interviews mentioned above. First of all, we added a sample analysis before the students wrote their first reflection. This step was taken because during the interviews conducted in the 2018/19 academic year, students communicated that the initial written assignment was stressful without previous experience and that they would welcome a sample reflection written by an expert teacher. Secondly, a whole set of steps was taken before the students actually entered the series of live lesson observations. These steps were adopted because the analysis of the written reflections (2018/19) showed that they focus primarily on the teacher. This outcome is consistent with other research (Hammer, 2000; Pavlasová, 2017). Even though they deepened their ability to annotate and analyse, there were still not many alterations. Furthermore, the ability to work with content knowledge was not sufficiently formed. For this reason, the modified OPC had the pre-service chemistry teachers observe one more lesson after the theoretical introduction to the 3A methodology and submit a written reflection using this theoretical framework. This was followed by a group brainstorming session that focused on critical moments and resulted in suggestions for changes. At the next meeting, the students observed an 8-minute teaching micro-situation (on the topic of redox equations) and then wrote their own reflections. Afterwards they received a 3A case study of this micro-situation, including the Model of the Deep Structure of Instruction (MDSI) (Janík et al., 2013). The student's task was to think about their reflections and compare them with the case study. The rest of the course was the same as in the previous academic year.

Teacher Self-Efficacy Questionnaire

A questionnaire of own design, based on Bandura (1997), was used to analyse the teacher's self-efficacy. The tool consists of two separate parts. The first part focuses on the subjects' perceived ability to reflect on specific aspects of teaching and also a statement expressing their attitude to whether they believe their ability to reflect on teaching will improve. The second part focuses in closer detail on the ability to reflect on educational content and its mediation. This aspect was monitored in three areas corresponding to the 3A methodology: annotation, analysis, alteration (Slavík et al., 2014). The components observed are based on literature by Kalhous and Obst (2002) and Pasch (1995), e.g. content, lesson goals, methods and organizational forms, pupils' motivation, evaluation methods and tools and classroom management. In the questionnaire, the students expressed their attitude towards these statements on a four-point Likert scale (false, rather false, rather true, true with values from 1 to 4 assigned to the responses).

Data analysis

Data gained from self-efficacy questionnaires were evaluated using MS Excel and IBM SPSS Statistics 26. With respect to the nature of the data, medians were used to descriptively evaluate self-efficacy questionnaires. For the second part of the research tool (three scales), the internal reliability was assessed using the Cronbach's alpha coefficient (Cronbach, 1951): initial reflection – annotation (α = .843), analysis (α = .864), alteration (α = .884) and for final reflection – annotation (α = .809), analysis (α = .815), alteration (α = .906). These values can be considered acceptable (Tavakol & Dennick, 2011), showing a satisfactory reliability. All items were therefore considered for further statistical reasoning as the value of the scales and the sum of the evaluations was used.

The assessment of the difference between the initial and final teacher self-efficacy questionnaires (all items from Part 1 and the scale values from Part 2) was assembled with the use of the Wilcoxon Single Rank Test. Pearson's coefficient r was used to determine the effect-size (Cohen, 1992). The test results for each category are given in the following chapter.

RESULTS AND DISCUSSION

Initial level of pre-service chemistry teachers' self-efficacy (RQ1)

The pre-test results show that the chemistry student teachers consider their ability to notice (describe) lesson in general to be on a good level (med 3). The same answers (all med 3) were obtained for their perceived: ability to evaluate observed lesson, ability to monitor teaching conditions, ability to evaluate quality of communication and classroom climate, ability to analyse use of teaching aids and instructional materials. With respect to the ability to propose appropriate changes, the responses were more cautious (med 2). When the particular criteria are observed from the annotation, analysis and alteration point of view, the respondents also gave rather negative answers (all med 2) showing their perception of the lack of experience.

The effect of the OPC on PST' self-efficacy (RQ2)

In the post-test, several shifts were recorded. The chemistry teacher students still rate their ability to notice and reflect on the lesson as *good.* In comparison to the pre-test statistically significant differences (α = .05) were found (see Tab. 1). All were with a medium effect, except for one: ability to evaluate the classroom climate which showed no statistically significant difference. Since pre-service teachers perceive their self-efficacy level higher and feel more confident in: monitoring teaching conditions, evaluating them, and analysing teaching aids and instructional materials, as well as proposing changes, the course may lead student teachers to be more sensitive about activation strategies and enhance their ability to recognize when they fail. This, then, allows the changes to be applied during teaching, which contributes to the fluidity of the overall teaching process.

Tab. 1 Shifts in values (medians and averages) of individual items from the first part of the questionnaire, concerning the ability to notice particular phenomena; including p-value and effect size.

Item	**Pre-test**		**Post-test**			
Ability to…	Mdn	Avg	Mdn	Avg	*p-value*	effect size (*r*)
Describe observed lesson	3	2.75	3	3.33	.038	.423
Evaluate observed lesson	3	2.33	3	3.08	.028	.447
Propose appropriate changes	2	2.08	3	2.92	.033	.436
Monitor teaching conditions	3	2.50	3	3.25	.018	.483
Evaluate quality of communication	3	2.33	3	3.33	.008	.544
Analyse use of teaching aids and instructional materials	3	2.58	3	3.42	.005	.572

The results from the scales regarding 3A methodology (Part 2 of the questionnaire) indicate a shift in all three areas and also show statistically significant differences (α = .01) with a medium effect for annotation (med 3; $p = .003; r = .599$), analysis (med 3; $p = .006; r = .560$) and alteration (med 3; $p =$

.010; r = .526). Thus, students after attending the Observation Practice Course rate their ability to annotate, analyse and alter rather positively.

Even though no statistically significant difference was found in terms of students' beliefs regarding their ability to improve their reflecting on teaching (med 4 for both initial and final questionnaire), it is worthwhile to pay attention to it because of its qualitative information - for five students out of twelve, the value did not decrease (stayed at "true"), and for another five students it increased (from "rather true" to "true"). The students seem to overestimate their ability to analyse and reflect on teaching when entering the course, and therefore cannot respond differently in the final questionnaire. These assumptions are confirmed by interviews conducted in the previous academic year. Furthermore, Pendergast et al. (2011) also found out that their research participants appeared to overestimate their level of teacher self-efficacy even as they lacked classroom experience as teachers.

Comparison of changes in PST self-efficacy between academic years (RQ3)

Further, the data suggest that the revised OPC (academic year 2019/20; see above) had a more significant effect on students' self-efficacy than in the previous academic year (2018/19) where only two items from the above were shown to be statistically significant: the ability to describe a lesson (*p = .027; r = .449*) and to propose appropriate changes (*p = .027; r = .449*). On the contrary, there was no statistical difference for ability to evaluate classroom climate in the 2019/20 academic year (2018/19 *p = .017; r = .483*). This may be caused by the adjustment of the OPC that, in comparison with the previous plan, focused more on the development of curriculum analysis, didactic transformation and teaching methods, i.e. on pedagogical knowledge and content knowledge rather than on the classroom climate which had previously proved to be an element perceived implicitly even without prior training.

CONCLUSION

The study results suggest that the OPC adjustment led to an increase in the level of pre-service chemistry teachers' self-efficacy (lesson description and evaluation, proposing changes, monitor teaching conditions, evaluate communication and teaching aids) and thus could have had a significant effect on their professional vision. Since it also affects teachers' decision making directly in the teaching process (i.e. "*professional vision in action*" (Sherin et al., 2008)), this seems to be an intended result. However, implicit bias in perception of students' own abilities needs to be borne in mind since their tendency to overestimate may lead to an unprofessional approach towards teaching practice (cp. Pendergast et al., 2011). As apparent from two-year research, pre-service teachers need to become aware of all aspects to be taken into account during teaching as they often do not have sufficient insight into the methods of observation when entering their follow-up master's studies. Additionally, when pre-service chemistry teachers' attention is not set right, it could lead to their neglecting particular activities in their own teaching practice. Teachers' awareness of these is the main factor leading to the continual process of self-corrections, i.e. never-ending spiral of reflecting on their own lessons. The deeper this is incorporated in teachers during their pre-service training, the more probable is they will continue to do so once in the practice.

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Citizens’ ideas about education of sustainable development goals

Anssi Lindell & Kristof Fenyvesi

Abstract

We assigned Sustainable development goals (SDG) as a premise of project-based education (PBE) and Science, Technology, Engineering, Arts, and Mathematics integration in teacher education. Teacher students designed a museum exhibition collaborating with science museum personnel. To assess citizen opinions on the relative importance of SDGs in PBE, we asked the exhibition visitors which SDGs they consider the most important. Most of them, 19%, top-ranked “Good Health and Well-being” and 16% “Climate action”. One of our goals in the teacher education courses is to offer more connections to the society outside the school community. These results helps us focusing our PBE assignments on real-life preferences.

Keywords

Sustainable development goals; project- based teacher education; real-life assignments

INTRODUCTION

Education for Sustainable Development: International Frameworks

Education has to connect with out-of-school perspectives. These include the global concept of Sustainable Development (SD), which is defined as a development that “meets the needs of the present without compromising the ability of future generations to meet their own needs” (Brundtland et al., 1987). The United Nations (UN) has suggested seventeen Sustainable Development Goals (SDG) *(United Nations, 2017)*, and its Educational, Scientific and Cultural Organization (UNESCO) have made recommendations about several learning objectives regarding Education for Sustainable Development (ESD) *(UNESCO, 2017)*. For each of the SDGs, UNESCO defined specific learning objectives in cognitive, socio-emotional, and behavioural domains. The cognitive domain includes content-specific knowledge and skills involved in the specific SDG. For example “Affordable and Clean Energy” (SDG 7.) targets “knowing about different energy sources –renewable and non-renewable”, among other aspects of energy consumption. The socio-emotional domain includes social skills, values, attitudes and motivation. In the case of SDG 7, this requires “readiness to communicate the different solutions for energy economy”, for example. The behavioural domain includes action competencies, like choosing and using different alternative energy sources (UNESCO, 2017). In short, one may call these domains (1) Knowing, (2) Letting to know and (3) Acting.

In addition to the specific learning objectives for each of the seventeen SDGs, UNESCO-defined Cross-cutting key competencies needed to achieve all the SDGs and live in the complex modern world. These key competencies are Systems Thinking, Anticipatory, Normative, Strategic, Collaboration, Critical Thinking, Self-awareness and Integrated Problem-solving. These competencies go beyond 'recipe-like' problem-solving strategies and can be learned through acting in real-life contexts, communities and environments (Weinert, 2001), rather than studying in traditional classroom settings.

Tab 1. Sustainable Development Goals to address modern global challenges (United Nations, 2017).

1. No Poverty	2. Zero Hunger	3. Good Health and Well-being	4. Quality Education	5. Gender Equality	6. Clean Water and Sanitation
7. Affordable and Clean Energy	8. Decent Work and Economic Growth	9. Industry, Innovation and Infrastructure	10. Reduced Inequality	11. Sustainable Cities and Communities	12. Responsible Consumption and Production
13. Climate Action	14. Life Below Water	15. Life on Land	16. Peace and Justice Strong Institutions	17. Partnerships to Achieve the Goals	

Sustainable Development Goals in the Finnish National Core Curriculum for Basic Education

Finnish National Core Curriculum for Basic Education (FNCC) (Opetushallitus, 2016) offers a comprehensive framework of ESD. It determines the "Necessity of a sustainable way of living" as one of the four main underlying values of basic education. The document defines the leading idea of sustainable development as "eco-social knowledge and ability to create ways of living and a culture that foster the inviolability of human dignity and the diversity and ability for renewal of ecosystems while building a competence base for a circular economy underpinned by sustainable use of natural resources" (Opetushallitus, 2016, p. 16). Sustainable development is also a topic of one of the seven transversal competences defined in FNCC. These transversal competences have a similar multidisciplinary role over all the school subjects as the UNESCO defined Cross-cutting key competences, have over the SDGs. FNCC states that one of the joint objective of transversal competences is to impart competences required for "sustainable way of living" (Opetushallitus, 2016, p. 21) . The tranversal competence of "Participation, involvement and building a sustainable future" supports for "The pupils to develop capabilities for evaluating both their own and their community's and society's operating methods and structures and for changing them to a sustainable future" (Opetushallitus, 2016). Also, ICT competence aims to prepare pupils to "assess the impact of ICT from the perspective of sustainable development" (Opetushallitus, 2016, p. 24).

The Science subject for grades 1-6 is *Environmental Studies* in Finland. The core curriculum states that the Environmental Studies needs to focus on sustainability's ecological, cultural, social and economic dimensions. Environmental Studies' learning objectives have been divided into three domains: "Significance, values and attitudes", "Research and working skills", and "Knowledge and understanding". Sustainable development is an objective in the first of these domains: "to support the development of the pupil's environmental awareness and to guide the pupil to act and become involved in his or her surroundings and community to promote sustainable development and to appreciate the significance of sustainable development to himself or herself and the world" (Optushallitus, 2016, p. 258). Sustainable development is also included in the objectives of the school subjects of *Visual arts* and *Crafts* (Technology). FNCC (Opetushallitus, 2016) describes as a goal of Aesthetic, ecological and ethical values "to encourage the pupil to take cultural diversity and sustainable development into account when selecting contents and working practices for visual production" (p. 286). Similarly, in Crafts, "knowledge of the surrounding material world lays a foundation for sustainable development and a sustainable way of living" (p. 462). FNCC does not mention sustainable development in the subject-specific description of Mathematics.

Sustainable Development Goals in Checkpoint Leonardo 'Sustainable' Project at the University of Jyväskylä

In teacher education, we assigned SDG, as a premise of project-based education (PBE) and Science, Technology, Engineering, Arts and Mathematics (STEAM) integration. Checkpoint Leonardo (CPL) "Sustainable"-project took place at University of Jyväskylä, in the winter and spring semester of 2019. The project was a co-operation between the Department of Teacher Education and the Natural History Museum of the University.

The project was composed of two independent phases (see Tab. 2). In Part 1 the teacher students were realizing an interactive STEAM exhibition in the museum, which was based on the following SDGs: "Good health and Well-being", "Affordable and Clean Energy, and Responsible Consumption and Production. Part 2 was designing a STEAM learning unit to utilize the exhibition in formal education.

The learning outcomes of the Part 2 of the project were to be able to:

1. Design active learning interventions to inquire about various phenomena using diverse scientific methods.
2. Combine scientific knowledge gained about a phenomenon through various school subjects.
3. Design creative content and activities, think critically, and utilize and assess individual skills.
4. Cooperate in out-of-school learning environments.

Tab. 2. The topics of the meetings in CPL's Sustainable–project. Each meeting took 2 h 30 minutes, unless it is mentioned otherwise.

Part 1: Designing the Exhibition	Part 2: Designing the Learning Unit
Project info, STEAM project-based education and science museum as a learning environment	Building the exhibition in the Museum. Opening of the exhibition (6 h)
Sustainable development goals by the UN, 21st-century learning goals by the World Economic Forum and the STEAM approach.	Inquiry-based science education and the Nature of Science
Museum staff, resources and introduction in designing an interactive museum exhibition	Instructed design of the teaching-learning materials
Writing a script for the exhibition and a screenplay for the movies supporting the exhibition	Instructed design and testing the teaching-learning materials
Instructed constructing of the exhibition	Introducing and peer–assessment of the teaching-learning materials
Peer assessment of the pieces of the exhibition and unifying the exhibition's appearance.	Project evaluation

The assessment of achieving these learning outcomes based on the designed plans and learning materials, using Science Lesson Plan Analysis Instrument (Jacobs et al., 2008). Learning was supported by formative evaluation during the project (Krajcik & Czerniak, 2014).

THEORETICAL BACKGROUND

Both international (UNESCO, 2017) and national (Opetushallitus, 2016) recommendations for ESD call for learning cross-cutting key competences by active learning through authentic assignments and contexts together with out-of-classroom communities, i.e. acting with and for real-life contexts. This kind of situated learning is the case in acknowledged models of PBE (Krajcik & Czerniak, 2014; Larmer et al., 2015). Authentic context means something that happens in the real world, even though it does not have to be actual for students at present (Larmer et al., 2015). When students design their own inquiries on questions that are important to them and their community, they also learn to apply the contents in wider contexts. Designing a climate-friendly electric system for a summer cabin is an example of an authentic context for middle school students. Personally interesting and meaningful assignments ensure that the learning is not just "for the school", but students will also discuss and analyse the outcomes in their everyday settings and personal communities, like relatives, friends, teammates, hobbies etc. Projects of increasing well-being, healthy food and physical training are typical examples of projects with personal authenticity. Personal authenticity connects the neighbouring community with the schools. Projects may also have a strong impact on the world in larger scale. According to Barron et al. (1998) such an impact makes the projects especially motivating for the students, offers quality control for the project, makes students to work outside the school hours and unites teachers and students because of the common challenge outside the school.

Media is an important link between environmental issues in students' personal communities and the world on a large scale. Children get 83% of the environmental information from the media (Coyle, 2005). Janouskova et al. (2019) studied the role of mass media as an information channel and agenda-setter of sustainable development. Their data mining from English-written printed newspapers revealed that "Climate Action", "Renewable energy", and "Gender equality" are the most frequently published SDGs. ElAlfy et al. (2020) analyzed more than 24,000 SDG-related tweets from 500 companies. They found that the tweets considered most often the SDGs of "Good Health and Well-being", "Affordable and Clean Energy" and "Gender Equality".

As the 17 SGGs and the three domains of special learning objectives for each of them, along with the cross-cutting key competencies (UNESCO, 2017), form a multidimensional, complex and cross-coupled learning space we are interested in how to focus the ESD by SDGs in real-life context. For this we set two research questions:

1. Which SDGs museum visitors consider the most important in basic education?
2. How do these compare with the exposure of the SDGs in media?

METHODOLOGY

The data was collected during the museum exhibition CPL Sustainable in Natural History Museum of the University of Jyväskylä. The exhibition was open 13th March - 27th September 2020, but the doors were closed 17th March – 16th August 2020 due to the local Covid-19 restrictions. Altogether 1400 persons visited the museum during the Sustainable exhibition. For the data collection, we prepared a recycled art installation re-using seventeen tins. Each tin represented an SDG, with its description glued on the tin. Visitors were given a ballot asking, "which SDG do you consider the most important to be introduced in basic education? What aspects of this specific goal should be emphasized?" A slit was cut on each of the tins for visitors to slip their ballots in. The tins were arranged on the wall by the entrance of the exhibition. Altogether 37 (yield 3%) of the visitors answered the survey. Two of the ballots were dropped into the indefinite space between the tins and did not have numbered SDG to support. These responses were rejected in the counting. We did not collect any demographic data from the respondents, as we were only interested in the responses of citizens in general. We calculated the counts of each SDG and compared their relative distribution with that in the occurrence in media.

RESULTS

Most (19%) of the respondents chose the SDG 3 (Tab. 3) “Good Health and Well-being” as the most important to be introduced in basic education. The second (16%) and the third (11%) popular were the SDGs 13 “Climate Action” and 2 “Zero Hunger”, respectively. The rest of the SDGs were mentioned in less than 10% of the responses each.

Tab 3. Counts for the SDGs that the museum visitors consider the most important to be introduced in the basic education. The SDG numbers refer to Tab. 1.

SDG	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
COUNTS	3	4	7	1	3	0	1	1	1	2	1	4	6	0	0	0	1

We also compared the museum visitors responses to the relative visibility of each SDG in mass media (Janoušková et al., 2019) and tweets by companies (ElAlfy et al., 2020). In the latter one we approximated the numbers from a graph as the raw data was not available. Fig. 1 represents this comparison visually.

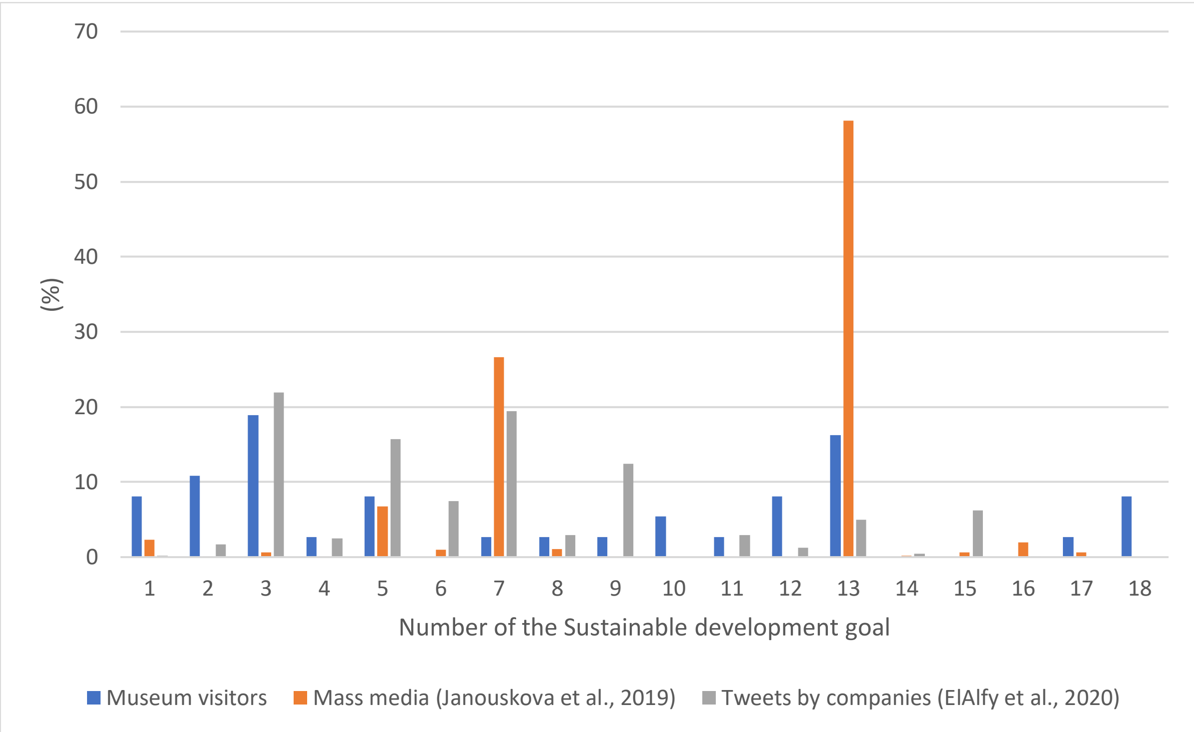

Fig. 1. Exhibition visitors’ distribution of responses to the question of the most important SDGs in basic education (blue pillars) compared to their appearance in the mass media (Janoušková et al., 2019) and tweets by companies (ElAlfy et al., 2020). The numbers of the SDGs refer to Tab. 1.

DISCUSSION

Teacher students chose the SDGs 3 “Good Health and Well-being”, 7 “Affordable and Clean Energy”, and 12 “Responsible Consumption and Production” to be introduced in their interactive museum exhibition design. The exhibition visitors voted the SDGs “Good Health and Well-being”, 13 “Climate Action”, and 2 “Zero Hunger” as the three most important to be introduced in basic education. Teacher students and visitors share the view of the importance of human well-being, the topic is also most often mentioned in the FNCC with 144 hits in search. On the other hand, teacher, students seemed to be more interested in “material issues”, energy and production, than museum visitors who considered universal themes of hunger and climate more important to be discussed in schools.

Two most important SDGs in school education according to the museum audience and relatively two most visible SDGs in mass media and tweets by companies form an interesting triangle. SDG “Good Health and Well-being” was the most important in schools according to museum visitors and the most frequent in the tweets by companies. SDG “Affordable and Clean Energy” was the second frequent in both mass media and tweets by companies. SDG “Climate Action” was the second important for schools in the museum visitors’ responses and the most visible in mass media. These numbers might suggest that global climate interests mass media, while well-being, which can be understood more private issue, companies. More museum visitors’ were supporting local contents, but still “Climate Action” was the second most popular SDG among them. However, the sample was too local and small for reliable evidence of these brave conclusions.

The common interest of teacher students and museum visitors was the SDG of “Good Health and Well-being”. Considering “Climate Action”, “No Poverty” and “Zero Hunger” were among the top interests by the visitors, but not by the teacher students.

CONCLUSION

According to the museum exhibition visitors, the SDGs 3 “Good Health and Well-being”, 12 “Climate Action” and 7 “Affordable and clean energy” form a base to build basic education of sustainable development in real-world context in consensus with museum visitors, the business world and mass media.

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What tasks are included in chemistry textbooks for lower-secondary schools: A qualitative view

Karel Vojíř

Abstract

One of the main determinants of effective learning is the students' activity. In this sense, learning tasks play a key role and affects the development of students' chemical thinking and science literacy. Textbooks are a widely used didactic aids representing the most specific elaboration of the intended curriculum, including tasks. The aim of this contribution was to identify the main types of tasks in chemistry textbook for lower-secondary education in Czechia. A qualitative approach was chosen for this purpose and the main types of tasks were described. Tasks using experiments demonstrated by a teacher are typically included as a means of acquiring new knowledge, other tasks are mainly aimed at fixation of the subject matter.

Keywords

Chemistry education; textbooks; learning tasks

INTRODUCTION

Textbooks play a key role in the educational process as a teaching aid that brings students and teachers a concrete transformation of educational content. In contrast to higher written curriculum levels, they represent the concretization of the intended curriculum into the form of specific activities. They, therefore, often define both the specific subject matter and the methods and forms of its mediation. They thus become a potentially realized curriculum (Törnroos, 2005) with a direct impact on students. This is conditioned by the students' work with the textbook. At the same time, the textbooks' impact on educational reality is enhanced by teachers using them to prepare for teaching (Vojíř & Rusek, 2021). They do so in terms of the educational content's choice and structure (Sikorová, 2010), or teaching methods and forms' adoption (Bergqvist & Rundgren, 2017).

The selection and mediation of a subject's educational content is largely based on the explanatory text in textbooks. Systematic attention has already been paid to this aspect to lower-secondary chemistry textbooks (Rusek et al., 2016; Rusek & Vojíř, 2019). With regard to the goals of education leading to competency development (RVP ZV, 2017), or science literacy (OECD, 2019), the students´ own activity is an integral part of the learning process. Tasks play a key role in this (Slavík et al., 2010), as a means of directing the student's attention and activity. In the science textbooks research, however, the tasks have so far received rather partial attention (cf. Vojíř & Rusek, 2019). There is a relationship between learning outcomes and the way students learn. In this sense, *opportunities to learn* are crucial (Yang et al., 2017). Different approaches to the tasks' structure and their content affect students' attention and their knowledge and skills development. Understanding learning opportunities that are provided to students through tasks can help to understand both the strengths of chemistry education and potential problems. As pointed out by Andersson-Bakken et al. (2020), in order to understand the potential educational impact of the included tasks, it is necessary not only to quantify them according to specific criteria such as cognitive difficulty, but also to describe the individual types in detail. The aim of this study was therefore to describe the basic types of tasks included in current Czech chemistry lower-secondary textbooks and identify the main differences in the approach to tasks in individual textbooks.

METHODOLOGY

With respect to this study's aim a qualitative approach was chosen to characterize the tasks in the textbooks. For a comprehensive insight into this field, the tasks were identified in terms of means that evoke, direct and support students' learning activities (Slavík et al., 2010). As tasks consist of different parts with specific functions, the tasks were first evaluated from their internal structure's point of view. For this purpose, the general scheme of tasks as reported by Chvál et al. (2015, p. 122) was used (see Tab. 1). Second, the individual identified parts of the tasks were further analysed. In the response types, the division of tasks into open-ended (with a short answer, or with a wide answer) and close-ended task (dichotomous, multiple-choice, matching, or organizing) was used. Cognitive demands and the required type of knowledge were assessed according to the Revised Bloom's taxonomy (Anderson & Krathwohl, 2001). In connection with these aspects, the approach to the tasks' analysis was qualitatively described in detail and compared among the individual textbooks.

Tab. 4 Evaluated parts of tasks

Part of the task	Examples of variants
Instructions	*answer in writing, circle all the correct answers*
Default text	*written text, graph, table, picture, demonstrated experiment*
Stem	*question, an unfinished sentence, incentive (e. g. observe)*
Response variants	*unstated (open-ended tasks), correct answer and distractors*
The method of evaluation	*scoring etc.*

Research sample

From the point of view of the tasks' concept and structure, 8th grade chemistry textbooks most often used in Czech lower-secondary schools were evaluated (cf. Vojíř & Rusek, 2021). Further in the text, these textbooks are referred to by abbreviations - see Tab. 2. The evaluation also included the most recently published textbook issued by Fraus with an approval clause from the Ministry of Education. A more detailed analysis revealed that these textbooks differ from the first version mainly in the order of individual topics and graphic processing (see Vojíř & Rusek, 2020), but not in didactic equipment (Rusek, Vojíř, et al., 2020). As there is no difference in the approach to classifying and formulating tasks between the new and the previously published edition, these textbooks are referred to together.

Tab. 5 Evaluated textbooks

Authors	Name	Publisher	Year of issue	In-text abbr.
Beneš P., Pumpr V., Banýr J.	Základy chemie 1	Fortuna	1993	ZCH
Beneš P., Pumpr V., Banýr J.	Základy praktické chemie 1	Fortuna	1999	PCH
Mach J., Plucková i., Šibor J.	Chemie pro 8. ročník	Nová Škola	2016	NŠ
Škoda J., Doulík P.	Chemie 8	Fraus	2006	Fr
Škoda J., Doulík P.	Chemie 8 (nová edice)	Fraus	2018	

The nature of the identified types of tasks was compared with 9th grade textbooks. Individual textbook series showed to maintain the same approach to 8th and 9th grade tasks' classification and internal structure. The results of the qualitative analysis are therefore generalizable to a number of textbooks. To illustrate a typical approach to the formulation and structure of tasks in the textbook, tasks from a chapter on *hydrogen* were selected for this paper. All analysed textbooks pay similar attention to this topic. At the same time, in all cases, all basic identified types of tasks are included in these chapters, which enables a clear comparison of textbooks. These chapters had also been analysed in previous research in terms of text difficulty (Rusek & Vojíř, 2019), which allows further comparison.

RESULTS AND DISCUSSION

The basic quantification revealed a high number of tasks in textbooks: ZCH – 561, PCH – 320, NŠ - 517, FR – 651 (or 685 in the new edition of FR). Tasks in all analysed textbooks contain typically only *stem* and possibly *default text* as a part of their structure. A typical variant of a *default text* is a laboratory activity. Other typical tasks in textbooks contain only a *stem* or a *stem and a brief default text* (maximum few sentences) and are focused on chemical topics or on cross-curricular links (connection the topics with other educational areas such as biology, geography, literature, history etc.).

Tasks associated with the laboratory activity of the teacher or student

Tasks associated with laboratory activities (typically of the teacher) were found in all evaluated textbooks. This fact can be perceived positively, as textbooks thus provide teachers with the necessary curricular support for school experiments as a specific transformation of chemical educational content (Rusek, Chroustová, et al., 2020). Unlike other types of tasks, they are included in all textbooks among other components of didactic equipment and are thus a component of the chapter's exposition part. However, it is often the teacher's laboratory activity, which students only observe. This finding probably explains teacher-demonstrated experiments' prevalence in Czech schools Rusek et al. (see Rusek, Chroustová, et al., 2020).

In all textbooks, tasks are clearly identifiable from the surrounding explanatory text. In newer textbook series (Fr, NŠ), the tasks are also connected with the textbook guiding system - instructional icons (e. g. in Fr: eye icon for observation, cobweb icon for context search, etc.) related to these textbooks' overall higher didactic equipment - guiding apparatus (Rusek, Vojíř, et al., 2020).

In all cases, the laboratory activities included in the textbook chapter related to hydrogen aim to demonstrate the explosive course of hydrogen combustion in a mixture with air. The default task text provides a description of the laboratory activities linked to the attached diagrams. However, processing the text parts of the initial task text and trunk differ significantly in the individual textbooks. The procedure of laboratory work in the NŠ textbook is described step by step and, in comparison with other textbooks, in much more detail - for example, including the volumes of vessels. At the same time, it is written in the imperative, which would indicate an active laboratory activity for the student. However, the task is marked as a *demonstration experiment for the teacher* by the guiding apparatus. (**NŠ (p. 48):** *Prepare a can (with a volume of approx. 300 cm^3) with an open bottom and an opening at the opposite end closed by a stopper. Place the can on a tripod covered with cardboard with a hole for a hose. Pour 30 cm^3 of 15% hydrochloric acid into a 500 cm^3 PET bottle and add a few pieces of zinc. … Observation and conclusion: The reaction of zinc with hydrochloric acid produces hydrogen gas relatively rapidly. It explodes from the air when the burning skewer approaches the can with its mixture of oxygen. After burning hydrogen with oxygen, water is formed. The can has misted inside.*)

Although the textbook is intended primarily as an aid for students, the formulation of the laboratory procedure suggests that it is intended for teachers. In the field of laboratory activities, this textbook aims to fulfil the purpose of teaching preparation. This way of using textbooks was also confirmed in Sikorová's research (2010), which places the textbook in the role of a potentially implemented curriculum (Törnroos, 2005).

Even in the ZCH and PCH textbooks, the individual steps of laboratory activities' procedure are captured, although in less detail than in the case of NŠ. In these textbooks, the text is written in the plural, but due to the nature of the task, which from the point of view of safety cannot be performed independently by lower-secondary school students, it is reasonable to assume that their determination is again for teachers. (**ZCH (p. 54):** *… d) We collect hydrogen above water in a test tube, which is initially completely filled with water. We will perform the explosion test again as in the previous experiment. If the gas does not explode, the test proves that there is no more air in the apparatus. Now we can ignite* *the hydrogen at the end of the apparatus. We hold a dry beaker over the hydrogen flame. We observe that the walls of the beaker have misted. Combustion of hydrogen with atmospheric oxygen produces water.* **PCH (p. 32):** … *We close the tube with a stopper through which a glass tube passes. We collect the escaping gas in a second test tube turned upside down. After two to three minutes, we close the upper tube with our thumb, we approach it to the flame of the torch and move our thumb away. The surprising "honking" of a mixture in a test tube is evidence of hydrogen, which forms an explosive mixture with air. The inner wall of the tube misted up. When a mixture of hydrogen and atmospheric oxygen explodes, water is formed.*)

The focus on teachers in the laboratory activities in these three textbooks is also shown in the stem of the task, which is included rather implicitly. While the teacher's task is to perform a laboratory activity according to the given instructions, the students' task is to observe the demonstration. There are no further instructions to predict, explain, assess, etc. which would further guide students' learning. From cognitive activity's point of view, it is only a matter of understanding the observed facts, which need not be further connected, evaluated, or interpreted. Even the observation itself is further reduced in the text by stating exactly what they observe. This brings the premise of correct observation, which does not direct the students' attention to the laboratory activity, but in the transmission of knowledge emphasizes the role of the authority of the textbook or the teacher who follows it. From the effective labs' point of view, this approach proved to be problematic (cf. van den Berg, 2013).

A different approach to the tasks associated with laboratory activities within the chapters was only found in the Fr textbooks. The initial text here represents the teacher's basic activity. The task stem is then open-ended questions. The questions direct the students to observe, but also to make further reasoning. It aims to help them understand not only factual but also conceptual knowledge. Although the implementation of the laboratory activity is again in the hands of the teacher, there is a greater emphasis on the task as a means of active learning for students (cf. Slavík et al., 2010). (**Fr (p. 34):** *The teacher assembles the apparatus for gas development. By reacting zinc with hydrochloric acid, it prepares hydrogen, which s/he collects above water into two larger tubes. S/he turns one tube upside down, leaving the other with the bottom down. S/he attaches a burning wooden skewer to the mouth of both tubes.* – What properties of hydrogen have you observed? Is hydrogen lighter or heavier than air? How did the reaction of hydrogen with atmospheric oxygen manifest itself?)

As noted by Pedaste et al. (2012) research consists of finding new contexts through experiments or observation. Although in the instructions for all evaluated textbooks, these activities are presented as experiments, they are actually only observational without investigating the cause and effect via changing a variable. From the point of view of scientific research, these tasks, which are based on observation and possible interpretation, only focus on investigation but completely neglect orientation in the problem and its conceptualization, which would be achieved by asking questions and formulating hypotheses, as well as accepting broader conclusions, their generalization, and reflection (cf. Pedaste et al., 2015).

Tasks of a theoretical nature focused on chemical topics

All analysed textbooks include tasks of a theoretical nature focusing on memorizing and understanding the factual and conceptual knowledge from chemistry's educational field. Tasks typically contain only the stem, possibly supplemented by a brief default text. These are often isolated questions. Clauses of a shorter scope are mostly used (cf. Koperová et al., 2020), which makes syntactic difficulty significantly lower than in the explanatory text (Rusek & Vojíř, 2019). Tasks in the form of questions lead to an open-ended form of answer. This type of tasks is the most common in all analysed textbooks. The findings correspond to conclusions by Priškinová and Held's (2019) conclusions. In this research, the analysed textbooks were included in a model creating the scientific image of the world. It presents chemistry as a scientific field applied in all areas of human activity and involves activities of various types. At the same time, however, knowledge prevails over activities in its content (Holada, 1985), which is confirmed by the identified task forms.

Significant differences between textbooks were found in tasks of a theoretical nature's inclusion in the context of other components of textbooks' didactic equipment. Only in newer textbooks published after the curricular reform introducing the framework educational program (cf. Vojíř & Rusek, 2020) are theoretical tasks more frequently included in the chapters among the explanatory text. In the chapters devoted to hydrogen, these are tasks connecting the educational content contained in the explanatory text with the knowledge of previous chapters devoted to the periodic law, resp. particle structure of matter. The structure of these textbooks shows the key moments of connection between the subject matter exposition and fixation, as intended by the authors. (**NŠ (p. 48):** *Why does hydrogen H in the periodic table lie on the opposite side from other non-metals?* **Fr (p. 34):** *Find hydrogen in the periodic table. How many protons and electrons does a hydrogen atom have? How many bonds does a hydrogen atom form?*)

In Fr textbooks, other tasks focusing on chemical subject topics are included among the marginals. The connection with everyday life or other areas of human activity was identified in the tasks. (**Fr (p. 35):** *Which waste product is generated when hydrogen is burned in hydrogen engines? Can we consider hydrogen as an ecological fuel?)*

Tasks aimed at consolidating the curriculum in chemistry's educational field are included in other textbooks at the ends of individual chapters (ZCH, NŠ), or in the bank of tasks summarizing the thematic unit (PCH). The connection between chemical knowledge and other aspects of human life and society was also found in the ZCH and PCH textbooks. (**ZCH (p. 55):** *Which property of hydrogen allows it to be used to fill fairground balloons and meteorological balloons? Which substance was formed during the explosion of the airship filled with hydrogen (Fig. 112)?* **PCH (p. 40):** *Which property of hydrogen allows it to be used to fill fairgrounds and meteorological balloons? Explain the danger of filling balloons with hydrogen.*) In the context of these tasks, however, the information is obsolete due to the year of the textbook's publication (cf. Vojíř & Rusek, 2020). In this case, the mentioned use of hydrogen to fill fairground balloons is currently not legal in the Czech Republic (ČSN 07 8304).

In the NŠ textbook, on the other hand, the tasks intended to strengthen the curriculum focus mainly on independent knowledge of chemistry's educational field without a broader context. (**NŠ (p. 53):** *What properties does hydrogen have?*) As Gilbert et al. (2011), point out, chemical concepts are often presented as isolated facts without a broader context. This factor is limiting both for the development of science literacy and for the perception of chemistry as a science. As teachers take over not only educational content but also teaching methods from textbooks (Bergqvist & Rundgren, 2017), the decontextualized form of textbook tasks can exacerbate this problem. Despite the declared compliance with the FEP, the textbook thus acts against the concept of scientific literacy incorporated in the FEP (see Janoušková et al., 2019)

Tasks focused on cross-curricular links

In comparison with other textbooks, tasks not directly related to the content of chemistry's educational field were also identified in the Fr textbooks. These tasks are typically located between the marginals and connect the topic discussed in the chapter with knowledge from other disciplines. In their inclusion, it is possible to see the authors' effort to prevent chemistry being taught as a pure science without connection with society and everyday life (cf. Witz & Lee, 2009). The structure of these tasks does not differ from tasks focused on chemical topics. From the point of view of cognitive demands, they typically aim at the reproduction of factual knowledge from memory. They are therefore aimed at evoking content-related knowledge, but there is no further interconnection or wider integration. (**Fr (p. 34):** *Our Sun is also formed mostly of hydrogen. What do we call the stellar galaxy in which the Sun is located?*)

CONCLUSION

The presented text provides an insight into the form of typical tasks in chemistry textbooks, illustrated in more detail in the tasks from the chapters about hydrogen. Significant similarities in the tasks' internal structure were found in the analysed textbooks. The tasks consist mainly of a stem, possibly accompanied by only a brief default text or a laboratory activity. While tasks using laboratory activities (especially teacher-demonstrated) are included as a means of acquiring new knowledge, other tasks are mainly aimed at fixing the subject matter. Although the tasks associated with laboratory activities were found in all textbooks, only in textbooks FR they were associated with explicit questions for students. Differences in the approach to formulating theoretically focused tasks between individual textbooks are shown mainly by including a broader context presenting chemical knowledge in accordance with other areas of human life. Analysed chemistry textbooks do not include tasks aimed at new knowledge and skills' acquisition in connection with scientific text, graphs, tables etc. As each type of task leads to the specific skills' development, innovation of materials in this sense seems appropriate. Also, the directing of students' activity in tasks requires further attention.

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