



The 10th International Conference on Research in Didactics of the Science (DidSci+ 2022)

Košice, Slovakia • 26-29 June 2022
Editors • Mária Ganajová, Jozef Hanč
Ivana Sotáková, Petra Letošníková

DidSci+
26-29 June 2022
Košice, Slovakia

**10th International Conference
on Research in Didactics of the Sciences**



DidSci+
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**Proceedings
Selected Papers**

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26th – 29th June, Košice, Slovakia

Science Education Research, Innovation and Digital
transformation of STEM education

EDITORS

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This book contains selected papers
presented at the DidSci + Conference 2022

DidSci+ Conference 2022
PROCEEDINGS – Selected Papers

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Preface: 10th International Conference on Research in Didactics of the Science (DidSci+ 2022)

From June 26 to 29, 2022 — as the global COVID-19 pandemic was drawing to a close — the International Conference on Didactics of the Science (DidSci+ 2022) warmly and lively welcomed more than a hundred researchers, scientists, educators, teachers, and Ph.D. students from the field of STEM education and STEM disciplines, primarily from Central Europe. This special edition of DidSci conferences, celebrating its 10th anniversary, was held, in Košice, Slovakia's second-largest city, at the Faculty of Science of Pavol Jozef Šafárik University. The DidSci+ conferences present a platform for enduring international cooperation, focusing on the frontiers and current challenges in science education research alongside existing progress in natural, pedagogic-psychological, and social sciences.

Concerning history, the Košice DidSci+ conference continues in a legacy of the successful series of prior DidSci conferences that originated in Poland (Krakow 2004, 2006, 2008, 2010, 2012, 2014, 2016), followed by gatherings in the Czech Republic (Prague 2018, Brno 2021) and the Slovak Republic (Trnava 2019, together with IOSTE 2019 conference). The DidSci conference's history is also interlinked with the DYDCHEM conference, which, in 2004-2008, transformed into the present DidSci format, primarily focusing on research in natural science didactics.

The main goal of the Košice DidSci+ conference was to facilitate the exchange of pedagogical experiences in STEM at all educational levels, from primary school through to higher education, with a particular emphasis on innovation and digital transformation within STEM education. Particularly, the Košice DidSci+ 2022 conference centered on the following main educational topics:

- Current Results of Natural Sciences Didactic Research
- Digital Transformation of STEM Education
- Active Learning and Development of Scientific Literacy
- Science Education Curriculum
- Teacher Training and Lifelong Learning

The DidSci+ 2022 conference participants themselves presented 57 contributions, of which 38 were in the form of talks and 19 as posters. In addition to the main conference program, various collaborative activities and social events took place, providing an opportunity for participants to communicate with other delegates and share their views on innovations in natural sciences education.

From the perspective of STEM disciplines, the majority of contributions were dominated by chemistry (43%) and general questions dealing with STEM education (27%). The predominance of chemistry-oriented contributions is due to the historical background of the conference's origin, as the conference initially took root within the chemist community. As for didactic topics, digital technologies (29%) and teacher training (19%) played a primary role, which can be interpreted as a consequence of the accelerated digitization and kickstart of massive digital transformation of STEM education triggered by the COVID-19 pandemic.

Highlights of the conference included seven plenary invited lectures. On Monday, Dušan Šveda presented the results and advancements of the digital transformation in Slovakia as part of the national project 'IT Academy - Education for the 21st Century'. In a complementary keynote talk, Katarina Kotuláková provided a detailed insight into the ongoing curricular reform in Slovakia, emphasizing the improvement of scientific literacy in primary education students together with the role of an inquiry-based approach, all within the 'Nature educational domain' of national curricula. Tuesday's plenary sessions were exclusively dedicated to innovative digital technologies and their role in STEM education. In the morning session, Petr Šmejkal addressed the question of whether Virtual Reality (or 3D virtual models), is a teaching aid or a headache for teaching substance structures in chemical education. Subsequently, Libor Koníček demonstrated, using the simple example of a cooling cup of tea, the stages, and sophisticated modeling approaches, as well as the importance and benefits of modeling in physics and also STEM education. In the afternoon session, Pawel Bernard focused on raising awareness of the inquiry-based approach via MOOCs in Poland. He detailed several existing MOOC courses with participants' reflections, where selected highly motivational online experiments played a critical role in promoting scientific literacy. Following Bernard's talk, Jozef Hanč shed light on using the online platform Perusall in teaching and learning STEM disciplines, where he

underscored how this advanced social annotation technology, backed by AI and data science reports based on Jupyter, facilitates formative assessment, tracking of student progress, and the identification of areas of difficulty. The final plenary lecture on Wednesday was delivered by Sohair Sleiman-Sakhnini, who provided her current perspective on how to integrate Nanotechnology into STEM Education as an example of Dynamic Points' implementation in the secondary school curriculum.

The conference proceedings present a selection of contributions, each of which underwent rigorous review scrutiny described below. The criteria used for evaluation encompassed aspects such as the currency of information, the quality and richness of content, relevance to the chosen thematic area, overall structure, lucidity, originality, validity, and their strong association with the conference's themes and academic fields. The entire proceeding is exclusively published in English. The review process was multi-tiered. Initially, before the DidSci+ 2022, the conference chairs, in collaboration with the international scientific committee in the role of the editorial board, determined the suitability of a paper for presentation at the conference. After the conference, the second review was undertaken by two independent reviewers in the frame of the standard double-blind peer-review procedure.

Regarding plenary lectures, efforts were made to avoid copyright infringement of previously published work and prioritize the greatest applicability in STEM education. Among the selected plenary talks, readers can find the article about Virtual Reality (VR) in chemistry education by Peter Šmejkal and his international team. Although VR has been known for more than five decades, it has only become a truly available and meaningful teaching aid for integration in STEM education in the last few years. Another highlighted plenary talk by Jozef Hanč and his colleagues focuses on the social reader, Perusall, a learning tool that has emerged as a pivotal asset for blended learning in any STEM discipline, validated even under strict social distancing and physical restrictions during the Covid-19 pandemic. The third published plenary talk, by Katarína Kotuláková, was selected for its insightful examination of ongoing curricular reform in Slovakia, emphasizing the enhancement of scientific literacy in primary education and the role of the IBSE approach.

This careful review process has led to two major publications offering a comprehensive look at the latest advances in STEM and science subjects education. The first output is published as the IOP Conference Series proceedings, Vol. 3037 (open access at <https://iopscience.iop.org/issue/1742-6596/3037/1>) and is primarily devoted to STEM education, assessment, evaluation, and feedback strategies, and teacher development. This second volume of selected papers focuses on curriculum development, educational innovation, and digital technologies, primarily in chemistry and biology.

In conclusion, we would like to express our sincere gratitude to the anonymous peer reviewers for their invisible, but fundamental work, without which these proceedings could not have been compiled. Our heartfelt thanks also go to all the authors based on their submissions. Finally, our appreciation goes to all the participants of the DidSci+2022 conference for their unwavering engagement, motivation, and enthusiasm, which significantly contributed to stimulating discussions about STEM education. All these elements together greatly enhanced the quality of the conference and its outcomes, setting a high bar for future DidSci+ conferences and educational dialogues in the realm of STEM education.

Mária Ganajová, Jozef Hanč, Ivana Sotáková, Petra Letošníková
Editors, Faculty of Science, Pavol Jozef Šafárik University in Košice

DidSci+
26–29 June 2022
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10th International Conference
on Research in Didactics of the Sciences



SELECTED PAPERS

- The papers are arranged by topic and then in alphabetical order by the first author's name.

Competence-Oriented Approach to Advanced Practical Exercises in Inorganic Chemistry: MINT Education, Industry Cooperation, and Formative Assessment

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Abstract. The article deals with the innovation of the practical tasks of the Advanced Practical Exercises in Inorganic Chemistry. The innovative practices were consulted and prepared by involving potential employers of graduates at the Institute of Chemistry of the Pavol Jozef Šafárik University in Košice, Slovak Republic, from the commercial as well as the public sector in the teaching process, with the intention of directly preparing students for the specific requirements of the labour market. The MINT system was also implemented within the course, which is an educational method based on educating students in four essential areas – mathematics, informatics, natural sciences, and technology. All the mentioned scientific and technical fields have been integrated, while students use different mathematical (Origin, Excel) and graphic programs (ChemSketch, ChemDraw, Diamond, Mercury), online databases (Scopus, Web of Science, CCDC, Reaxys) in their teaching, which represent the implementation of mathematics and informatics. From the view of complementary natural sciences, chemistry is mainly represented, primarily inorganic chemistry, but also physical, organic, analytical, coordination, organometallic, bioinorganic chemistry, and biochemistry. Other natural science subjects, such as physics and biology, are also included in the experimental tasks. Technology and chemical technology are included in practical exercises by direct application of prepared compounds in practice, respectively, students are informed about the manufacturing processes of the products. As part of the practical exercises, student self-assessment was implemented through student self-evaluation cards in which the student answered questions related to the experimental task. Based on their answers, the teacher receives feedback from the students and discusses and explains the given problem in case of ambiguities. According to the statistical overview of student responses to the self-assessment cards of students in the years 2017- 2022, it can be concluded that students manage practical exercises at a high level, and minor problems appear in interdisciplinary tasks that include physics and biology. We hope and believe that the innovative experimental tasks will help graduates to better apply and enter the labour market.

1. Introduction

Education plays a pivotal role in shaping individuals' future opportunities, particularly influencing how effectively young people transition into the labour market. In recent years, many European countries have faced persistently high youth unemployment rates, making it increasingly challenging for graduates to secure employment. These difficulties are compounded by evolving labour market demands, which now emphasize a broader range of competencies beyond traditional knowledge. Employers expect new graduates to possess advanced information-processing skills, including reading comprehension, quantitative reasoning, and the ability to solve complex problems (Almáši et al., 2020b; Vargová et al., 2019).

In response to these shifts, the importance of sustained dialogue and collaboration between educational institutions and industry stakeholders has become more apparent. This is particularly relevant for chemistry-related disciplines, where aligning academic training with professional requirements is essential. Practical subjects within the natural sciences curriculum are instrumental in preparing students for real-world applications of their knowledge. Accordingly, in partnership with industry representatives, we have undertaken a comprehensive revision of advanced laboratory courses at the bachelor's level—spanning inorganic, analytical, physical chemistry, and biochemistry—to better reflect current workplace expectations and enhance graduate employability. Individual chemical departments have established cooperation with the companies in Slovakia for example, BovaCHEM (is a chemical company focusing on radiation, chemical and biological protection), The Criminalistic and Expertise Department of the Police Corps (examines traces and samples from the crime scene, or samples otherwise related to the offence, which law enforcement agencies and courts mainly examine) and DUSLO (is one of the most important chemical companies in Slovakia and its produce is oriented on the preparation of fertilizer producer and rubber chemicals) (Almáši et al., 2019; Vargová et al., 2020; Vargová et al., 2021). The content of the practical exercises was discussed with the workers of external companies so that the students acquire the necessary knowledge and skills that are necessary and imposed on employees in the given companies (Vargová et al., 2020).

As part of the practical training, the MINT educational framework was implemented. MINT – an acronym for Mathematics, Informatics, Natural Sciences, and Technology – represents a multidisciplinary approach that integrates these four domains into a cohesive learning experience. Unlike traditional instructional models, which typically treat each subject in isolation, the MINT methodology emphasizes interconnected teaching, aiming to reflect the complexity and integration found in real-world applications. By presenting these disciplines in a unified context, students are better able to grasp the interrelations among concepts, leading to a deeper understanding and an enhanced ability to transfer knowledge to everyday situations. This holistic approach fosters simultaneous learning across subjects, acquiring knowledge more intuitive and engaging. MINT also distinguishes itself through its emphasis on digital tools and experiential learning alongside conventional classroom instruction. In addition to strengthening foundational competencies in STEM fields, the MINT system actively cultivates students' logical reasoning and problem-solving abilities, thereby equipping them with essential skills for both academic and professional success (Jirát et al., 2013; Řezanka et al., 2013; Cohen et al., 2019).

In the present article, we present new content, forms, changes, and methods of subject Advanced Practical Exercises in Inorganic Chemistry in order to develop the scientific, practical, and digital competencies of graduates needed for employment in the labour market.

2. Practical exercises and their content

Within the subject of Advanced Practical Exercises in Inorganic Chemistry, various experimental tasks were created after consultation with experts from external companies. In addition to expanding the basics of inorganic chemistry, it also includes novel knowledge from coordination, bioinorganic, physical, analytical, organometallic, and organic chemistry, and biochemistry. The exercises also marginally include other natural science subjects (biology, physics, mathematics, and informatics) and chemical technologies connected to the MINT educational system. The Advanced Practical Exercises in Inorganic Chemistry (Almáši et al., 2017) are intended for students in the third year of bachelor's studies, which is carried out in the summer semester and, therefore, the final semester of their study, and includes the following eight experimental tasks:

1. Preparation of model receptors imitating molecules of biological importance I.: Model of the oxygen transporter

The task consists of synthesising the organic ligand H_2salen through a condensation reaction and determining its purity through thin layer chromatography (TLC) and the melting point. Preparation of

the [Co(*salen*)] complex as a model oxygen transporter in a vacuum. This is followed by the preparation of oxygen and its adsorption using the [Co(*salen*)] complex, the measuring of the adsorption isotherm, the determination of the maximum adsorption capacity and the application of various mathematical models to fit the obtained data.

2. *Preparation of organometallic compounds: Ferrocene*

At the beginning of the practical exercise, it is necessary to carry out the process of dicyclopentadiene cracking into its monomeric form in an inert atmosphere of argon and to prepare various solutions necessary for synthesising ferrocene. This is followed by the synthesis of ferrocene itself, its isolation, and purification through sublimation. Another task is the acetylation of the prepared ferrocene by Friedel-Craft acylation using AlCl_3 as a catalyst, the isolation of the prepared products by thin layer (TLC) and column chromatography (CC), and the characterization of the compounds by infrared spectroscopy, nuclear magnetic resonance (NMR), and determination of the melting point.

3. *Heteropolycompounds: Preparation of tetrahydrogensilico-dodecatungstic acid heptahydrate $\text{H}_4\text{SiW}_{12}\text{O}_{40}\cdot 7\text{H}_2\text{O}$*

The basis of the task is the preparation of heteropolyacid $\text{H}_4\text{SiW}_{12}\text{O}_{40}\cdot 7\text{H}_2\text{O}$ by polycondensation reaction in a special isolated apparatus. The isolation of the product by the extraction process, crystallization, and subsequent determination of saturation by acid-base titration. The following is a study of the product's catalytic activity by the bromine reaction with cyclohexene.

4. *Preparation of complex compounds: Acetylacetonate complexes of transition metals*

The experimental task is focused on the preparation of various complexes containing acetylacetonate ligand in combination with Cr(III), Mn(III) and Cu(II) cations. Various weak bases are used for the deprotonation of acetylacetonate, while various reaction mechanisms such as symprotonation, disproportionation, and substitution reactions are used in the complex preparation procedure.

5. *Unconventional synthetic procedures: Preparation of industrially used dyes: Phthalocyanines*

The essence of the task is the study of photophysical and photochemical properties of phthalocyanines as industrially used dyes. The dyes are synthesized through the template polycondensation reaction of trimellitic anhydride molecules and ammonium molybdate as a heterogeneous catalyst. The colour of the resulting product depends on the chosen central atom (Zn(II), Cu(II), Ni(II), Co(II)), which ranges from blue, green, and yellow to red. The prepared products are subsequently characterized by infrared and UV-VIS spectroscopy.

6. *Reactions in the solid phase: Preparation and characterization of the "1-2-3" superconductor $\text{YBa}_2\text{Cu}_3\text{O}_x$*

The goal of the assignment is the preparation of a high-temperature superconductor based on a ternary oxide with a non-stoichiometric composition of $\text{YBa}_2\text{Cu}_3\text{O}_x$. The basis of superconductor preparation is the precipitation of nitrates of the relevant metals (Y(III), Ba(II), and Cu(II)) by gradually lowering the *pH* of the solution and calcination of the product at high temperatures. The prepared powder material is subsequently pressed under high pressure into the form of pellets with different thicknesses, on which the Meissner effect is demonstrated and studied.

7. *Preparation of model receptors imitating molecules of biological importance II: Template synthesis of cyclam and preparation of the complex $[\text{Zn}(\text{cyc})(\text{H}_2\text{O})_2](\text{CH}_3\text{COO})_2$*

The experimental task consists of the template synthesis of the macrocyclic ligand cyclam (*cyc*) by the condensation reaction of 1,2-bis(3-aminopropylamino)-1,2-ethane with glyoxal and Ni(II) cation as a template. In the next step, the Ni(II) cation is removed, and the final product is isolated and characterized by infrared spectroscopy and NMR. The last task of the exercise is the synthesis of the

complex $[\text{Zn}(\text{cyc})(\text{H}_2\text{O})_2](\text{CH}_3\text{COO})_2$, which will be studied in the next task as a model compound for studying SOD (superoxide dismutase) mimetic activity.

8. SOD mimetic activity of selected cyclam complexes

The goal of the task is the synthesis of various complexes containing the cyclam molecule as a ligand and Zn(II), Cu(II), Ni(II), and Fe(II) as central ions. The prepared complexes are subsequently studied for their mimetic activity using the NBT (nitro blue tetrazolium) test through UV-VIS spectroscopy and determination and calculation of IC_{50} values.

Each of the experimental tasks consists of six parts. At the beginning of each practical exercise, the meaning, essence, and application of the prepared compound in practice are described (Theoretical introduction). The Experimental part follows, where the procedure for synthesizing the given compound, preparation of solutions, further experimental work connected with the application of the given compound, and its characterization are described in detail. Each experimental task also includes Supplementary questions related to the given issue, which are intended to expand the student's knowledge of the given topic. The Literature section summarizes the current literary sources used to complete the experimental task. In each assignment, there is also a free space called Calculations and results, which is intended for recording the necessary chemical calculations and partial results achieved, which the student will use when submitting the resulting report. From the point of view of formative assessment, at the end of each experimental task, there is a table called the Self-assessment card of the student for the given exercise (Ganajová et al., 2021; Ganajová et al., 2022). The table contains formative assessment questions related to a specific experimental task, which include the questions: I can point out ..., I know ..., I can determine ..., I can suggest ..., I can describe ..., which results in the student choosing from three possible answers: independently, with a little help from the teacher or with significant help from the teacher. An example of a formative assessment in the form of a student's self-assessment card for the experimental task: "Preparation of model receptors imitating molecules of biological importance I.: Model of the oxygen transporter" is listed in Table 1.

Table 1. Student's sample self-assessment card for the task "Preparation of model receptors imitating molecules of biological importance I.: Model of the oxygen transporter".

STUDENT'S SELF-ASSESSMENT CARD for the exercise entitled "Preparation of model receptors imitating molecules of biological importance I.: Model of the oxygen transporter"			
Name and surname:	Study group:	Date:	
Topic: Preparation of a model receptor and adsorption of oxygen			
Research activities: Respiratory pigments and their function in the organism, preparation of a model compound, and monitoring of oxygen adsorption.	independently	with a little help from the teacher	with significant help from the teacher
I can point out the importance of the presence of haemoglobin and myoglobin in the human body.			
I know the active sites of respiratory pigments and the way oxygen binds in them.			
I can determine the adsorbed amount of oxygen in the model carrier.			

I can suggest

determining the amount of different gases.

I can describe

the transport mechanisms and metabolic pathways of the gases of cellular respiration.

3. Implementation of MINT education

As already mentioned above in the text, MINT is an abbreviation of the initial letters of the words mathematics, informatics, natural sciences, and technologies, which, after consultation with experts from practice and external companies, we tried to incorporate into the practical tasks of the Advanced Practical Exercises in Inorganic Chemistry. This section presents specific examples of applying individual scientific and technical subjects.

Mathematics and Informatics: Using the graphics and mathematics program Origin or Excel, students plot and fit the measured data using different kinetic models, as shown in Fig. 1a. This is specifically the adsorption curve of oxygen by the complex [Co(salen)], which is part of the first exercise, "Preparation of model receptors imitating molecules of biological importance I.: Model of the oxygen transporter". Students also use these programs to create statistics and process measured data, for example, when determining IC_{50} values, or creating calibration curves and equations for UV-VIS measurements. Other programs that students use when developing protocols and creating answers to supplemental questions are ChemDraw or SchemSketch, and Diamond or Mercury. ChemDraw or ChemSketch programs are used to draw the course of chemical reactions (see Fig. 1b). Diamond or Mercury programs are used to draw crystal structures of compounds, where the connectivity and the connection of atoms are shown (see Fig. 1c). As an example, the supplementary questions found below:

- What is the basic structural motif found in haemoglobin and myoglobin? Draw its molecular structure using available programs (ChemDraw, ChemSketch). (1. Preparation of model receptors imitating molecules of biological importance I.: Model of the oxygen transporter)
- Using an available graphics program (Diamond, Mercury), draw the structure of the anion $SiW_{12}O_{40}^{4-}$, based on the .cif file you receive. (3. Heteropolycompounds: Preparation of tetrahydrogensilico-dodecatungstic acid heptahydrate $H_4SiW_{12}O_{40} \cdot 7H_2O$)
- Search the literature for the reaction mechanism of the reversible catalytic conversion of CO_2 and H_2O by carbonic anhydrase and show it schematically using a graphics program (ChemDraw, ChemSketch). (7. Preparation of model receptors imitating molecules of biological importance II: Template synthesis of cyclam and preparation of the complex $[Zn(cyc)(H_2O)_2](CH_3COO)_2$)
- Based on the measured SOD mimetic activity data using UV-VIS spectroscopy, calculate the IC_{50} values of the prepared complex. (8. SOD mimetic activity of selected cyclam complexes)

In addition to the mentioned graphics programs, students also use online databases. The Cambridge Crystallographic Data Center (CCDC), where all the compounds prepared so far with a determined crystal structure can be found. Students search for specific compounds in the database according to the assignment, where they perform a statistical analysis and then draw the selected compounds using the Diamond or Mercury program. The second online database that students work with is Reaxys, which contains all organic syntheses published. With the help of this database, students search for alternative ways of preparing organic molecules, which they realized in the exercise.

- Use the CCDC database to find which three transition metal ions are most commonly used to prepare complexes with the acetylacetonate ligand. Determine whether they are tris- or bis-

chelate complexes and give an example for each of the mentioned pairs, and draw it using an available graphics program (Diamond, Mercury, and others). (4. Preparation of complex compounds: Acetylacetonate complexes of transition metals)

- Using the Reaxys database, search for and design another method of synthesizing phthalocyanines and schematically represent it using a graphics program. (5. Unconventional synthetic procedures: Preparation of industrially used dyes: Phthalocyanines)
- Use the Reaxys database to search for another way to synthesize the cyclam molecule. (7. Preparation of model receptors imitating molecules of biological importance II: Template synthesis of cyclam and preparation of the complex $[Zn(cyc)(H_2O)_2](CH_3COO)_2$)

Natural sciences: Chemistry is dominantly represented in the experimental tasks from the point of view of natural sciences. Although practical exercises are mainly devoted to inorganic chemistry, there are also other areas of chemistry. We can mention physical chemistry, which is represented by adsorption processes, kinetic models (see Fig. 1a) and the principle of photodynamic therapy; organic chemistry – preparation of phthalocyanines (see Fig. 1b) and cyclam; coordination chemistry – preparation of acetylacetonate complexes (see Fig. 1c); organometallic chemistry – preparation of ferrocene; biochemistry and bioinorganic chemistry – study of SOD activity. As other natural science subjects, we can mention physics, which is dedicated to the exercise related to the preparation of $YBa_2Cu_3O_x$ superconductor and the study of the Meissner effect (see Fig. 1d). Biology is included in the above-mentioned task dealing with SOD mimetic activity of cyclam complexes, but also models of the oxygen transporter represented by the $[Co(salen)]$ complex.

Technology is applied in practical exercises in many experimental exercises. Examples include phthalocyanine dyes, which are commercially used as pigments for water tank coatings due to their antimicrobial activity and self-cleaning ability. $YBa_2Cu_3O_x$ superconductors find their application in transport, especially trains (Japan), due to the ability to levitate. In addition, we can mention magnetic resonance imaging (MRI) and magnetoencephalography for the diagnosis of various diseases, research on high-energy particles, and electrical generators and transformers. Students will also become familiar with the application of ferrocene and its derivatives as antiknock agents used in the fuel for petrol engines, which are safer than the previously used tetraethyllead. Students are also informed about the application and mechanism of ferrocene derivatives as solid rocket fuels used as high-burning rate catalysts in ammonium perchlorate-based composite propellants.

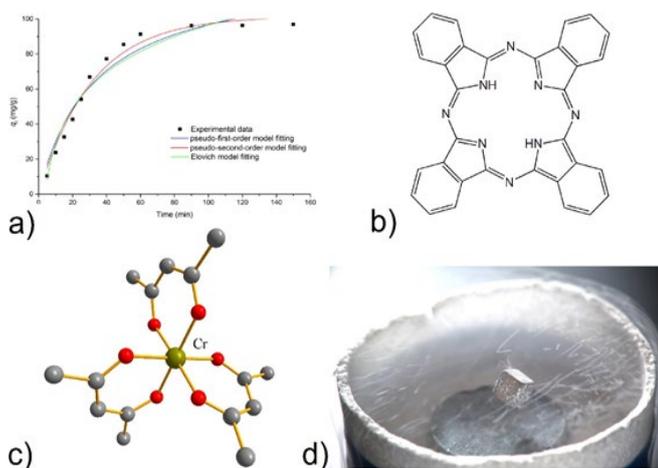


Figure 1. Demonstration examples of the MINT system application in the subject Advanced Practical Exercises in Inorganic Chemistry. a) Different kinetic models were used to fit the O_2 adsorption curve by the $[Co(salen)]$ complex. b) The figure of phthalocyanine drawn using the ChemDraw program. c) A view of the crystal structure of compound $[Cr(acac)_3]$ drawn using the Diamond program (acac - acetylacetonate). d) Demonstration of the Meissner effect using a levitating magnet above a superconductor immersed in liquid N_2 .

It is also appropriate to mention that the students themselves also participated in the creation of the tasks, who applied and developed the newly incorporated procedures. Moreover, they used learned techniques and methods in their own research, which was part of their diploma theses, resulting in publications in CC journals (Garg et al., 2021; Király et al. 2023; Zauška et al., 2022; Zauška et al. 2025; Zelenka et al., 2022; Zelenák et al., 2009).

4. Evaluation of students' self-assessment cards from the individual practical exercise's tasks

In the years 2017-2022 (6 years), a total of 37 students participated in the subject Advanced Practical Exercises in Inorganic Chemistry, representing an average number of 6 students per year. The number of students who completed the course in individual years is shown in Fig. 2a.

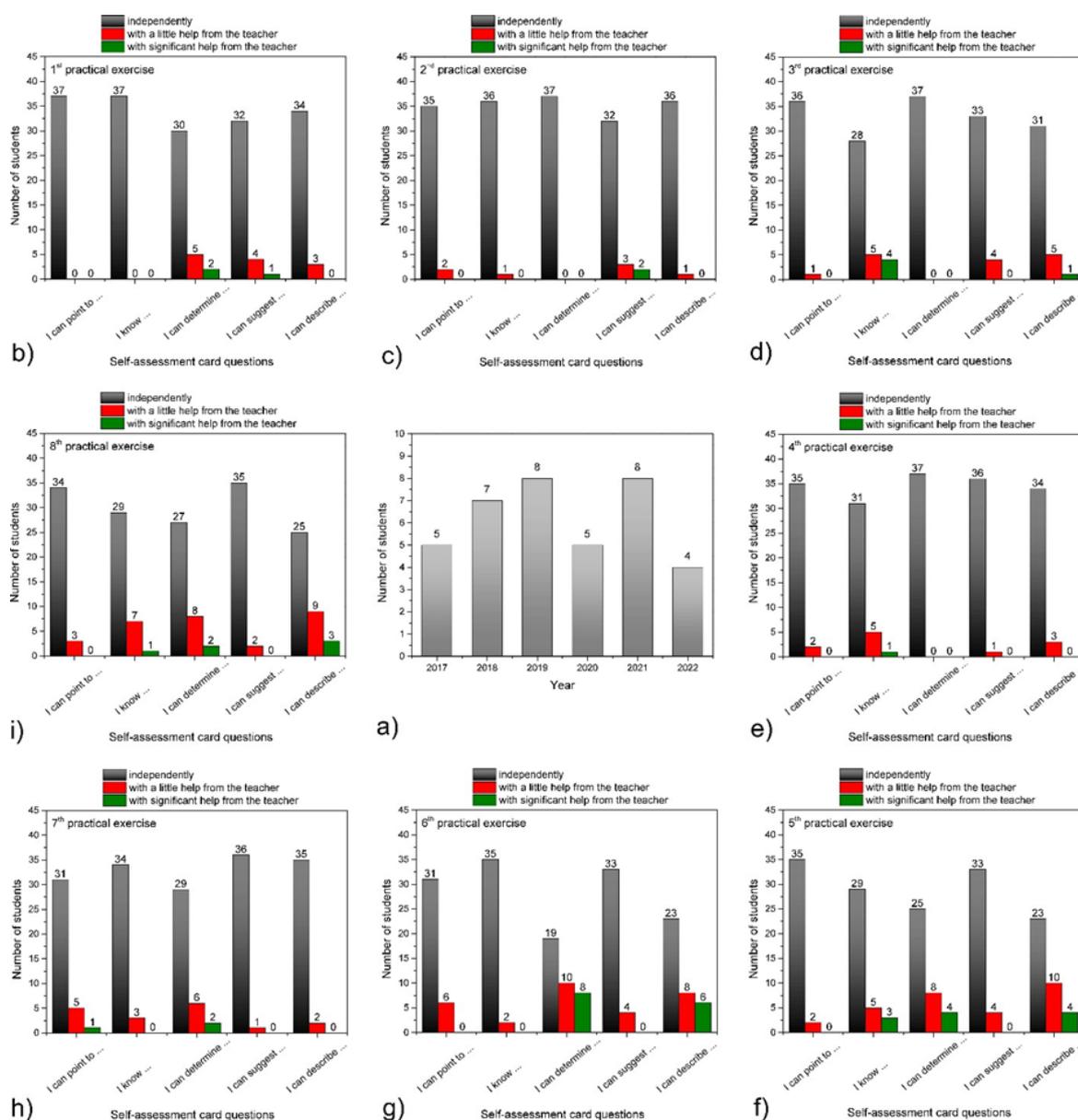


Figure 2. The students' formative self-assessment card results from the individual practical exercise's task

Figs 2b-2i show the results of students' self-assessment cards for individual experimental tasks. As shown in Figs 2b-2i, most students had no problem with the experimental tasks. Students had the most issues with practical exercises 5-8, due to the interdisciplinary nature of the tasks. The main character of task no. 5 is associated with organic chemistry, task no. 6 is physics, and exercises 7 and 8 are biology, biochemistry, and bioinorganic chemistry, with which students of inorganic chemistry do not have many practical skills. For the mentioned reason, the students had problems with the given experimental tasks. Although some questions or the essence of exercises were not apparent to the students, these deficiencies were explained and eliminated after mutual consultation and discussion between the teacher and students.

5. Overall evaluation of students in the subject

At the Pavol Jozef Šafárik University in Košice, Slovak Republic, course evaluation is based on the ECTS credit system. The study's credit system allows the student to evaluate the burden associated with passing the subject of the given program through credits, supports student mobility and provides the student with the opportunity to create his own study plan. Credits are numerical values assigned to subjects that characterize the amount of work required for their successful completion. The standard student load for the entire academic year is 60 credits, 30 credits per semester. Credit evaluation of the course Advanced Practical Exercises in Inorganic Chemistry is 6 credits, and the subject evaluation consists of four components.

1. The first condition for successful completion of the subject is active participation and implementation of all practical exercises, while each task is implemented by the student independently.
2. The output of each practical exercise is the creation of a protocol in which the student processes the given issue and the achieved experimental results. At the beginning of the protocol, the student prepares a theoretical introduction to the given task, followed by calculations and results, determination of product yield, fitting of the obtained data, creation of crystal structure figures of compounds, chemical reactions, or their mechanisms, statistics, and so on. In the end, the student summarizes the relevant results, compares them with the literature, interprets the achieved results, describes the observed phenomena, and justifies them.
3. The third part of the subject evaluation consists of creating answers to additional questions directly related to the experimental task. However, it should be noted that the supplementary questions are difficult, and when they are developed, it is necessary to use many graphic and mathematical programs, databases, and to look for answers to the questions in the scientific literature on Scopus or the Web of Science.
4. The last part of the subject evaluation is the successful completion of two written tests realized in the middle and at the end of the semester, while the final mark of the test depends on the achieved percentage evaluation: 100-91% A, 90-81% B, 80-71% C, 70-61% D, 60-51% E a 50-0% F_x.

From an ecological point of view, students do not submit protocols in printed paper form but send them by e-mail in the form of a Word file. The teacher will then read the entire protocol, and the student will receive feedback on the correctness/incorrectness of the protocol preparation. If some parts need to be supplemented, or the answer to a supplementary question is not correct or precise, the teacher will create a commentary. Subsequently, the protocol with comments is sent back to the student for addition, and communication between the student and the teacher takes place in this way until the protocol contains all the necessary data and answers.

In the end, it can be concluded that the students successfully conducted the subject, as the final evaluations of students who completed this subject in the years 2017-2022 were 100% A, 0% B, 0% C, 0% D, 0% E, and 0% F_x. During the entire existence of the subject (since 2005), 91 students graduated from this subject, while the resulting grades were 95.6% A, 4.4% B, 0% C, 0% D, 0% E,

and 0% F_x . In the final conclusion, we believe and hope that the newly implemented tasks created in cooperation with the employees of external companies will contribute to a better and easier application of students in the labour market.

6. Conclusion

This article presented a comprehensive overview of the systematic innovations introduced in the course Advanced Practical Exercises in Inorganic Chemistry, with the aim of enhancing the practical preparedness and employability of graduates. Two primary strategies were employed to achieve this objective. The first involved direct collaboration with companies from both the commercial and public sectors in the development of experimental tasks. These assignments were designed using real-world procedures applied in the participating institutions, thereby enabling students to gain hands-on experience with techniques directly transferable to professional settings. The second strategy focused on broadening students' interdisciplinary understanding through the integration of the MINT educational approach, which encompasses Mathematics, Informatics, Natural Sciences, and Technology. This framework was implemented using specialized software tools—such as Origin and Excel for data analysis, ChemSketch, ChemDraw, Diamond, and Mercury for molecular visualization—and academic databases including Scopus, Web of Science, CCDC, and Reaxys. Within the natural sciences, the curriculum emphasized chemistry, while elements of biology and physics were incorporated into specific interdisciplinary experiments. Technological applications were addressed through the practical use of synthesized compounds in relevant real-world contexts. The article also outlined the subject's assessment methodology, which includes student participation, laboratory report development, written examinations, and oral responses to subject-specific questions. A key innovation in this process was the introduction of student self-assessment cards tailored to each experimental task. These served as a formative assessment tool, providing instructors with valuable feedback on student comprehension and offering opportunities for targeted clarification and discussion. Analysis of self-assessment data collected over six academic years (2017–2022) indicates that students were generally successful in completing experimental tasks. Challenges primarily arose in interdisciplinary activities involving chemistry–physics and chemistry–biology intersections, where students' background knowledge in the secondary disciplines was less robust. Nevertheless, these gaps were effectively addressed through post-experiment discussions, as reflected in the high number of students achieving top final grades (A). Overall, the use of self-assessment cards has proven to be an effective means of fostering reflective learning and enhancing communication between students and instructors. These innovations contribute meaningfully to aligning chemical education with the practical expectations of the labour market.

Acknowledgments

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References

- Almáši, M., Vargová, Z., Oriňáková, R., Ganajová, M., Serbin, R., Varháč, R., & Dinajová, J. (2020b). The innovation of laboratory practices in cooperation with industrial companies. *DidSci2020 – 8th International Conference on Research in Didactics of the Sciences, Book of Abstracts*, pp. 66, 2020, June 17-19, Pedagogical University of Cracow, Cracow, Poland.
- Almáši, M., Vargová, Z., Oriňáková, R., Serbin, R., Varháč, R., Ganajová, M., & Dinajová, J. (2019). Innovation of laboratory practices for bachelor students in cooperation with industrial companies. *15.*

- Europäischer Chemielehrer/innenkongress, Book of Abstracts*, pp. 15, 2019, April 24-27, Technical University of Wien, Wien, Austria.
- Almáši, M., Vargová, Z., Zeleňák, V., & Ganajová, M. (2017). *Pokročilé praktikum z anorganickej, bioanorganickej a koordinačnej chémie* [Advanced practical exercises in inorganic, bioinorganic and coordination chemistry]. Univerzita Pavla Jozefa Šafárika v Košiciach.
- Cohen, R., & Kelly, A. M. (2019). Community college chemistry coursetaking and STEM academic persistence. *J. Chem. Educat.*, 96(1), 3-11. <https://doi.org/10.1021/acs.jchemed.8b00586>
- Ganajová, M., Sotaková, I., Lukáč, S., Ješková, Z., Jurková, V., & Orosova, R. (2021). Formative assessment as a tool to enhance the development of inquiry skills in science education. *J. Baltic Sci. Educat.*, 20(2), 204-222. <https://doi.org/10.33225/jbse/21.20.204>
- Ganajová, M., Guniš, J., Ješková, Z., Kireš, M., Laufková, V., Lešková, A., Lukáč, S., Orosová, R., Sotaková, I., Szarka, K., & Šnajder, Ľ. (2022). *Formatívne hodnotenie a jeho implementácia do výučby prírodných vied, matematiky a informatiky* [Formative assessment and its implementation into teaching science, mathematics, and informatics] (pp. 97–102). Wolters Kluwer.
- Garg, A., Almáši, M., Paul, D. R., Poonia, E., Luthra, J. R., & Sharma, A. (2021). Metal-Organic Framework MOF-76(Nd): Synthesis, characterization, and study of hydrogen storage and humidity sensing. *Front. Energy Res.*, 8, 604735. <https://doi.org/10.3389/fenrg.2020.604735>
- Jirát, J., Čech, P., Znamenáček, J., Šimek, M., Škuta, C., Vaněk, T., Dibuszová, E., Nič, M., & Svozil, D. (2013). Developing and implementing a combined chemistry and informatics curriculum for undergraduate and graduate students in the Czech Republic. *J. Chem. Educat.*, 90(3), 315-319. <https://doi.org/10.1021/ed3001446>
- Király, N., Capková, D., Gyepes, R., Vargová, N., Kazda, T., Bednarčík, J., Yudina, D., Zelenka, T., Čudek, P., Zeleňák, V., Sharma, A., Meynen, V., Hornebecq, V., Fedorková, A. S., & Almáši, M. (2023). Sr(II) and Ba(II) alkaline earth metal-organic frameworks (AE-MOFs) for selective gas adsorption, energy storage, and environmental application. *Nanomater.*, 13(2), 234. <https://doi.org/10.3390/nano13020234>
- Řezanka, P., Šimůnek, O., Zajícová, M., Míka, L., Bartoň, J., & Řezanka, M. (2013). Fast and Attractive Chemical Education: A chemical competition for high school students in the Czech Republic. *J. of Chem. Educat.*, 90(10), 1259–1262. <https://doi.org/10.1021/ed300882z>
- Vargová, Z., Almáši, M., Oriňáková, R., Serbin, R., Varhač, R., Ganajová, M., Dinajová, J., Chovan, P., Dzura, M., & Bova, Š. (2020). Direct participation of experts from companies and institutions in chemical laboratory practices. *DidSci2020 – 8th International Conference on Research in Didactics of the Sciences, Book of Abstracts*, pp. 66, 2020, June 17-19, Pedagogical University of Cracow, Cracow, Poland.
- Vargová, Z., Almáši, M., Rendošová, M., Oriňáková, R., Hamuláková, S., Varhač, R., Víglašký, V., Šandrejová, J., Ganajová, M. (2021). The social demand of the professionally focused study program „Chemical laboratory technician - specialist“. *New trends in chemistry, research and education at the Faculty of Science of Pavol Jozef Šafárik University in Košice 2021, Book of Abstracts*, pp. 54, 2021, November 26, Pavol Jozef Šafárik University in Košice, Košice, Slovak Republic.
- Vargová, Z., Oriňáková, R., Almáši, M., Serbin, R., Varhač, R., Ganajová, M., & Dinajová, J. (2019). Chemical laboratory practices innovation with direct cooperation of potential employer. *15. Europäischer Chemielehrer/innenkongress, Book of Abstracts*, pp. 86, 2019, April 24-27, Technical University of Wien, Wien, Austria.
- Zauška, L., Beňová, E., Urbanová, M., Brus, J., Zeleňák, V., Hornebecq, V., & Almáši, M. (2022). Adsorption and release properties of drug delivery system Naproxen-SBA-15: Effect of surface polarity, sodium/acid drug form and pH. *J. Funct. Biomater.*, 13(4), 275. <https://doi.org/10.3390/jfb13040275>
- Zauška, L., Pillárová, P., Volavka, D., Kinnertová, E., Bednarčík, J., Brus, J., Hornebecq, V., & Almáši, M. (2025). Kinetic adsorption mechanism of cobalt(II) ions and Congo red on pristine and Schiff base-surface-modified MIL-101(Fe)-NH₂. *Microp. Mesop. Mater.*, 386, 113493. <https://doi.org/10.1016/j.micromeso.2025.113493>
- Zelenka, T., Simanova, K., Saini, R., Zelenkova, G., Nehra, S. P., Sharma, A., & Almasi, M. (2022). Carbon dioxide and hydrogen adsorption study on surface-modified HKUST-1 with diamine/triamine. *Sci. Rep.*, 12(1), 17366. <https://doi.org/10.1038/s41598-022-22273-2>
- Zeleňák, V., Vargová, Z., Almáši, M., Zeleňáková, A., & Kuchár, J. (2009). Layer-pillared zinc(II) metal-organic framework built from 4,4'-azo(bis)pyridine and 1,4-BDC. *Microp. Mesop. Mater.*, 129(3), 354–359. <https://doi.org/10.1016/j.micromeso.2009.11.002>

Discussing a Study Involving Participants of the Chemistry Olympics: Forty Years Later

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Abstract. Creativity in students has once again become a hot topic among researchers and education professionals. The main reason for this renewed interest is the PISA 2021 framework for testing, which took place in the spring of 2022 due to the pandemic. The testing consisted of a series of tasks, which assessed pupils' creativity as well as other, more traditional areas of testing. For this reason, we dusted off our research and experience from almost 40 years ago and prepared one task, which was subsequently accepted in the pilot testing. At Comenius University in Trnava and Bratislava, I and my colleagues Liphay and Prokša carried out research into creativity during chemistry lessons in the 1980s. We later began studying other matters. When we reviewed a study that we carried out at the regional level of the chemistry Olympics (Category A), we realized that some of the participants' details were incomplete. For this reason, we tried to find and establish contact with the individual participants. Using the internet alone, we managed to identify almost half of the participants and map their professional careers. Using the original data from the Torrance Tests of Creative Thinking, as well as the participants' career data over a period of 40 years, we analyzed the predictive validity of these tests. As case reports, we also present the careers of the two participants of the study who achieved the highest scores in the tests.

1. Introduction

In the current literature, various aspects of creativity in students have been discussed at length. The roots of modern research into this matter go back to 1950, when Guilford introduced the concept of creative (divergent) thinking (Guilford, 1950).

Recent creativity research has focused on process versus product, as well as on generality in creativity versus focus on a particular domain of activity. Current theories of creativity emphasize complexity or multi-component approaches. One separate area of research concerns the role of schools in strengthening creativity. In this regard, the following questions are often asked: What makes it possible to express creative thinking in the classroom? How can we record and support the creative activity of students in the classroom? (OECD, 2019).

The current paper does not provide a comprehensive overview of the current creativity research. Those interested in this issue should peruse any of the recent encyclopedic works in this area (e.g., Runco, 2019).

The main rationale for the present study was the PISA 2021 framework for testing, which took place in the spring of 2022 due to the pandemic. The testing consisted of a series of tasks, which assessed pupils' creativity as well as other, more traditional areas of testing. We were approached by the national coordinator of the testing to create a task that could be used to identify creativity levels.

For this reason, we dusted off our research and experience from more than 40 years ago (Kováč et al., 1984) and prepared one task for this purpose, which was subsequently accepted in the pilot testing. When we reviewed a study that we carried out at the regional level of the chemistry Olympics (Category A), we realized that some of the participants' personal details were incomplete. For this reason, we tried to find and establish contact with the individual participants. Using the internet alone, we managed to identify almost half of the participants and map their professional careers. Using the original data from

the Torrance Tests of Creative Thinking, as well as the participants' career data over a period of 40 years, we analyzed the predictive validity of these tests.

2. Research carried out 40 years ago

We applied Guilford's approach to chemistry instruction. In our research work, we developed and used an analogy between divergent thinking as a characteristic of the creative personality and divergent possibilities in synthetic organic chemistry.

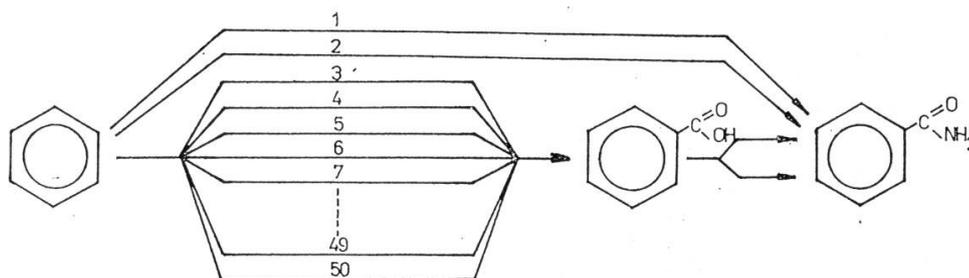


Figure 1. Schematic showing the synthesis of benzamide from benzene.

Our approach is well illustrated by the synthesis of benzamide from benzene, which can be accomplished in at least ten different ways. Figure 1 shows the flexibility of the synthetic approach, which can be accomplished using routes described in nearly any standard university textbook of introductory organic chemistry. We therefore hypothesized that, if the task is set in an appropriate way, divergent thinking in creative students will manifest as the ability to suggest many different and original solutions. We verified this premise by comparing the results of the divergent task test with those of the chemical Olympics, which is a competition organized for talented pupils. In our empirical investigations, we have also assigned tasks such as: Give as many reactions as you can for the following compound:



During the 1981/82 school year, we presented the following tasks to 22 participants in a district competition of the highest grammar school category: a test of organic chemistry knowledge, an intelligence test, and the Torrance Tests of Creative Thinking (Hlavsa & Jurčová, 1987). The results of the test with divergent tasks were rated as follows:

1. We discarded answers, suggestions, and reactions that were not founded on objective (scientifically correct) presumptions. For example, we cannot presume that hydrogen has been substituted by bromine on double bonded carbon if we have not used HBr under standard conditions. When HBr was used, bromine was added to the unsaturated bond.
2. Suggestions based on true presumptions were rated like this:

Fluency	1 point for each new suggestion
Flexibility	1 point for each different suggestion (e.g., addition of HCl), (addition of HBr or HI to the unsaturated bond was considered a related suggestion)
Originality	1–3 points for original answers in which the degree of originality was estimated based on the statistical occurrence of a given reaction within the set of all answers (up to 5%)
Elaboration	was evaluated from 0 to 1 according to the accuracy of the suggestion (i.e., referring to catalysts, etc.)

The test of knowledge consisted of 14 traditional tasks in which the pupils were expected to find the reaction product of a prescribed reactant and reagent. These knowledge tasks were connected with testing creative thinking in chemistry. To this end, they involved the reactions of double bonds and hydroxyl groups covered in the grammar school chemistry curriculum.

In addition to our research, three standard psychological assessments were applied: an intelligence test (Vana, VIT) and the Torrance Tests of Creative Thinking, which assess consequences, unusual usage of things, and improvement.

The data obtained from this research were subjected to statistical analyses that disclosed dependencies between certain variables. These mutual relations, expressed by the Pearson coefficient of correlation, are presented in Table 1.

Table 1. Relationship between pupil success in the chemistry Olympics and results in the test.

		Pearson's correlation coefficient
test of intelligence by Vana	results achieved in the chemistry Olympics	0.46 ⁺
Torrance Tests of Creative Thinking	results achieved in the chemistry Olympics	0.04
test of knowledge	results achieved in the chemistry Olympics	0,31
test of creative thinking in chemistry	results achieved in the chemistry Olympics	0,71 ⁺⁺⁺

+p < 0.05, +++..... p < 0.001

According to Table 1, two statistically significant correlations were obtained. These were:

1. Performance on the intelligence task correlated with results in the chemistry Olympics (at the 5% level).
2. Performance on the test of creative thinking in chemistry correlated with results in the chemistry Olympics (at the 0,1% level).

The tests (test of creative thinking in chemistry and test of knowledge) covered the same content, but the methods of task solution and evaluation differed. The results suggest that a test of creativity may be predictive of results in the chemistry Olympics.

3. Our respondents 40 years later

When we returned to the matter of creativity in chemistry class 40 years later, we realized that some of the participants' personal details were incomplete. We found one sheet of paper with the respondents' names and data on fluency and flexibility from the Torrance Tests of Creativity (tests of consequences, unusual use of things, and improvement) (Hlavsa & Jurčová, 1978). Based on this information, we tried to find and establish contact with the individual participants. Using only the internet, we managed to identify some of the participants and map their professional careers. Five of our participants were academic or scientific workers employed at universities, while four were either doctors or veterinarians. All of them agreed to be interviewed. We believe that this cross-section of the sample was relevant to the conclusions we were trying to draw from the original data fragments.

From a methodological perspective, this study could be characterized as behavioral research with a longitudinal element. We used data that measured fluency and flexibility of thought, as well as details from the Web of Science database about the number of publications and citations. In addition, we present below two case studies describing the careers of the respondents with the greatest creative potential (fluency and flexibility) measured 40 years ago. Pearson's rank coefficient of correlation in Excel was used for statistical evaluation.

3.1 Publications of the academic workers in our research

In this part of the study, we used the online Web of Science database. For clarity, we have presented the results of our participants' research in the table below. We subjected individual research areas to detailed analysis using Pearson's coefficient of correlation. Among the participants who were still employed in academia (only chemistry), the number of publications was highly correlated ($r = 0.96$) with creative (divergent) thinking, fluency, and flexibility determined 40 years ago. Similarly, the number of citations was highly correlated with fluency and flexibility ($r = 0.92$). On the other hand, the participants' specific research areas were not all comparable: one of the five respondents published in the humanities, while the others worked in chemistry.

Table 2. An overview of the data from the Web of Science database, as well as the participants' creativity, was measured using the Torrance Tests of Creativity 40 years ago.

Respondent	Publications	Citations	Creativity
1	14 (biblical studies)	16	70
2	122 (chemistry)	2888	117
3	46 (chemistry)	385	56
4	34 (chemistry)	617	44
5	30 (chemistry)	371	15

3.2 Career stories

In this part of the paper, we present two anonymous cases of successful academic careers from our sample (Melicheríková, 2020). Both professors scored highest in fluency and flexibility within our sample from 40 years ago.

prof. RNDr. B. J., DrSc.

Professor B. J. was already interested in chemistry during his studies, and he enjoyed taking part in the Olympics. His friend joined him there, and they enjoyed each other's company. They took part in Olympic events several times during their high school studies. Because he was interested in chemistry for its own sake, he never undertook any special preparation for the Olympics – he carried out minimal preparation with his chemistry teacher for the events. Instead, he read material about chemistry on his own initiative. He spent time with his friend in their laboratory, where they manufactured explosive materials and spent time in similar activities.

In his final year of school, he was deciding between two Slovak universities that focused on chemical sciences: the Faculty of Chemical Technology and the Faculty of Biology. In the end, he chose to attend the Faculty of Biology. At high school, he never considered himself a good student; instead, he saw himself as a pupil who maintained a high level of freedom. He never understood why he should learn about the 12 drainage basins of Slovakia or why he should remember them going forward. At university, it was better, in his words; he felt at home. He believes that anyone who tries just a little will manage university and that there is no specific instruction book for getting through. During his studies, he relaxed by playing popular sports recreationally and spending time with friends. After high school graduation, he registered for full-time study at the university and remained as a doctoral student.

In the following years, he worked at the Slovak Academy of Sciences, although he is now employed once more at the Faculty of Biology. He has also studied abroad for several months at a time; his longest program of study abroad took place in America, where he lived for 18 months. Professor B. J. feels that he has advanced thanks to his career experiences. He did not plan this career; instead, his professional course unfolded gradually. In his opinion, anyone who is qualified for similar positions will gradually achieve them.

He applies his creativity in his experimental work, which works completely differently from how he imagined. Creativity is necessary when searching for reasons why an experiment has turned out other

than expected: Was the experiment badly designed or executed? Was the student who carried out the experiment irresponsible? The work itself sharpens B. J.'s creativity; he requires no special training.

prof. Ing. D. P., ThD.

Professor D. P. was convinced by his chemistry teacher to take part in the chemistry Olympics. In his own words, the teacher knew how to inspire her students, and chemistry itself was interesting to D. P., so he enjoyed attending the Olympics. Since professor D. P. enjoyed chemistry, he had a small private laboratory at home. He also enjoyed collecting and borrowing books about chemistry. He even discovered later that some of them were his university textbooks. Later, the chemistry teacher helped her Olympians to choose a university: she organized visits to university institutions, where her pupils gained some inside information about how these facilities worked and were therefore better able to choose their future direction of study.

Because D. P. had poor social credit in the communist regime, he was unable to study at the Biology Faculty of Comenius University. For this reason, he chose to study at the similarly focused Faculty of Chemical Technology. He completed his studies with first-class honors. He carried out further study after working for several years at the Oncological Institute of the Slovak Academy of Sciences, where he worked with innovative equipment and with specimens from all over socialist Europe. Afterwards, he undertook a 2-year program at the Theological Faculty. He then went to the Bible Institute in Rome for 5 years and finally to Harvard University, where he carried out a doctoral study for 6 more years. At Harvard, he was one of only two successful candidates out of 120 who underwent the selection process.

Afterwards, he became dean of the Pontificio Istituto Biblico at Pope Gregory University in Rome.

Because he had completed study at Harvard University, he had privileged access to the best institutions, so he established contact with many respected universities in his field. He spearheaded the organization of worldwide conferences, with many of the world's leading experts in biblical studies among the delegates.

4. Discussion

We realize that these empirical results are minuscule compared to the kinds of studies that are regularly carried out nowadays. Unfortunately, many of the original details were missing, so we could not describe, prove, and interpret the experiments any better than in their published versions (Kováč et al., 1984). The present study showed that we had managed to devise a simple test of divergent thinking in chemistry-related tasks. These tests predicted well the results of the chemistry Olympics, which we considered at the time to represent a performance in chemistry that was high above average school performance. Notably, the results of the Torrance Tests of Creative Thinking did not seem relevant in identifying exceptional results in the competition.

However, when, by chance, we discovered the Torrance Test data of 22 students, we were able to look at the relevance of these results after more than 40 years. From this perspective, the results of the tests seemed extremely interesting; they appeared to correlate with the success of the subjects' scientific careers. Of course, we must note that our sample of students only consisted of those who were strongly motivated towards the study of chemistry – most scientific workers carried out home-made experiments during childhood and had well-equipped laboratories at home. The participants stated that they never achieved exceptional results in the chemistry Olympics, although we cannot prove this, as we have no access to the results of the competitions themselves.

The group of doctors and veterinarians, whose results we did not present in the present paper, saw the competition as an opportunity to prepare for future medical study. Our results contribute to the discussion about the advantages of creativity over domain specificity. We suggest that, within the limits of the sample, which was heavily skewed towards one field, general tests of creativity may have significant predictive potential. We also submit that creative processes may be correlated with creative

output. The results of the creative tasks in the Torrance Tests were significantly correlated with the results of creative scientific work. At this stage, we consider our conclusions and interpretations as merely well-founded hypotheses since the original data were so sparse. Our findings should be compared with other results. Nonetheless, we believe that publishing these results may inspire and serve other researchers in this area.

5. Conclusion

Creativity in natural science pedagogy, which we researched in the 1980s, is once again at the forefront of discourse after almost half a century, as can be seen in the PISA framework from 2022. The original results of the research from 40 years ago, as well as the recent statements and data of the respondents, suggest that the general tests of creativity in tasks at the beginning of an academic career correlate well with the success of creative scientific research at the end of a professional career, within the narrow limits of the sample, which represented only one field.

The two respondents with the highest scores achieved excellent results in their scientific careers. Their stories are described above. We believe that even our incomplete details will serve and inspire other researchers in this area.

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References

- Hlavsa, J., & Jurčová, M. (1987). *Psychologické metódy zisťovania tvorivosti* [Psychological methods of determining creativity]. *Psychodiagnostické a didaktické testy*.
- Guilford, J. P. (1950). Creativity. *American Psychologist*, 5, 444-454.
- Kováč, T., Held, L., & Liphay, T. (1984). Tvorivé myslenie žiakov pri vyučovaní chémie [Creative thinking of pupils at chemistry lessons]. *Psychológia a Patopsychológia Dieťaťa*, 19(6), 553-560.
- Runco, M., A., & Pritzker, S., R. (Eds.). (2019). *Encyclopedia of creativity* (3rd ed.). Elsevier.
- Melicheríková, S. (2020). *Chemickí olympionici po štyridsiatich rokoch / Chemical Olympians after forty years* [Diploma thesis, Trnava University in Trnava].
- OECD. (2019). *PISA 2021 Creative thinking framework third draft*. OECD. <https://www.oecd.org/pisa/publications/PISA-2021-creative-thinking-framework.pdf>

Reform of Pregraduate Preparation of Teachers

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Abstract. The primary purpose of the current reform of pregraduate preparation of teachers in the Czech Republic is to prepare future teachers for educating students in accordance with the objectives of the Strategy 2030+. Basically, this means providing students with such competencies that will enable them to use their full potential in the dynamically changing world, both for their benefit and the benefit of society. Objectives of the long-term conception of education of students are, of course, the need to adapt the system of pregraduate preparation of teachers. The submitted paper presents not only the main areas of the reform of the education of teachers in general, but it also states particular aspects of teachers' preparation at the University of Ostrava. It also includes current innovations and proposals for considering the main objectives of the reform in the future.

1. Introduction

The world is constantly changing. These changes must be reflected in all areas of human activity – the educational system included. Partial changes in education are continuous, and certain major conception changes are prepared and implemented irregularly. A proposal for such a change in conception is also part of the Strategy 2030+ of the Czech Republic.

2. Conception of education according to the strategy 2030+

2.1 Strategy 2030+

Strategy 2030+ (Ministerstvo školství, mládeže a tělovýchovy / Ministry of Education, Youth and Sports of the Czech Republic, MŠMT in Czech, 2020) is heading towards creating and developing an educational system that reacts to the changing external environment and provides relevant educational content from a lifelong perspective. Its objective is to modernise education so that both children and adults can stand the dynamic and constantly changing world of the 21st century.

In this respect, the organisation and way of education require a change since they still reflect the needs of the past rather than the future. The strategy objectives (i.e., to develop the educational system to provide knowledge, skills, and opinions usable in personal, civil, and professional life) must govern the content, methods, and forms of education. In addition, the educational institutions must create such an environment that would be safe, fair, inspiring, and challenging enough for everyone.

2.2 Reform of teachers' preparation

The reform of teachers' preparation has been prepared within the implementation of the Strategy 2030+ and the Strategic Plan for Higher Education since 2021.

Regarding the preparation of the reform of teachers' preparation, the systems of teachers' preparation in various countries have been analysed. The reform also takes grounds in existing documents devoted to the pregraduate preparation of teachers in the Czech Republic (Janík, 2005; MŠMT, 2004, 2021).

The data analysis revealed 6 primary opportunities to improve the pregraduate preparation (MSMT, 2021):

- 1. A missing vision of teachers' preparation objective, mistrust between the main stakeholders (Faculties-MEYS) and the lack of information on the quality of the graduates.** To deal with the quality of teachers' preparation, there must be a clear idea of their competencies. These have not been specified yet. Current mechanisms of the quality check of the teachers' preparation primarily focus on inputs (approval of accreditations); there are no mechanisms at the level of the MEYS which would deal with outputs (quality of the provision of the teachers' preparation). A lot of information states that Czech graduates of teacher's studies fundamentally lag behind their European colleagues, primarily in the area of motivation to study and guiding students to critical thinking.
- 2. Insufficient interconnection with the practice.** The extent of practice in the pregraduate preparation of teachers in the Czech Republic. It has increased in recent years, yet still belongs to the lowest among the analysed European countries. The critical indicator cannot be a mere length of the practice but primarily the quality and related conditions: senior active teachers are not remunerated adequately, they do not have sufficient support for their education in this role, and the practice is not concentrated at the best teachers. Although the Faculties have quite a wide range of faculty schools, but the intensity of the cooperation and the engagement of senior active teachers with active experience at lower grades of schools in the teachers' preparation is insufficient.
- 3. Little room for innovations in studies.** Although framework requirements of the MEYS guarantee minimum standards of the structure of teachers' preparation, they significantly limit the room for innovations – for example, for a more significant increase of the practice or conceptions of programmes with a qualification in the area of education in framework educational programmes (e.g. Man and Nature) instead of specialisation combination.
- 4. Room for the Faculties to be more open.** Faculties of Education employ a minimum of foreign academic employees. There is a huge opportunity to share good practices.
- 5. An opportunity to admit – 1-2 thousand applicants for study with good prerequisites and interest in learning.** The preparation of quality teachers depends on two fundamental factors: the first being the quality of the preparation, the second being the motivation and personal dispositions of the applicants for study.
- 6. Insufficient information on the capacities of the system, primarily in the field of didactics.**

All of the above-listed opportunities must be used so that the pregraduate preparation of teachers could be improved. In our paper, we will focus only on one opportunity – to improve the interconnection of the pregraduate preparation with the practice. The meaning of the pedagogical practice is derived from the statement that “practical execution of an activity results in the acquisition of experience, therefore, in the improvement of the activity.” (Solfronk, 2003).

Regarding the interconnection of the preparation and practice, the Czech Republic is close to the so-called “Scandinavian model” (see Fig. 1), which consists in a relatively small extent of the practice, but emphasises the quality of the practice and its quality.

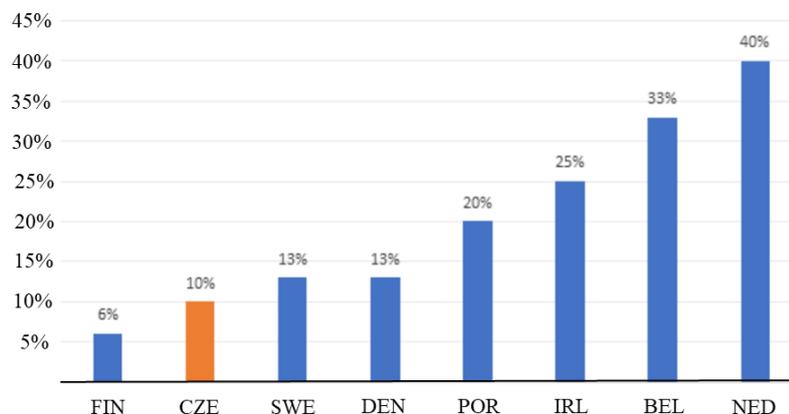


Figure 1. Minimum ratio of practice in the study of Teaching for the lower secondary schools in the Czech Republic and selected European countries (MŠMT, 2021).

In this context, the practice must concentrate in a network of faculty and clinical school and at teachers identified as the best for supervision. They must be adequately remunerated for this activity. They should participate in the output training and acquire suitable mentoring support from field didacticians and heads of practices at the faculty level.

Apart from practice, there are also other opportunities for personal interconnection with the practice, primarily engagement of active teachers and other experts outside the academic area in teachers' preparation.

3. Clinical school and its role in teachers' education

The need to provide future teachers with both theoretical and practical preparation was the driving idea of interconnecting a school preparing future teachers with the place of their future execution of their pedagogical practice. This role has been fulfilled by training and faculty schools.

However, we cannot interchange a faculty school with a clinical school, even though students perform their pedagogical practice there. The difference between a faculty and clinical school is that a faculty school concludes an agreement of cooperation, or a partnership agreement, with the faculty of education (or any other) preparing teachers. Apart from this agreement, faculty schools are not interconnected with the faculty that prepares teachers in any way (organisation, premises, staff, or economic and legislative issues). This is not the case of a clinical school. A clinical school is a primary or secondary school whose institutor is an institution preparing future teachers. In an ideal case, a clinical school is an environment to develop pedagogical experience, transfer scientific findings into the school practice, and cooperate with students of teaching, teachers of the clinical school, teachers of future teachers, and researchers. A clinical school is then understood as a primary or secondary school established for the purposes of students of teaching, i.e., future teachers (Bendl et al., 2011).

Of course, there are many organisational variants of the interconnection of a primary and secondary school with the faculty preparing teachers. These variants differ, for example, in the level of freedom of engaging teachers from clinical schools in teaching at the faculty level, the level of engagement in scientific and research activities, etc.

An important role of clinical schools in teachers' education is specified in the reform of teachers' preparation, namely in the area of the main objectives of the reform development and measures to achieve them by 2024.

It concerns the specification of the following objectives (Bendl et al., 2011):

1. Faculties cooperate with a network of faculty and clinical schools at several levels:
 - a. They conduct research there and pilot new didactic methods and materials.
 - b. Directors and teachers of these schools participate in decision making on the

curriculum of teachers' preparation.

2. Effective interconnection of the faculties and practice requires fulfillment of the following factors:
 - a. Most students' practice is conducted at the faculty and clinical school.
 - b. The teacher reflects on each lesson taught by the student.
 - c. Ongoing and continuous practices are conducted under the supervision of teachers who have participated in the output education of the faculty. The teachers then receive support from the faculty for their activities.
 - d. A significant part of the teachers at the faculty and clinical schools is involved in teaching at the faculty.
 - e. Most teachers at the faculty, primarily dealing with teachers' preparation, are also senior active teachers.

4. Activities strengthening the interconnection of the pregraduate preparation of teachers with the practice

As it was already mentioned in Chapter 2, our paper is going to focus on activities oriented on the improvement of the interconnection of the pregraduate studies with the practice. We will present activities that are already being implemented as well as those planned.

4.1 Extent of pedagogical practice and its quality

As stated in (MŠMT, 2021), despite the fact that the extent of pedagogical practice has increased in the Czech Republic in recent years, it belongs to the lowest among the European countries. According to the framework requirements of the MEYS (MŠMT, 2017), the practical part (i.e. supervised and reflected hearing, ongoing, and continuous practice) in degree programmes for teachers of lower secondary and secondary schools must constitute 8-10 % of the overall preparation, which corresponds with 24-30 credits. Under the assumption of a 30-hour workload per 1 ECTS credit, corresponding with 720-900 hours. All Faculties of the University of Ostrava, preparing future teachers of secondary schools, award 24 credits for the practice. Before the institutional accreditation was awarded, the Faculty of Science, University of Ostrava, had been exceptional for having extra two weeks of continuous practice for each specialisation compared with other fields of study. However, the length has been unified to five weeks, and the students might extend it with the guarantor's consent. Therefore, there is room for discussion about the possibilities of an increase. However, this might happen within future accreditation. Therefore, we have decided to offer the students so-called supplementary pedagogical practice.

It concerns an optional system of pedagogical practice when a student can take advantage of a wide range of additional activities, ranging from observation and analysis of hearings in related specialisation subjects, observation and active participation in other school and after-school activities, to individual daily practice in the form of "A day with a teacher in a school", when a student spends a day/more days with a teacher, takes part in all activities of the teacher, and discusses the activities with the teacher. The choice of activities is primarily bound with the degree programme type and the year of the student's studies, i.e., the connection with the student's previous experience with the pedagogical practice.

Although such practices are not obligatory (the student will not get any credits) and the school instruction was restricted due to the pandemic in 2020 and 2021, the practices were attended by 74 students (sometimes repeatedly) and actively joined by 34 teachers of secondary and primary schools. Since the organisation of these practices is time-consuming with such a large number of students and teachers, students of informatics created a booking system as their Annual project. This system enables the teachers to register and insert offers for this additional practice, and students can select and book them. It also provided room for evaluation of these practices by both sides.

However, the extent of the practice itself is not the only essential indicator of a sufficient interconnection of the studies with the practice. We are sure that quality practice requires the reflection of all stakeholders, i.e., students (future teachers), senior active teachers, and field didacticians. Therefore,

we engaged senior active teachers (which relates to their higher remuneration) in the preparation, implementation, and reflection of ongoing pedagogical practice. We also created a detailed, structured electronic questionnaire that serves as a self-evaluating and evaluating tool for a detailed reflection. The e-reflective questionnaires had more variants (preparation for a lesson, self-reflection of the lesson, reflection of the lesson in face-to-face/online form, self-reflection of audio-visual recording) which took into consideration the needs of individual stakeholders involved in the practice reflection (Václavíková, 2019; Václavíková et al., 2022; Václavíková et al., to appear). In 2021, we received almost 300 e-reflective questionnaires in various variants.

If the self-reflection and reflection of teaching are to be of high quality, a good evaluation tool is not enough. A deep analysis of the quality must be carried out. Therefore, we also focused on acquiring audio-visual recordings of lessons, which is a huge benefit for such an analysis. A database of these recordings also helped us implement practices during the school closure.

4.2 Involvement of teachers from practice into teaching

The objective of another activity was to involve experienced teachers from practice in the preparation of future teachers as much as possible. The participation of these teachers from practice in the education of future teachers can be of various forms, ranging from seminars and lectures to workshops, excursions, etc. The objective is mainly to share good practices, the development of pedagogical competencies of future teachers, and the higher use of interactive and activation teaching methods.

In 2020, there were 22 actively engaged teachers and other experts outside the academic area. In 2021, it was 26. In total, they participated in 55 educational activities. For interest, there are some of the topics:

- Development of computational thinking in the context of the upcoming changes to the Framework Educational Programme.
- Modern trends in teaching programming at secondary schools supporting independence from a specific programming language.
- Experiences with online teaching in primary schools.
- The function of the textbook and experience with its creation.
- A teacher-beginner from the perspective of school management.
- Working with pupils with support measures, the role of the teaching assistant and the educational advisor, and the pedagogical support plan.
- Teaching science to gifted pupils.
- How to work with film.
- Media education.
- Occupational safety in teaching chemistry.
- Management of the heterogeneous classroom and communication with parents.
- Teaching in a Waldorf school.
- Teaching science subjects in the context of the findings of neuropedagogy and neuropsychology.
- The use of GeoGebra for teaching mathematics in secondary schools.
- Problems in *maturita* (*secondary-school leaving*) tests and entrance examinations.
- Financial mathematics.
- Mathematics in biology.
- Motivation in teaching mathematics to older pupils in secondary schools.

4.3 Cooperation with schools and teachers in the area of research and creative activities

An inseparable part of the close interconnection with the practice is the cooperation within creative activities and mutual participation in the implementation of research activities. This cooperation is sought by both sides. A school is a platform to implement action research aiming at identifying a place to improve education. It is also necessary for the acquisition of feedback on the quality of the pregraduate

preparation of teachers, both in the implementation of reflective pedagogical practice and in the evaluation of the integration of new graduates (teachers) into individual processes at the corresponding school.

On the other hand, a university can (and should) provide primary and secondary schools with the transfer of new trends, methodologies, or directions stemming from current research results in education. Those should be reflected both in the preparation of future teachers and in the offer of lifelong learning courses for teachers.

Finally, yet importantly, research activities might be performed directly in the school. This brings along a synergic effect when a pair of teacher-academic or a triplet teacher-future teacher-academic create a team that conducts research on a given area of teaching processes, evaluates them, and implements the results into the educational process in order to increase its quality.

Cooperating with teachers of primary and secondary schools, we created our first case reports (Konečná & Vavroš, 2017; Kričfaluši et al., 2017), others are being intensively worked on. We also carried out a survey on the quality of the preparation of future teachers (Konečná, 2012). Surveys are usually linked to specific periods related to the current concept of pregraduate teacher training, its evaluation, and the proposal of adjustments to the concept. As we had to accredit all existing programmes preparing future teachers according to the new rules in the period 2016-2018, the first students who have completed the entire teachers' preparation (i.e., Bachelor's and consecutive Master's programmes) under the new concept will graduate in 2024. For this reason, a similar survey has not been carried out in recent years.

We also deal with innovation and the preparation of lifelong learning programmes designed for further education of pedagogical staff. The innovation primarily concerns so-called extension studies, which are intended for teachers who wish to broaden their qualifications. The creation of new courses is inspired by the current needs of schools. For instance, changes in the Framework Educational Programme for primary education in the area of informatics and digital competencies and related implementation of computational thinking at primary and secondary schools resulted in a complete revision of programmes of qualification extension in the field of informatics. Due to the need for the transition to the distance form of studies at all schools during the pandemic, questionnaire surveys were carried out to find out the effectiveness of the online tools used in primary and secondary schools. As a result, a course called "Online vyučování na ZŠ a SŠ" [Online Education in Primary and Secondary Schools] was created and accredited, including supporting educational materials.

4.4 Objectives for the next period

In this and following years, we want to continue in the activities implemented before. We want to develop and possibly supplement them.

Regarding the implementation of reflective practices, the booking system for optional practice will be piloted this year. In the next years, we would like to extend its functionality for other types of practices. We also want to acquire audio-visual recording as much as possible to enable detailed reflections, deep analyses, or the creation of didactic case reports. In addition, we would like to maintain and even develop the involvement of teachers from practice to teaching. For example, it could concern tandem teaching when preparing future teachers.

We are also planning to organise a joint meeting with representatives of secondary and primary schools in the Moravian-Silesian Region or other neighbouring regions. During this meeting, we want to discuss, in particular, the possibilities of intensified cooperation with schools and teachers in shortage qualifications, and the possibilities of popularising shortage qualifications among secondary school students in order to increase the number of applicants for/graduates from these qualifications, suggestions for improving the quality of pregraduate teachers' preparation and specific requirements of schools to provide further education of pedagogical staff through lifelong learning programmes.

We also want to strengthen the cooperation with teachers from practice in the framework of creative and research activities. We want to involve them more in joint research activities, in consulting,

supervising, or opposing Bachelor's and Master's theses. This also includes offering them passive and active participation in our professional seminar for didacticians, etc.

At the same time, an intensive discussion is taking place at the university management level, with faculty representatives and representatives of the Moravian-Silesian Region on the possibility of establishing a clinical school at the University of Ostrava. This would, of course, enable a more systematic and intensive implementation of our planned activities, especially in research and creative activities. However, the establishment of such a school requires, first of all, an adjustment of the existing legislation in the Czech Republic.

5. Conclusion

Historically, teaching belongs to one of the oldest professions. Transfer of various knowledge, findings, and skills was ensured by the elders, priests, tribe chieftains, shamans, parents, and, of course, specialists in this area – teachers. They all pursued the goal of preparing the trainee for practical life as best as possible. We also follow this goal in the area of pregraduate preparation and postgraduate education of teachers.

References

- Bendl, S., Pišová, M., Šťáva, J., Jursová, J., Betáková, L., Dokoupilová, L., Kostková, K., Kovaříková, M., Maněnová, M., Mazáčová, N., Mojžíšová, J., Musilová, M., Pavlišová, J., Podhajska, E., Prokop, J., Rýdl, K., Uhlířová, J., Váňová, R., Voňková, H., & Zvířotský, M. (2011). *Klinická škola: místo pro výzkum a praktickou přípravu budoucích učitelů* [Clinical school: A place for research and practical training of future teachers]. Univerzita Karlova v Praze.
- Janík, T. (2005). *Znalost jako klíčová kategorie učitelského vzdělávání* [Knowledge as a key category of teacher education]. Paido. <https://www.ped.muni.cz/weduresearch/publikace/pvtp02.pdf>
- Konečná, P. (2012). Pregraduální příprava učitelů na Přírodovědecké fakultě Ostravské univerzity v Ostravě - hodnocení, problémy a řešení [Pregraduate teacher training at the Faculty of Science of the University of Ostrava in Ostrava: Evaluation, problems and solutions]. In *Odborová didaktika: Interdisciplinární dialóg 2012* (pp. 143-150). VERBUM.
- Konečná, P., & Vavroš, M. (2017). Mocniny a jejich užití pro zápis velkých a malých čísel [Powers and their use for writing large and small numbers]. In J. Slavík, J. Stará, K. Uličná, & P. Najvar, et al., *Didaktické kazuistiky v oborech školního vzdělávání* (pp. 217-232). Masarykova univerzita. http://didacticaviva.ped.muni.cz/data_PDF/kazuistiky/Konecna.pdf
- Kričfalúši, D., Prášilová, J., & Trčková, K. (2017). Konstituční izomerie (využití tyčinkových modelů při výuce řetězové izomerie alkanů) [Constitutional isomerism (use of stick models in teaching chain isomerism of alkanes)]. In J. Slavík, J. Stará, K. Uličná, & P. Najvar, et al., *Didaktické kazuistiky v oborech školního vzdělávání* (pp. 233-242). Masarykova univerzita. <https://docplayer.cz/106932788-11-konstitucni-izomerie-vyuziti-tycinkovych-modelu-pri-vyuce-retezove-izomerie-alkanu.html>
- MŠMT. (2004). *Koncepce pregraduální přípravy učitelů základních a středních škol* [The concept of pregraduate training for primary and secondary school teachers]. https://www.msmt.cz/uploads/odbor_30/Jakub/Koncepce_pregraduální_přípravy_ucitelu_zakladních_a_středních_skol.pdf
- MŠMT. (2017). *Rámcové požadavky na studijní programy, jejichž absolvováním se získává odborná kvalifikace k výkonu regulovaných povolání pedagogických pracovníků* [Framework requirements for study programs, the completion of which provides a professional qualification for the performance of regulated professions of teaching staff]. https://www.msmt.cz/file/44244_1_1/download/
- MŠMT. (2020). *Strategie vzdělávací politiky České republiky do roku 2030+* [Strategy for the education policy of the Czech republic up to 2030+]. https://www.msmt.cz/uploads/Brozura_S2030_online_CZ.pdf
- MŠMT. (2021). *Reforma přípravy učitelů a učitelek v ČR* [Teacher training reform in the Czech Republic]. <https://www.edu.cz/wp-content/uploads/2022/01/Reforma-pr%CC%8C%8A%81pravy-uc%CC%8C%8A%8A.pdf>
- Solfronk, J. (2003). Systémový přístup k pedagogické praxi [Systemic approach to pedagogical practice]. In K. Marková, (Ed.), *Pedagogická praxe: Sborník příspěvků z III. celostátní konference, Praha 22. ledna 2003*, (pp. 37-40). Univerzita Karlova v Praze.

- Václavíková, Z. (2019). Using video as a tool for the improvement of teachers' abilities and skills. *AIP Conference Proceedings*, 2186(1), 060018. <https://doi.org/10.1063/1.5137972>
- Václavíková, Z., Žáček, M., Smolka, P., Trčková, K., & Konečná, P. (2022). The power of video in teachers' training and in their professional development. *AIP Conference Proceedings*, 2425(1), 060009. <https://doi.org/10.1063/5.0081429>
- Václavíková, Z., Konečná, P., Žáček, M., Smolka, P., & Trčková, K. (to appear). Improving the professional vision of pre-service teachers using video. *AIP Conference Proceedings 2021-09-20 Rhodes*. AIP Publishing, 2021.

Alzheimer's Disease as a Cross-cutting Theme in Chemistry?

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Abstract. Neurodegenerative diseases of the central nervous system are now considered a serious problem. These diseases are often considered only as diseases of the elderly and are therefore collectively referred to as senile diseases. However, research shows that more and more young people are suffering from neurodegenerative diseases of the central nervous system. The work examined the knowledge and awareness of high school students about neurodegenerative diseases of the central nervous system, especially Alzheimer's disease.

1. Introduction

Neurodegenerative diseases are characterized by nerve cells' gradual death and subsequent memory impairment. Throughout the nervous system, neuronal changes occur, which in the very end cause the complete disintegration of the individual and the loss of the individual's self-sufficiency. Sick people are gradually becoming dependent on the people around them. As the world's population grows, so does the number of patients suffering from any central nervous system diseases. These diseases include Alzheimer's disease (AD), Parkinson's disease, Huntington's disease, and others (Nevšimalová et al., 2002). Alzheimer's disease is often confused with another type of neurodegenerative disease because their mechanisms are very similar.

During the onset and development of diseases of the nervous system, biological changes in the nervous system occur, and gradual changes in biochemical processes, which occur at the cell level and the entire nervous system, are closely connected with this. We perceive the impact of these changes as the development of the disease. Neurodegenerative diseases are diseases that significantly affect the lives of individuals and their families and loved ones. Therefore, this topic should be included in biology and chemistry lessons. An analysis of the biochemical events that accompany this disease can help students better understand the mechanisms and effects of the disease on the human body.

2. Central nervous system

To properly understand the development of neurodegenerative diseases, it is necessary to explain how the central nervous system works. It consists of the brain, the elongated spinal cord, and variously advanced nerve pathways. Its basic building block is a neuron composed of dendrites, cell body, initial segment, axon, and nerve endings - synapses (Novotný & Hruška, 2015). In addition, the neuron comprises lipid-forming chemicals, specifically phosphoglycerolipids and sphingolipids (Koolman & Röhm, 2012).

The end of an axon, a long fiber coming from the body of a neuron, is richly branched. Individual endings connect with the fibrous ends of other neurons. To do this, specialized ends of the axon, the so-called synapse, are taught, enabling the secretion of neurotransmitters. The transmission of nerve impulses, which takes the form of the action potential, increases the permeability, i.e., the permeability of the presynaptic membrane to calcium ions, and opens up the corresponding channels. The release of mediators is due to the exocytotic mechanism of synaptic vesicles (Trojan et al., 2003).

3. Alzheimer's disease

In the subconscious of the general public, it is referred to as an elderly disease. However, this claim is increasingly being made as it affects more and more young people. Alzheimer's disease (AD) is characterized by nerve cell death, which causes brain loss and memory impairment (Bauer et al., 2021).

3.1 History

AD is one of the extrapyramidal neurodegenerative diseases belonging to the group of amyloidopathies. In 1907, Alois Alzheimer described the case of a 51-year-old woman who suffered from rapidly worsening memory loss and other psychiatric disorders. She died about four years later. Several progressive and fatal neurological conditions have been known, including senile dementia. Even so, this condition was something new and undescribed for Alzheimer's. Later, AD was divided into two clinical conditions depending on the age of onset. The term presenile dementia was reserved for the age group up to 65 years, and the term Alzheimer's type dementia was used for patients over 65. Today, this definition does not apply, and therefore, the single term Alzheimer's disease is used (Castellani et al., 2010).

This disease is a chronic-progressive disease of the nervous system. Degenerative neuronal death, i.e., the death of nerve cells, occurs with the simultaneous formation of histopathological changes. This is currently one of the most severe health and socio-economic problems (Nevšímalová et al., 2002). AD is recognized by the World Health Organization (WHO) as a global public health priority. No treatment has been found since the first case reported in 1907 (Bauer et al., 2021).

3.2 Description of the disease

The disease must be distinguished from other conditions based on causes and symptoms, despite their interconnectedness and remarkable similarity. Although no completely reliable biochemical indicator today can unambiguously confirm AD, the indicators for either Parkinson's disease or Lewy body dementia are different. Therefore, histological examination of the brain at necropsy remains the only accurate determination of AD (Castellani et al., 2010).

It is reported that in 2018, AD had almost 6 million people, of whom 200,000 were under the age of 65. Another prognosis says that the number of patients with AD will increase to more than 100 million cases by 2050. Every 20 years, AD findings regularly double (Bauer et al., 2021).

3.3 Chemical effects

The main features of Alzheimer's pathology are amyloid plaques, also referred to as Alzheimer's plaques, and neurofibrillary tangles composed of paired helical fibers. Amyloid plaques are extracellularly accumulated peptides consisting of 40 or 42 amino acids that form β -amyloid ($A\beta$). $A\beta$ concentrates in larger aggregates and impairs nerve function or indicates inflammatory processes (Lane et al., 2017).

Proteases produce β -amyloid protein (APP) precursors with unknown functions. In normal functioning, APP is cleaved by two proteases that convert insoluble membrane protein to soluble peptides. In patients with AD, APP is cleaved by another secretase that acts elsewhere and forms a precursor of insoluble $A\beta$ (Koolman & Röhm, 2012). Form $A\beta_{42}$ is the key in the pathogenesis of AD (Lane et al., 2017).

In addition to the above pathological features, neuropile fibers, affected neurites, and glial activation, i.e., nerve cell activity, are observed. These pathological processes include neurodegeneration and neuronal loss, leading to macroscopic atrophy - brain shrinkage (Lane et al., 2017). The whole process of degeneration and $A\beta$ plaques can be seen in the figure 1.

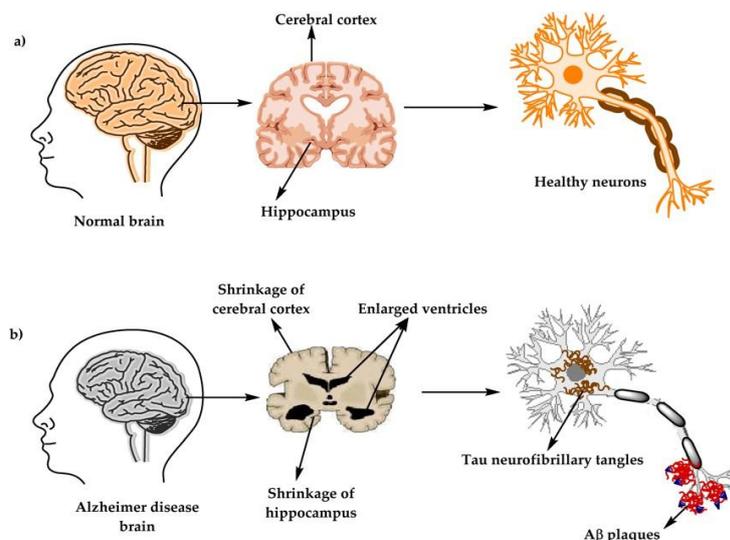


Figure 1. Healthy brain vs. Alzheimer's disease (available from: www.mdpi.com).

Inflammation of the nervous system is closely associated with AD. It was discovered more than 30 years ago, but it is still unclear whether it is a cause or a consequence of the disease. Usually, the inflammation subsides on its own, but if its symptoms persist, the inflammation becomes chronic. Chronic inflammation can have detrimental effects on brain function due to the release of cytotoxic factors. There is ample evidence to suggest an effect of inflammation in the pathogenesis of AD. The primary sources of cytokines, proteins responsible for immune responses, are microglia and astrocytes, which contribute to the development of inflammation. They also play a crucial role in observing the brain and its homeostasis. Under normal conditions, they have neuroprotective effects, participate in phagocytosis, and maintain a healthy brain environment. In response to disease, inflammation, or injury, they are activated, leading to the production and release of inflammatory cytokines, including various interleukins, i.e., peptide chains involved in the regulation of immune processes (Ozben & Ozben, 2019). During the presymptomatic phase of AD, microglia are activated by pro-inflammatory mediators, leading to synaptic dysfunction and even neuronal death. Active microglia have been shown to produce free radicals, such as nitric oxide or neurotoxic substances that kill neurons. The presence of active microglia surrounding amyloid plaques and increased levels of pro-inflammatory cytokines in the periphery and the autonomic nervous system promotes inflammation during AD (Ozben & Ozben, 2019). The mechanisms leading to the development of AD symptoms are, for example, apoptosis, the action of amino acids, aluminium and other chemical elements, free radical reactions, lipoperoxidation processes, and others. There is a decrease in the number of cholinergic neurons and acetylcholine in the cerebral cortex. Acetylcholine deficiency is the starting point of memory disorders, which is the basis for some AD treatments (Nevšimalová et al., 2002).

Acetylcholine (ACh) formation occurs in the presynaptic axons' cytoplasm through the enzymatic action of acetyl-CoA and choline. Subsequently, ACh is stored in synaptic vesicles. Exocytotically secreted ACh diffusely travels to postsynaptic membrane receptors. In the synaptic cleft, ACh inactivation begins by hydrolysis to acetate and choline. The reaction is catalyzed by acetylcholinesterase, which removes precipitated ACh. Choline is then taken up by the presynaptic neuron and glial cells and reused for ACh synthesis (Koolman & Röhm, 2012).

A clinical picture of memory loss and at least one other impairment of another cognitive component, such as social or work disorders, is necessary to diagnose AD. For example, dysfunction gradually manifests itself to varying degrees in speech, personality, judgment, vision, or motor function (Castellani et al., 2010).

The disease is also known as tauopathy due to an incorrectly assembled and insoluble tau protein. This protein is concentrated in a part of the brain called the hippocampus. It is part of the neurofibrillary protein cluster, typical in patients with AD and other neurodegenerative diseases. It is a protein that controls the mechanisms in the brain. When tau protein autophagy is suppressed or partially fails, a neurodegenerative process begins that manifests in the brains of patients with AD (Bauer et al., 2021).

A growing number of studies also attribute oxidative stress - lipid peroxidation and DNA and protein production are increasing in patients' brains. As a highly oxidizing organ, the brain consumes 20% of the body's oxygen. During ageing, metal ions of iron (Fe), zinc (Zn), and copper (Cu) accumulate in the brain, which affects the reactions taking place in the brain. In AD, the β -amyloid peptide can efficiently produce reactive oxygen species. Amyloid forms free radicals that extract protons from surrounding lipids by reducing copper ions. The copper cation then reacts with the molecular oxygen formed to form hydrogen peroxide (Smith et al., 2007).

Metal ions mediate the oxidative stress mechanism of β amyloid toxicity and modulate it in neuronal cultures, with copper ions increasing toxicity while zinc ions weaken it. Amyloid dissolved in a medium containing iron ions is also toxic to neurons (Smith et al., 2007).

In addition to the influence of metal cations, other substances, such as D galactose, may be an early sign of AD progression. When too much D-galactose is present in the body compared to D glucose, metabolic dysfunction occurs, and oxidative stress is induced (Bauer et al., 2021).

AD is based on chemical indicators in the brains of patients and is a combination of various biochemical processes in which acetylcholine, β -amyloid, τ -proteins, D-galactose and others play an essential role.

3.4 Therapy

Czech scientists, led by renowned neurologist Martin Tolar, are preparing a test to detect the disease before the first symptoms appear. Then you can start early treatment, which is not to stop the disease, but only to significantly slow it down. Attention is paid to toxins that destroy brain cells that appear in the cerebrospinal fluid. The cerebrospinal fluid contains large amounts of salts, proteins, and other substances that significantly complicate the recognition of toxins. A method of treating cerebrospinal fluid samples in which accumulating substances would be detectable is currently being prepared. In parallel with toxin research, a sense is developing that should prevent their formation in the brain. If this test and drug prove functional, they should be available in 3 years (Karlík, 2021).

In February 2022, according to the Forbes website, Martin Tolar and his company, Alzheon, discovered the positive results of a study of the ALZ-801 tablet. The tablet's functionality is caused by identifying the toxin, which, according to the authors, is the cause of AD (Saiver, 2022).

4. Research at school

The research focused on students in primary schools and grammar schools. Data collection took place in two age categories, aged 13-15 and 16-18. The questionnaire contained three basic questions dealing with the topic of neurodegenerative diseases.

The first question was the selection of diseases that fall into neurodegenerative disorders. From an open selection of options where diabetes and epilepsy also occurred, the correct answers were Parkinson's disease and Lewy body dementia. The wrong possibility of epilepsy often occurs in older and younger age groups. Although it is a neurological disease, it is caused by the abnormal activity of neurons (nerve cells), not their extinction. In diabetes or diabetes, there is insufficient insulin production in the pancreas, and thus an excessive amount of glucose appears in the blood of the person in question.

The second question looked at the age at which Alzheimer's disease can occur. The correct and only answer is that it does not matter what your age is. There is often a mistaken assumption that this is an old age disease. More and more young people are suffering from this disease, so it is essential to pay close attention to any symptoms and not underestimate them. The prevalence of Alzheimer's

disease is high, and research shows that the incidence of Alzheimer's disease doubles every 20 years.

The third question asked what characterizes Alzheimer's disease. The disease is usually accompanied by forgetting and the death of nerve cells. As a result, there is a loss of self-sufficiency and physical ability. However, nausea or hair loss is not a typical feature of this disease, as are tics that occur, for example, in Tourette's syndrome, which occur spontaneously.

4.1 Research conclusions

Based on the answers obtained, we think the students did well for the most part. They could be seen to have some knowledge about this phenomenon. Nevertheless, we think that including neurodegenerative diseases in teaching chemistry and biology would be necessary. In the general public, this topic does not fall into the group of popular topics. As Alzheimer's disease (as well as other neurodegenerative diseases) is key to detection as soon as possible, it could provide better orientation in the future.

5. Conclusion

If we were to summarize the most significant errors that appeared in the questionnaires, then we would mention the following:

- epilepsy does not belong to the group of neurodegenerative diseases;
- Alzheimer's disease is not age-dependent;
- Tics are not a manifestation of Alzheimer's disease.

Biochemical processes in patients' brains help to understand their functioning. Therefore, students should be at least generally acquainted with this issue.

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References

- Bauer, S., Jin, W., Zhang, F., & Linhardt, R. J. (2021). The application of seaweed polysaccharides and their derived products with potential for the treatment of Alzheimer's disease. *Mar. Drugs* 2021, 19(2), 89. <https://doi.org/10.3390/md19020089>
- Breijyeh, Z., & Karaman, R. (2020). Comprehensive review on Alzheimer's disease: Causes and treatment. *Molecules*, 25, 5789. <https://doi.org/10.3390/molecules25245789>
- Castellani, R. J., Rolston, R. K., & Smith, M. (2010). Alzheimer disease. *Disease a Month*, 56(9), 484-546. <https://doi.org/10.1016/j.disamonth.2010.06.001>
- Karlík, T. (2021, June 7). *Čeští vědci pracují na arzenálu zbraní proti Alzheimerově nemoci. Pomoci může test i lék* [Video]. ČT24. Česká televize. <https://ct24.ceskatelevize.cz/veda/3307375-cesti-vedci-pracuji-na-arzenalu-zbrani-proti-alzheimerove-nemoci-pomoci-muze-test-i-lek>
- Koolman, J., & Röhm, K. H. (2012). *Barevný atlas biochemie* [Color atlas of biochemistry] (4th ed.). Grada Publishing, a.s.
- Lane, C. A., Hardy, J., & Schott, J. M. (2017). Alzheimer's disease. *European Journal of Neurology*, 25(1), 59-70. <https://doi.org/10.1111/ene.13439>
- Nevšimalová, S. et al. 2002. *Neurologie* [Neurology] (1st ed.). Galén.
- Novotný, I., & Hruška, M. (2015). *Biologie člověka* [Human biology] (5th ed.). Fortuna.
- Ozben, T., & Ozben, S. (2019). Neuro-inflammation and anti-inflammatory treatment options for Alzheimer's disease. *Clinical Biochemistry*, 72, 87-89. <https://doi.org/10.1016/j.clinbiochem.2019.04.001>
- Saiver, F. (2022 February 8). *Lék na Alzheimer je zase blíž. Martin Tolar označil výsledky studie své pilulky za převratné*. Forbes. Retrieved June 4, 2022, from <https://forbes.cz/lek-na-alzheimer-je-zase-bliz-martin-tolar-oznacil-vysledky-studie-sve-pilulky-za-prevratne/>
- Smith, D. G., Cappai, R., & Barnham, K. J. (2007). *The redox chemistry of the Alzheimer's disease amyloid β peptide*. *Biochimica et Biophysica Acta (BBA) – Biomembranes*, 1768(8), 1976-1990. <https://doi.org/10.1016/j.bbamem.2007.02.002>
- Trojan, S. et al. (2003). *Lékařská fyziologie* [Medical physiology] (4th ed.). Grada Publishing a.s.

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The Impact of Inquiry-based Education in Geography and Biology on Pupils' Skills to Use Graphs

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Abstract. Reading, interpreting, and constructing graphs is an important skill in scientific work and an important part of scientific literacy. This competence is gradually developed in several subjects at primary schools. Many studies show that the inductive approach and integrative themes in the IBSE allow for a greater development of scientific skills than in the traditional way of teaching. The article deals with research on the influence of Inquiry-based science education on the pupils' skills of interpretation of data presented in graphic form and on the skills of creating graphs. In our research, we examined whether the systematic implementation of appropriate enquired tasks into the biology and geography teaching process affects the development of pupils' skills of understanding data expressed in graphs. For this purpose, we compiled our own testing tool, consisting of complex tasks focused on active work with graphs, as well as a questionnaire focused on pupils' perception of their own graphic skills. We compared the results of pupils from seventh grade in primary school, who have been learning biology and geography in an inquiry way for almost three years, with pupils who are learning these subjects in the traditional way. The obtained results confirmed that the implementation of inquiry-based education with frequent use of graphs had a positive effect on pupils' skills to read, interpret, and construct graphs.

1. Introduction

Graphs represent the part of our life not only in school or scientific disciplines, but also in everyday work or private life. Due to the increasing importance of graphs, graphic skills have become one of the basic skills of the 21st century that need to be acquired at an early age (Patahuddin & Lowrie, 2019). Graphical skills are essential in science and reading literacy (Ludewig et al., 2020). However, as reported by international PISA tests (Koršňáková et al., 2010; Šiškovič & Toman, 2014), Slovak pupils have long-term problems with reading graphs, and overall their performance is evaluated, compared to pupils from other countries, OECD, as worrying. The results of studies by authors from abroad (Boote, 2014; Bursal & Yetis, 2020; Ozmen et al., 2020) also show that, in general, pupils have problems with graph tasks that require more profound skills, such as graph interpretation and graph construction. As a solution to this situation, several experts (Al-Balushi & Al-Aamri, 2014; Gillette, 2015; Karolčík et al., 2018) recommend a targeted and methodologically well-thought-out application of learning tasks and activities focused on research with frequent use of working with graphs. This enables inquiry-based education (abbreviation IBE). Efforts to effectively implement IBE have been ongoing in the Slovak educational environment for more than ten years (more in Dostál, 2015). During this period, several projects were created to support this concept of teaching in school practice, e.g., the Expedition – try, explore, learn project (Škodová, 2018a, 2018b) or the IT Academy (more Csachová, 2018). Several studies confirm that the inductive approach in IBE generally allows for more significant development of pupils' scientific work abilities (e.g., Ganajová, 2016; Škodová & Turošíková, 2020; Žoncová & Vojteková, 2018), natural science, and reading literacy, as is the case with the traditional teaching method (TTM). Whether this is also the case in the area of reading, analyzing, and interpreting graphically represented information and creating data in graphic form represents the subject of this study.

2. The importance of developing the skills to work with graphs

Graphical skills are among the most critical for processing and visualizing a rapidly growing amount of data in today's world (Patahuddin & Lowrie, 2019; Zhang, 2016). Graphs represent a very effective way of presenting data, and their essence is the skills to organize the obtained information by visualizing the relationships between them (Fry, 1981; Shah & Hoeffner, 2002; Wainer, 1992). Graphical representation, for example, can help us understand elements and relationships between variables or tendencies that require complex, deep, and abstract thinking. Graphs are perceived as non-continuous texts (along with tables). Although graphs are not as accurate as tables, they can provide a quick and better visual representation (Karolčík et al., 2018). Like any other language, graphic language is built according to its rules and regularities and uses its methods and techniques (Fry, 1981).

Some authors (e.g., Woller-Carter & Okan, 2012) classify the skills to work with information in graphs into a separate category as graphic or visual literacy. Fry (1981) created one of the first definitions of graphic literacy as the skills to read and draw graphs. Visual literacy is crucial for effective scientific and professional communication and argumentation (Leu et al., 2004). Its necessary condition is a sufficiently developed skill of abstraction and spatial imagination. For pupils with a low level of understanding of a continuous text, graphs can help understand it (Sofa, 1985). The development of graphic skills is connected with the development of visual analysis - the skills to analyze, isolate essential elements, and correlate them with each other. Friel, Curcio, and Bright (2001) define pupils' graph comprehension as the skills to read and make sense of graphs created by others or by themselves. Graphics skills need to be developed continuously throughout formal education. In elementary school, this skill is developed primarily in mathematics or physics. However, developing the skills to work with information in graphic form is also essential in other educational subjects, where pupils can understand the interpretive value of graphs more naturally (Boote, 2014; Lowrie & Diezmann, 2011; Shah & Hoeffner, 2002). Many experts (Capraro et al., 2005; Karolčík et al., 2018) are convinced that reading, analyzing, or interpreting graphically represented information and creating data in graphic form should be a regular part of geographical and biological activities, learning tasks, and tests. An encouraging element is, e.g., the results of the study by Karolčík et al. (2018) on a sample of 42 pupils, according to whom the skills to read graphs and interpret the data expressed in them were significantly improved by the targeted and methodologically well-thought-out application of tasks aimed at working with graphs. The gender of the pupils does not play a significant role in this, but as stated by several studies, pupils in higher grades almost always achieve better results than younger pupils (Berg & Smith, 1994; Koparan & Güven, 2013).

3. Current status and possibilities of developing the skills of working with graphs in Slovakia

Systematic development of science literacy, including the skills to create and interpret data presented in graphic form, is not an isolated task of any educational field or general education subject. As a cross-curricular competence, it requires a well-thought-out learning strategy incorporated into curriculum documents and contents of educational programs in other subjects, such as mathematics or physics. It is essential that pupils learn to create graphs and tables in the subjects of mathematics and physics so that they can then use graphs in specific situations in other subjects for analysis, argumentation, or interpretation of presented facts (Boote, 2014; Ludewig, 2018; Shah & Freedman, 2011). The trend to include work with graphs in the curriculum of various subjects is evident worldwide, including in Slovakia (Friel et al., 2001; Lowrie & Diezmann, 2011). Looking at the current standards of geography and biology (ISCED 2) in Slovakia, it is already clear from the general goals that they emphasize, among other things, working with information in various forms (ŠPÚ/NEI, 2014):

GEO 1: pupils will search for, compare, assess the validity, and evaluate available information about the landscape from various information sources,

GEO 2: pupils present information about the landscape in various forms (graphs, tables, diagrams, diagrams, photos, films, etc.),

BIO 1: pupils analyze, interpret, sort, and evaluate information about organisms and nature.

In the currently prepared Basics of Changes in Educational Fields (ŠPÚ/NEI, 2021), in the

educational field of Man and Society, one of the goals of the third educational cycle is to "acquire the skills to use various tools, such as general and thematic maps, graphs, photographs, tables, diagrams" (ŠPÚ/NEI, 2021, p. 52). Also, in the educational field of Man and nature, one of the goals is to "acquire the skills to systematically organize and express the obtained data (construction of tables and graphs)" (ŠPÚ/NEI, 2021, p. 45). Several studies present different levels of working with graphs. One of them is a three-level division (Friel et al., 2001) – reading information (visible values in the graph), reading between information (comparing, observing, and inferring relationships), reading beyond the displayed information (creating conclusions, predictions). For the needs of this study, we defined four related areas of working with graphs: 1. read information from a graph, 2. analyze information in a graph, 3. interpret information from a graph, and 4. present information in the form of a graph (create a graph). The mentioned areas can be developed through tasks that differ significantly depending on the student's thought operations (they have different difficulty levels). The following two-dimensional table expresses these levels of difficulty within individual graphics skills (Tab. 1).

Table 1. Difficulty levels within individual areas of graphics skills.

Area/Level of Difficulty	Perceive	Perform by imitation	Perform individually	Create new patterns
<p>Read the information from the graph</p> <p>(e.g., population, average temperature, number of endangered species)</p>	The pupil can say whether it is possible to read the given information from the graph.	The pupil can read the information from the graph according to the instructions or an analogous example.	The pupil can read the required information from the graph.	The pupil reads information from the graph that was not required of him in the past.
<p>Analyze the information in the graph</p> <p>(e.g., characteristics of climate, population, the composition of human diet)</p>	The pupil can say whether it is possible to compare/sort the properties/information displayed by the graph.	The pupil can compare/sort the properties/information displayed by the graph according to the instructions or by an analogous example.	The pupil can compare/sort the properties/information displayed by the graph.	The pupil compares/sorts the properties/information displayed in charts that were not required in the past.
<p>Interpret the information from the graph</p> <p>(e.g., development of atmospheric temperature, living standards of the population, causes of species extinction)</p>	The pupil can say whether it is possible to interpret the given phenomena/trends from the graph.	The pupil can interpret the given phenomena/trends from the graph according to the instructions or an analogous example.	The pupil can interpret the given phenomena/trends from the graph.	The pupil interprets from the graph the phenomena/trends that he was not required in the past.

<p>Present information in the form of a graph</p> <p>(e.g., pie, column, continuous, climate graph, age/food pyramid, etc.)</p>	<p>The pupil can say whether it is possible to create a graph from the given data (e.g., in a table).</p>	<p>The pupil can create a suitable graph or add the required data to the graph according to the instructions or an analogous example.</p>	<p>The pupil can design and create the most suitable type of graph from the given data (e.g., in a table).</p>	<p>The pupil processes and presents data not required in the past (e.g., from field research) in graphs.</p>
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But what are the possibilities and ways of developing pupils in the particular areas of working with graphs? Considering the studies devoted to this issue, we find several of them (Al-Balushi & Al-Aamri, 2014; Farárik, 2022; Gillette, 2015; Karolčík et al., 2018). When increasing graphic literacy, it is necessary to look at the issue from two points of view. First of all, it is necessary to teach pupils to read graphs, understand them, and know how to connect information from them and see connections. An understanding of graphic language is a prerequisite. Therefore, the teacher's first step should be to teach the meaning-making systems of graphic representations, such as the importance of headings, labeling of axes, the meaning of colors, and the appropriate type of graph. Only afterward is it possible to move on to work with information explicitly or implicitly expressed in the graph? A suitable strategy to support pupils when working with graphs is the use of unfinished sentences (e.g., This graph shows ...; The x-axis represents ...; The difference between the data in the red and blue columns is ...; The data that interested me the most was ...; Based on the information in the graph, I expect that will happen...; My prediction is supported by data... etc.). As pupils become more adept at interpreting data independently, they can be provided with frameworks to help structure the analysis of the graphs (e.g., introduction, highlights, anomalies, trends, conclusions, and recommendations). Research by Bursal and Yetis (2020) revealed that seventh-grade elementary school pupils have a significantly higher personal perception of graphic literacy for bar graphs than for line and pie graphs. These are more difficult to understand because they require more abstraction, such as proportional reasoning in pie charts and understanding trends of continuous variables in line charts (Tiefenbruck, 2007). Therefore, it is recommended to start working with bar graphs. It is also essential that pupils have ample opportunities to explain and justify their reasoning and receive feedback from others. Therefore, activities in pairs or small groups are recommended (Ozmen et al., 2020). The second point of view is that it is necessary to teach pupils to look for important information in continuous text or tables and to be able to process them in the form of a graph. Pupils' skills to work with information in graphs requires specific essential and integrated abilities of scientific work (e.g. Held et al., 2011), e.g. observing, judging, classifying, interpreting data, controlling variables and describing relationships between them. IBE is aimed at their development. Therefore, pupils can be more successful in classes with this education concept (Ganajová, 2016; Nicolaou et al., 2007; Picone et al., 2007).

4. Goals and research methods

The research aimed to study the impact of a research-oriented educational program on the subjects of geography and biology on the skills of pupils to work with information in the form of graphs in pupils in the 7th grade of primary school. The research has the character of a case study (Mareš, 2015). One possible method of reasoning within a case study is theory testing through hypothesis verification (Johanson, 2003). Several studies (e.g., Beler, 2009) show that some pupils dislike graphs and feel anxious when reading and interpreting them, which worsens their understanding of graphs. Therefore, in addition to cognitive abilities in using graphs, we also investigated the pupils' beliefs about their abilities when working with graphs. In this way, they obtained a more comprehensive picture of the graphic literacy level of the pupils. Based on the above findings, we formulated a relational research question: RQ1 –What is the connection between the perception of one's skills to work with graphs and the dominant teaching strategy? In connection with RQ1, we made the following assumption: A1 – Pupils in a class with a dominant IBE perceive their skills to work with graphs more positively than pupils with

a traditional teaching method (hereafter TTM).

By comparing the performance standard of selected thematic units of the subject geography, biology, and mathematics (ŠPÚ/NEI, 2014a, 2014b, 2014c), we concluded that the graphic tasks correspond significantly with the skills and content that the 7th-grade pupils have mastered in the subject of mathematics. That is why we asked ourselves a descriptive and relational research question: RQ2 – In which subjects do pupils often solve problems with graphs? and RQ3 – What is the connection between the pupils' results in solving graphic tasks and their grades in mathematics? In connection with RQ2 and RQ3, we made the following assumptions: A2 – Pupils solve graphic tasks much more often in the subject of mathematics than in the subjects of biology and geography, and A3 – Pupils with a better grade in mathematics achieve better performance in solving graphic tasks than pupils with a worse grade in mathematics.

Several studies (e.g., Nicolaou et al., 2007; Picone et al., 2007;) show that the abilities of scientific work and, within them, the skills of pupils to work with information in the form of graphs are much more developed in constructivist-oriented or IBE, as in the standard way of teaching. We have therefore formulated a descriptive and relational research question: RQ4 – Through which teaching strategies do pupils work more with graphs? and RQ5 – What is the connection between the pupils' results in solving graphic tasks and the dominant teaching strategy? In connection with these research questions, we made the following assumptions: A4 – Pupils in a class with dominant IBE solve graphic tasks more often than pupils in classes with TTM and A5 – Through IBE, pupils of the experimental group (hereafter EG) achieve better than the control group (TTM) performance in solving graphic tasks.

The research tools were a questionnaire and a self-designed worksheet in printed form. After considering all the facts found from their pilot verification (two pupils with different grades), we set the time to solve at 45 minutes. The questionnaire and worksheet were identical for both the research and control groups. Respondents in individual items of the questionnaire chose a value on a five-point numerical scale (from 1 – almost always to 5 – almost never). The questionnaire contained ten items within three monitored areas:

1. Frequency of solving tasks with graphs in geography, biology, and mathematics lessons (How often do I solve tasks with graphs in geography/biology/mathematics lessons?)
2. Developing levels of graphic skills in geography and biology lessons (Do I read data from graphs in geography and biology lessons? Do I analyze a graph in geography and biology lessons – what is its function, what does it show, what relationships does it describe, what follows from the graph, etc.? Do I have the opportunity to create my graphs in geography and biology classes?)
3. Perception of my abilities when working with a graph (Do I understand the graphs I see in class? Do I know what information the graphs I see provide? Can I solve the tasks in which the graph is located? Can I explain the relationships between the quantities in the graphs?)

The worksheet was processed according to the principles of creating a worksheet (Žáčok & Schlarmanová, 2005), test tasks (Csachová, 2016; Tolmáči & Križan, 2014), and principles of creating graphic tasks (Lapitková et al., 2015). It consisted of four complex tasks and ten sub-tasks of different types. According to Chrásek (1999), it is the minimum number to ensure acceptable test reliability (more details in Kalhous & Obst, 2002). They are focused on the following skills: read the information in graphs, analyze information in graphs, interpret information in graphs, and construct graphs (Tab. 2).

Table 2. Monitored competencies, focused on working with graphs in worksheet tasks.

Task	Task 1			Task 2		Task 3			Task 4	
	PT 1	PT 2	PT 3	PT 4	PT 5	PT 6	PT 7	PT 8	PT 9	PT 10
Skills	Read information in graphs	Interpret information in graphs	Interpret information in graphs	Interpret information in graphs	Analyze information in graphs	Read information in graphs	Analyze information in graphs	Construct graphs	Read and interpret information in graphs	Interpret information in graphs

Note: PT – Partial Task

When designing the individual tasks, the intersubject relationships of biology, geography, and mathematics were used based on the content and performance standards of these subjects (ŠPÚ/NEI, 2014a, 2014b, 2014c). The central theme of the worksheet was the occurrence of ticks and the risk of diseases transmitted by ticks, depending on several spatial and biological aspects expressed in graphs, tables, and text. In the worksheets, we have included graphs used most often in geography and biology classes (line, bar, and composite graphs) and information in text and tables that pupils should express in the form of a graph. Sub-tasks represented questions and tasks at different levels of cognitive difficulty and stimulated reading, interpretation and analysis of information in graphs (e.g., "How would you name your graph?"; "Name at least two data that you can find out from the graph."; "Write at least three statements that follow from the graph."; "What is the relationship between the displayed graphs? How are they different?"; "How is the graph from task 4 related to the other tasks in the worksheet?" etc.).

The research sample comprised 56 pupils in the 7th year of elementary school and the second year of an eight-year high school. To be able to objectively determine whether the dominant concept of teaching affects the level of pupils' graphic skills in the subjects of biology and geography, two groups of respondents were included in the survey: the experimental group (hereafter EG – research method of teaching biology and geography according to the educational program ExpEedícia – try, investigate, learn at Elementary School in Banská Bystrica, 23 pupils) and a control group (hereafter CG – the traditional way of teaching biology and geography at school in Ružomberok, 33 pupils). Based on the assessment (using a questionnaire) of the half-year grades in the subjects of geography, biology and mathematics, we were able to identify both groups as equal in terms of the achieved knowledge in these subjects (ES: BIO – 1.26; GEO – 1.26; MAT – 1.52; CG: BIO – 1.13; GEO – 1.44; MAT – 1.55).

The survey was conducted in April of the 2021–2022 school year. The questionnaire and the worksheet were filled out (after the same introductory instruction) by EG and CG pupils, always in one lesson, and it was neither the first nor the last. Mathematical-statistical methods were used to process the obtained data, such as the arithmetic mean of the obtained absolute and relative scores of the evaluated areas and a simple linear correlation using the Pearson correlation coefficient. We analyzed the obtained data quantitatively and qualitatively within the evaluated areas. After evaluating the worksheets, pupils were given feedback on their skills to work with information in graphic form. Even though it was only an available selection of respondents (Gavora, 2010) and a relatively small research sample, as stated by Flybvjerg (2006), even based on an individual case (case study), it is possible to conclude a specific development of scientific knowledge.

5. Results

The result of the data analysis from a questionnaire survey (N=56), focused on the frequency of using graphs within the two dominant teaching strategies (TTM vs. IBE) and within individual educational subjects, is that pupils in the class with IBE work on these subjects with graphs much more often, even though the educational program ExpEedícia – try, explore, learn is not explicitly focused on the

development of this skills in the subjects of geography and biology. We found that pupils in the classroom with TTM hardly work with graphs in geography and biology (on average, only 9.4% of pupils said that they only "sometimes" work with graphs). This is also related to the frequency of use of individual levels of skills to work with information in graphic form (reading, interpreting, analyzing, creating graphs), then pupils from the class with IBE devoted themselves to these levels several times more often. On the contrary, the frequency of working with graphs in mathematics classes was more significant in the class with TTM than in the class with IBE. In both groups, however, the assumption that pupils solve graphic tasks much more often in the subject of mathematics than in the subjects of biology and geography was confirmed (Fig. 1). Regarding the perception of their abilities when working with graphs, pupils with TTM evaluated them somewhat more positively (76.75% of pupils almost always or often understand graphs and can solve tasks in which graphs are found). Pupils with IBE chose these options in 70.56%.

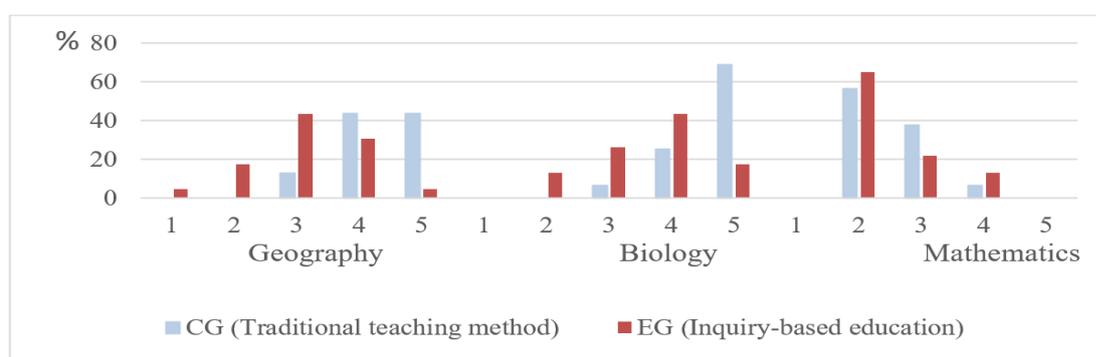


Figure 1. Frequency of working with graphs in the lessons of geography, biology, and mathematics in the classroom with TTM and IBE, explanations: 1 – almost always, 2 – often, 3 – sometimes, 4 – mostly not, 5 – almost never.

We also researched the connection between the pupils' results in solving graphic tasks in the subjects of geography and biology and the dominant teaching strategy. We focused on comparing student performance in individual and partial tasks (in the context of individual levels of work with information in graphic form) between the research and control groups (Fig. 2).

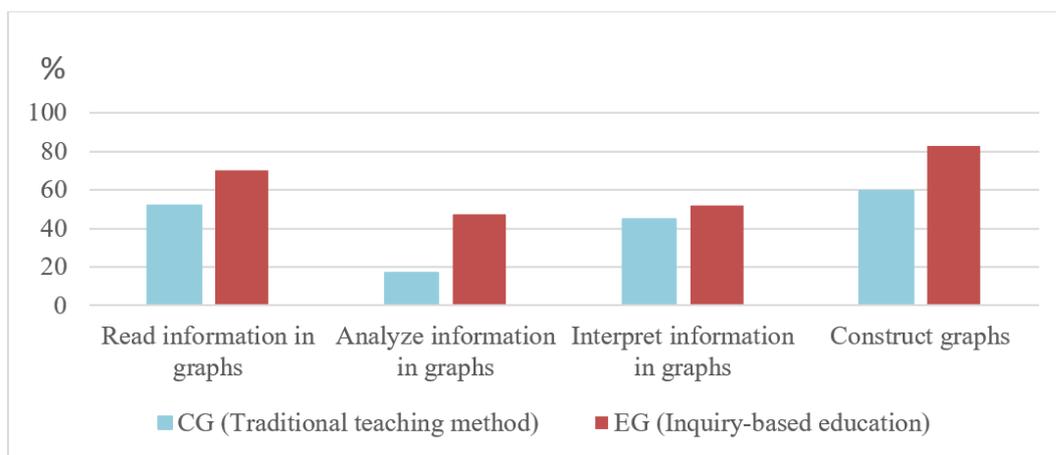


Figure 2. Pupils' success in tasks focused on individual areas of working with graphs.

The lowest level is the skills **to read from the graph the information that is explicitly marked on it**, for example, "In which location did the scientists find the most ticks?", "In which year was there the fewest ticks?" (Task no. 1), "What was the number of tick-borne diseases encephalitis between 2010

and 2012?" (Task no. 6). Pupils often had problems finding and understanding the connections between the question and the data in the graph, even when they were explicitly stated in the graph. Other mistakes were that the pupils did not notice the marking of the axes, wrote their judgments in the answers, not the information they could read from the graph, and added up the found values for no reason. When comparing research samples, EG (IBE) achieved a higher success rate (average score 70.3%) than CG (TTM) (average score 51.85%).

Analyzing information in graphic form means comparing specific information, selecting the highest, lowest, or somewhat interesting or different values. The task for the analyst in the worksheet was to compare two graphs and express how they differ (Task no. 5), search for similar information in several graphs (Task no. 7) or compare information from several years in one graph (Task no. 9). The most common mistake was that the pupils could not perceive and understand several pieces of information in the graph at the same time, compare them and record the differences appropriately. When comparing research samples, EG (IBE) achieved a higher success rate (average score 47.5%) than CG (TTM) (average score 17.2%).

Interpreting information in graphic form means finding the information from the graph that is not explicitly recorded, describing the relationships between variables, making judgments, and generalizations. Such tasks for working with information in graphs are quite common. In the worksheet, one of the tasks of this nature included naming the graph (e.g., "Incidence of ticks in the years 2016-2018", especially the pupils in CG were creative, they named their graph as "Tick graph", "My graph about ticks", etc.) (Task no. 9), description of what the graph expresses (Task no. 10), write at least two statements that result from the graph (Task no. 2-4). The most common mistake was that the pupils were unable to assess the relationship between the two quantities in the graph, express the content of the graph in the form of its appropriate name, and were unable to interpret and generalize from the graph information that was not explicitly recorded in it (e.g., "The number of ticks decreases with altitude"). When comparing research samples, EG (IBE) achieved a higher success rate (average score 51.78%) than CG (TTM) (average score 44.68%).

We consider the skills to **present information in graphic form** (create a graph) to be the highest level of working with information in the form of a graph. Task no. 8 was focused on this competence. The student's task was to express the information in the text, table, and graph in the form of a graph. The most common mistake was that the pupils did not take into account the graph's legend, did not mark the graph's axes, and did not choose the correct type of graph. Out of the total number of pupils (N=56), 79.49% of pupils successfully solved the task (2-1.5 points). When comparing research samples, EG (IBE) achieved a higher success rate (average score 82.6%) than CG (TTM) (average score 59.4%).

Thus, we have confirmed the assumption that through IBE, the pupils of the experimental group (IBE) will achieve better performance in solving graphic tasks compared to the control group (TTM). In all monitored areas, ES pupils showed higher scores than CG (Fig. 2). Together, their performances improved by 19.76% (EG 63.05%; CG 43.28%). Even though the educational program Expedition – try, explore, learn is not primarily focused on working with graphs in the subjects of geography and biology, the pupils were able to read, analyze, interpret, and create graphs better. We noticed the most significant difference in tasks requiring analysis of information in graphic form (30.3%) and construction of graphs (23.2%). Pupils in EG also showed more courage and creativity when working with graphs.

Using the Pearson correlation coefficient, we researched whether there is a relationship between the achieved scores of pupils (N=56) in the graphic tasks of the worksheet and the pupils' final half-year grades in mathematics. According to Cohen's interpretation of the correlation coefficient (Cohen, 1988), the determined values indicate a moderate mutual correlation of the evaluated indicators (r is -0.37).

6. Discussion and conclusion

One of the critical tasks of geography and biology, as scientific disciplines and educational subjects, is to develop students' knowledge, abilities, and skills regarding the search, evaluation, interpretation, and presentation of information about the landscape, nature, and their components (ŠPÚ/NEI, 2014a, 2014b). One of the effective options is the use of graphs. From the cognitive level of working with graphs, we found that pupils achieved better results in questions of graphing skills at the primary level (reading data) (61% success). Still, they had more problems with questions of graphing skills at the intermediate level (analysis, interpretation) (42% success rate). These findings are parallel to several previous studies (Bursal & Yetis, 2020; Koparan & Güven, 2013; Lai et al., 2016; Ozmen et al., 2020), with the difference that the pupils of our research sample did not have such big problems with the construction of graphs, as was the case in the studies above. The main reason for the lower success of pupils with intermediate graphic skills can be explained as the tendency of pupils to focus on explicit rather than implicit information in graphs, which is also stated by Postigo and Pozo (2004). The results of a questionnaire survey of pupils with TTM and IBE in the subjects of geography and biology point to graphic literacy in both groups, which is often developed in mathematics class. According to several studies (Ludewig, 2018; Yingkang and Yoong, 2007), pupils generally believe that their skills are high enough to work with graphs. This was also confirmed in our findings; in the TTM (CG) class, this attitude was even more positive than in the IBE (EG) class. One of the possible explanations is minimal exposure to graphs, which may result in overestimating one's graphic skills. When evaluating the pupils' performances themselves in the context of several areas of the skills to work with information in graphic form (through a worksheet), we found both a lower than the pupils' expected level of graphic skills and a significant difference (by 19.76%) between pupils with TTM and IBE. Pupils' performance with the research method of teaching was better than that of pupils with TTM. The most significant difference was in the analysis of graphic information (30.3%) and the creation of a graph (23.2%). When analyzing the pupils' performances, we also revealed several specific problems mentioned in other studies (e.g., Capraro et al., 2010; Boote, 2014; Kulm, & Capraro, 2005). The most important reason why pupils encounter these problems is the ineffectiveness of school teaching in developing their graphic literacy (Gioka, 2007; Tairab & Al-Naqbi, 2004; Uk et al., 2016). Even though the research educational program Expedition - try, explore, learn is not primarily focused on working with graphs in the subjects of geography and biology, as a result of the fact that pupils with IBE have better developed essential and integrated abilities of scientific work, which is vital as a prerequisite for working with information in graphic form (Škodová, 2018a), our findings point to a positive effect of IBE in this area. We recommend, also within IBE, to include in the teaching of geography and biology tasks requiring work with information expressed in various types of graphs, to emphasize the correct acquisition of the conceptual apparatus related to graphs and to guide pupils to create graphs when presenting the information and data obtained. This study was conducted on a sample of Slovak pupils. Still, the literature emphasizes that problems related to graphs are common in all countries and levels of education. Therefore, new studies presenting the effects of innovative teaching concepts on the cognitive level and attitudes of pupils in the context of their graphic skills are needed.

Acknowledgments

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References

- Al-Bahushi, S. M., & Al-Aamri, S. S. (2014). The effect of environmental science projects on students' environmental knowledge and science attitudes. *International Research in Geographical and Environmental Education*, 23(3), 213-227. <https://doi.org/10.1080/10382046.2014.927167>
- Belser, Ş. (2009). *Determining 8th grade students' difficulties in reading and interpreting graphs of the photosynthesis subject*. Blacksea Technical University.

- Berg, C. A., & Smith, P. (1994). Assessing students' abilities to construct and interpret line graphs: Disparities between multiple-choice and free-response instruments. *Science Education*, 78(6), 527-554. <https://doi.org/10.1002/sce.3730780602>
- Boote, S. K. (2014). Assessing and understanding line graph interpretations using a scoring rubric of organized cited factors. *Journal of Science Teacher Education*, 25(1), 333-354. <http://dx.doi.org/10.1007/s10972-012-9318-8>
- Bursal, M. & Yetiş, S. (2020). Middle school students' graph skills and affective states about graphs. *International Journal of Research in Education and Science (IJRES)*, 6(4), 692-704. <https://doi.org/10.46328/ijres.v6i4.1136>
- Capraro, M. M., Kulm, G., & Capraro, R. M. (2005). Middle grades: Misconceptions in statistical thinking. *School Science and Mathematics*, 105(4), 165-174. <https://doi.org/10.1111/j.1949-8594.2005.tb18156.x>
- Chráska, M. (1999). *Didaktické testy ve školní praxi* [Didactic tests in school practice]. Paido.
- Csachová, S. (2016). Nepresnosti vo formulovaní testových úloh z geografie [Inaccuracies in formulating questions in geography test]. *Geogr. Cassoviensis*, 10(2), 122-130.
- Csachová, S. (2018). Directed transfer of innovations to geographical education – experience from the IT Academy project. In H. Čtrnáctová et al. (Eds.). *DidSci Plus: Research in Didactics of Science PLUS* (pp. 479-487). Charles University.
- Dostál, J. (2015). *Badatelsky orientovaná výuka: pojetí, podstata, význam a přínosy* [Inquiry-based instruction Concept, essence, importance and contribution]. Univerzita Palackého v Olomouci.
- Farárik, P. (2022). *Geografia je úzko prepojená s matematikou, preto by mali učitelia týchto predmetov viac spolupracovať. Pozrime sa, ako na to* [Geography is closely linked to mathematics, so teachers in these subjects should cooperate more. Let's see how you do that]. <https://lepsiageografia.sk>
- Flybvjerg, B. (2006). Five misunderstandings about case study research. *Reis*, 106(4), 33-62. <https://doi.org/10.2307/40184584>
- Friel, S. N., Curcio, F. R., & Bright, G.W. (2001). Making sense of graphs: Critical factors influencing comprehension and instructional implications. *Journal for Research in Mathematics Education*, 32(2), 124-158. <https://doi.org/10.2307/749671>
- Fry, E. (1981). Graphical literacy. *Journal of Reading*, 24(5), 383-389.
- Ganajová, M. (2016). *Bádateľsky orientovaná výučba so zameraním na overovanie porozumenia a rozvoja bádateľských zručností* [Inquiry-based teaching with the aim of verifying understanding and the development of inquiry skills]. In Ivan, M., & Sulcová, R. (Eds.). *11. Mezinárodní seminář studentů doktorského studia oboru Didaktika chemie* (pp. 8-19). Nakladatelství P3K.
- Gavora, P., et al. (2010). *Elektronická učebnica pedagogického výskumu* [Electronic book of pedagogical research]. Univerzita Komenského. <http://www.e-metodologia.fedu.uniba.sk>
- Gillette, B. (2015). The nature and process of science and applications to geography education: a US perspective. *International Research in Geographical and Environmental Education*. 24(1), 6-12. <https://doi.org/10.1080/10382046.2014.967112>
- Gioka, O. (2007). Assessment for learning in teaching and assessing graphs in science investigation lessons. *Science Education International*, 18(3), 189-208.
- Held, L., Žoldošová, K., Orolínová, M., Juricová, I., & Kotuláková, K. (2011). *Výskumne ladená koncepcia prírodovedného vzdelávania*. (IBSE v slovenskom kontexte) [Inquiry-based science education. (IBSE) in the Slovak context]. Typi Universitatis Tyrnaviensis.
- Johanson, R. (2003). Case study methodology. *Acta linguistica Hungarica*, 32(1), 22-24.
- Karolík, Š., Král, M., & Čipková, E. (2018). Does the application of tasks focused on the active work with graphs affect students' skills of reading and interpreting graphs? *Biologie, chemie, zeměpis*, 27(3), 31-42.
- Koparan, T., & Güven, B. (2013). A study on the differentiation levels of middle school students' statistical thinking. *Elementary Education Online*, 12(1), 158-178. <https://ilkogretim-online.org/index.php/pub/article/view/5315>
- Koršňáková, P., Kováčová, J., & Heldová, D. (2010). *Národná správa OECD PISA SK 2009 [PISA 2009: Slovakia national report]*. Národný ústav certifikovaných meraní vzdelávania / National Institute for Certified Educational Measurements. https://www2.nucem.sk/dl/3487/N%C3%A1rodn%C3%A1_spr%C3%A1va_PISA_2009.pdf
- Lai, K., Cabrera, J., Vitale, J. M., Madhok, J., Tinker, R., & Linn, M. C. (2016). Measuring graph comprehension, critique, and construction in science. *Journal of Science Education and Technology*, 25(4), 665-681. <https://doi.org/10.1007/s10956-016-9621-9>

- Leu, D. J., Kinzer, C. K., Corio, J. L., & Cammack, D. W. (2004). Towards a theory of new literacies emerging from the internet and other information and communication technologies. In Unrau, N. J. & Ruddell, R. B. (Eds.), *Theoretical models and process of reading 5* (pp. 1570-1613). International Reading Association.
- Lowrie, T., & Diezmann, C. M. (2011). Solving graphics tasks: Gender differences in middle-school students. *Learning and Instruction, 21*(1), 109-125. <https://doi.org/10.1016/j.learninstruc.2009.11.005>
- Ludewig, U., Lambert, K., Dackermann, T., Scheiter, K., & Möller, K. (2020). Influences of basic numerical abilities on graph reading performance. *Psychological Research, 84*(5), 1198-1210. <https://doi.org/10.1007/s00426-019-01144-y>
- Mareš, J. (2015). Výukové prípadové studie a jejich využití [Instructional case studies and their use]. *Orbis scholae, 10*(1), 121-139. <https://doi.org/10.14712/23363177.2016.16>
- Nicolao, C. T., Nicolaidou, I. A., Zacharia, Z. C., & Constantinou, C. P. (2007). Enhancing fourth graders' ability to interpret graphical repr. through the use of microcomputer-based labs implemented within an inquiry-based activity sequence. *The Journal of Computers in Mathematics and Science Teaching, 26*(1), 75-84.
- Ozmen, Z. M., Guven, B., & Kurak, Y. (2020). Determining the graphical literacy levels of 8th grade students. *Eurasian Journal of Educational Research, 86*, 269-292.
- Patahuddin, S. M., & Lowrie, T. (2019). Examining teachers' knowledge of line graph task: A case of travel task. *International Journal of Science and Mathematics Education, 17*(4), 781-800. <https://doi.org/10.1007/s10763-018-9893-z>
- Picone, Ch., Rhode, J., Hyatt, L., Parshall, T. (2007). Assessing gains in undergraduate students' abilities to analyze graphical data. *Teaching Issues and Experiments in Ecology, 5*(1), 1-54.
- Postigo, Y., & Pozo, J. I. (2004). On the road to graphicacy: The learning of graphical representation systems. *Educational Psychology, 24*(5), 623-644. <https://doi.org/10.1080/0144341042000262944>
- Shah, P., & Hoeffner, J. (2002). Review of graph comprehension research: Implications for instruction. *Educational Psychology Review, 14*(1), 47-69. <https://doi.org/10.1023/A:1013180410169>
- Sofa, F. (1985). Graphic literacy: Part I. A review of the literature. *Journal of Vocational Education and Training, 37*(98), 107-113. <https://doi.org/10.1080/10408347308002541>
- Šiškovič, M., & Toman, J. (2014). *PISA 2012: Výsledky Slovenska v kocke* [Slovakia's results in cube]. Inštitút vzdelávacej politiky, MŠVVaŠ SR, Komentár 01/2014.
- Škodová, M., & Turošíková, M. (2020). Hodnotenie bádateľsky orientovaného vyučovania geografie na ZŠ [Evaluation of inquiry-based geography education in elementary school]. *Geografické informácie, 24*(1), 254-268. <https://doi.org/10.17846/gi.2020.24.1.254-268>
- Škodová, M. (2018a). Príklady aplikácie induktívneho prístupu vo vyučovaní tematického celku zobrazovanie Zeme na ZŠ [Examples of the inductive approach application in teaching about imaging earth in elementary school]. *Geografické informácie, 22*(1), 485-495. <https://doi.org/10.17846/gi.2018.22.1.485-495>
- Škodová, M. (2018b). Bádateľsky orientované aktivity vo vyučovaní geografie miestnej krajiny [Application of inquiry-based methods in teaching geography]. In Rusek, M., Honskusová, L. & Vojíš, K. (Eds.), *Projektové vyučovanie v prírodovedných predmätach XV.: Praktické námety*. Project-based education in science education in practice XV (pp. 51-57). Univerzita Karlova. https://pages.pedf.cuni.cz/pbe/files/2019/09/PBE2017_prakticke_final.pdf
- ŠPÚ/NEI (National Institute for Education, Slovakia). (2014). *Inovovaný Štátny vzdelávací program pre nižšie stredné vzdelávanie: Geografia, Biológia* [The State Education Programme for Lower Secondary Education: Geography, Biology]. https://www.statpedu.sk/files/articles/dokumenty/inovovany-statny-vzdelavaci-program/geografia_nsv_2014.pdf, https://www.statpedu.sk/files/articles/dokumenty/inovovany-statny-vzdelavaci-program/biologia_nsv_2014.pdf
- ŠPÚ/NEI (National Institute for Education, Slovakia). (2021). *Vzdelávanie pre 21. storočie: Východiská zmien v kurikule základného vzdelávania* [Education for the 21st century: Background to changes in the primary education curriculum]. <https://vzdelavanie21.sk/zmeny-v-obsahu-a-forme-vzdelavania/elementor-688/>
- Tairab, H. H., & Al-Naqbi, A. K. K. (2004). How do secondary school science students interpret and construct scientific graphs? *Journal of Biological Education, 38*(3), 127-132. <https://doi.org/10.1080/00219266.2004.9655920>

- Tiefenbruck, B. F. (2007). *Elementary teachers' conceptions of graphical representations of categorical data*. University of Minnesota.
- Tolmáči, L., & Križan, F. (2014). *Tvorba testových úloh pre predmet geografia. Špecifická tvorby testov v geografii* [Creation of test tasks for the geography subject. Specifics of creating tests in geography]. Materiál pre projekt Moderné vzdelávanie pre vedomostnú spoločnosť. Metodicko-pedagogické centrum v Bratislave.
- Tomková, V. (2012). Priestorová predstavivosť vo vzdelávaní na základnej škole [The space imagination in primary school education]. *Trendy ve vzdelávaní*, 5(1), 304-308.
- Uk, I., Matuk, C., & Linn, M. C. (2016). Students using graphs to understand the process of cancer treatment. In Looi, Ch., & Polman, J. (Eds.), *International Conference of the Learning Sciences* (pp. 721-728), National Institute of Education.
- Wainer, H. (1992). Understanding graphs and tables. *Educational Researcher*, 21(1), 14-23. <https://doi.org/10.3102/0013189X021001014>
- Woller-Carter, M. M., Okan, Y., Cokely, E. T., & Garcia-Retamero, R. (2012). Communicating and distorting risks with graphs: An eye-tracking study. *Annual Meeting of the Human Factors and Ergonomics Society*, 56 (1), 345-352. <https://doi.org/10.1177/1071181312561345>
- Ying kang, W., & Yoong, W. K. (2007). Exploring attitude toward statistical graphs among Singapore secondary school students. *The Mathematics Educator*, 10(1), 39-58. https://math.nie.edu.sg/ame/matheduc/journal/v10/v10_39.aspx
- Zhang, D. C. (2016). *Using icon array as a visual aid for communicating validity information*. Bowling Green State University.
- Žáčok, E., & Schlarmanová, J. (2005). Metodika tvorby pracovných listov pre základné školy [Methodology for creating worksheets for primary schools]. *Technológia vzdelávania*, 13(7), 23-34.
- Žoncová, M., & Vojteková, J. (2018). Vzdelávacie aktivity zamerané na geografiu v predprimárnom vzdelávaní [Educational activities focused on geography in pre-primary education]. *Geografické informácie*, 22(1), 552-562. <https://doi.org/10.17846/GI.2018.22.1.552-56>

Colors from the Perspective of a Chemistry Teacher

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Abstract. Color reactions, or chemical reactions where colors are changed, are often used in chemistry teaching. Chemical reactions that take place with a color change are more attractive to students and increase their attention. And from the students' point of view, the change of color proves that a chemical reaction is taking place. In the teaching of chemistry, we encounter a number of color reactions, such as carbohydrate evidence reactions, analytical reactions using the formation of a precipitate or a change in the color of indicators in acid-base reactions, or color reactions of natural substances. The work is focused on the perception of colors and their change in connection with chemical reactions and changes in the structure of compounds.

1. Introduction

Engaging students in the classroom is an increasingly challenging task for teachers. Pupils spend more and more time watching videos and entertainment channels on the Internet and find "ordinary" life boring and less interesting (Smahel et al., 2020). This is why activating pupils in the classroom has become one of the main topics for teachers. Topics that are attractive to pupils, increase their attention, and evoke a positive emotional connection contribute to activation. Another important role is played by an appropriate teaching method. Modern teaching methods such as IBSE, STEM, TASC, or project-based learning help pupils to actively develop and process the assigned topic, teach them to be independent, and help them to fulfil the key competences as defined in the RVP (Ministry of Education, Youth and Sports of the Czech Republic - MEYS, MŠMT in Czech, 2021).

A topic that offers pupils a lot of topics is "Colors". The colors of substances, the composition of colors, the nature of color vision, color reactions, or chemical reactions in which colors change. The topic of "Colors" is a suitable cross-curricular topic that develops inter-subject relations and deepens the connection between the partial knowledge of the individual science subjects.

2. Perception of light

Physics describes light as an electromagnetic wave with a wavelength λ in the range of 400nm to 700nm, which evokes a color sensation in the human brain. The light enters the eye through the cornea, where the beam is refracted and progresses through the conjunctiva and vitreous to the light-sensitive layer - the retina. The events that take place on the retina and the resulting sensations we perceive are the result of photochemical-neurological processes in the brain and psychological responses. The explanation of the processes and the origin of the sensations that are associated with vision, and their full understanding, must go beyond the ordinary conception of individual subjects, whether chemistry, biology, or physics. Even the division into individual teaching subjects is itself a humanly established convention and, in effect, an unnatural thing. Therefore, even the separate perception of physical, chemical, and biological processes is inherently nonsensical.

The retina is composed of cells of two kinds: rods and cones. Color vision is dependent on the intensity of light. Vision at low light intensity is mediated exclusively by rods. As the light intensity increases, the cones begin to process information, and the human eye begins to perceive color, which is why objects seen in dimness have no color. The change in the eye's sensitivity to particular wavelengths as a function of light intensity (Figure 1) is called the Purkinje effect. Inadequate illumination causes

color distortion, so sufficient illumination intensity is important when carrying out color chemical reactions.

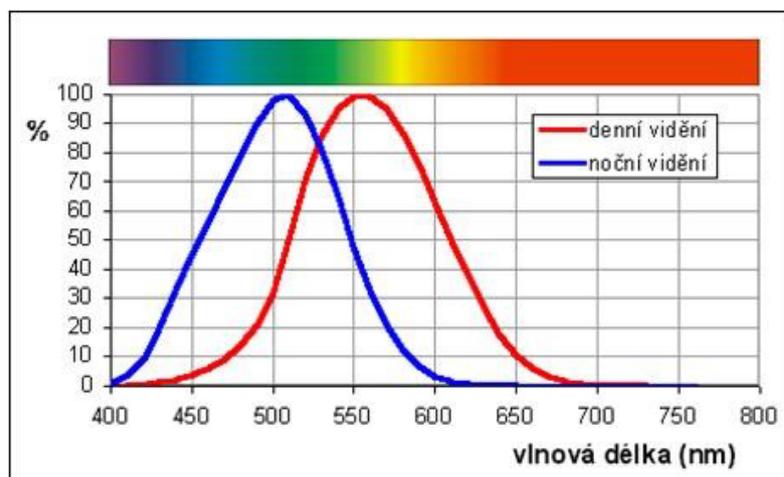


Figure 1. Purkinje effect (Wikisofia, 2022).

White light can be decomposed into a spectrum of individual wavelengths that we perceive as colors. The different light sources can be physically analyzed and described in terms of wavelength and intensity, but from a chemical and biological point of view, the important thing is the resulting perception caused by the effects of electromagnetic radiation, i.e., the color we see (Feynman et al., 2013).

The different colors of the color spectrum are produced by selecting a particular part of the electromagnetic spectrum or by adding up different wavelengths of the visible spectrum. The addition of different wavelengths is referred to as color mixing. Mixing produces different colors. For example, mixing wavelengths from the red and green regions of the spectrum produces the color yellow. Depending on the ratio of the wavelengths mixed, we get different shades of yellow. By mixing wavelengths from the green, red, and blue regions (often referred to by the English abbreviations Red, Green, Blue), we obtain the color white as the resulting color (Feynman et al., 2013).

3. Absorption of electromagnetic radiation

Color and color depend on the interaction of light with the molecules or ions of the substance under consideration. If visible light of a certain wavelength or range of wavelengths is absorbed by a substance, the remaining light has a complementary color. Examples are chlorophyll a, which absorbs light at 430nm and 662nm, or chlorophyll b with absorption maxima of 453nm and 642nm (Figure 2), these wavelengths corresponding to light in the blue and red regions of the spectrum. They are complementary to electromagnetic radiation from the green and green-yellow regions of the electromagnetic spectrum, which is why we perceive green plants as green (Amann et al., 2000).

By absorbing light of a certain wavelength, the electrons of atoms or molecules are transferred from the ground state (energy E_1) to the excited state (energy E_2). The difference in these energies corresponds to the energy of the absorbed light (Equation 1). Where h is Planck's constant and f is the frequency of the photon.

$$\Delta E = E_2 - E_1 = h \cdot \nu = h \cdot \frac{c}{\lambda}$$

Equation 1. The difference in energies (Amann et al., 2000).

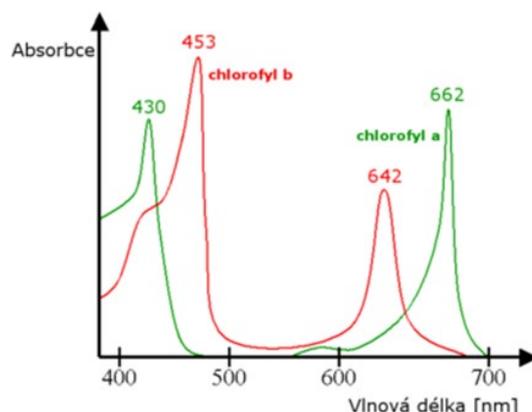


Figure 2. Absorption maximum of Chlorophyll a and b (Wikipedie, 2022).

Relatively easily excited are electrons of non-bonded electron pairs and π -electrons of double bonds. As the number of conjugated double bonds in a molecule increases, the energy supplied by light needed to excite an electron decreases. This implies that light absorption can occur in the longer-wavelength region of light - a shift into the visible region occurs.

The electron systems that absorb visible light in a molecule, thereby imparting color to the substance, are called chromophores. This interaction is used in dyes that we use as pH indicators. Phenolphthalein and malachite green are representatives of triphenylmethane dyes. In malachite green, the π -electron ring is spread over up to two dimethylamino groups, which can be represented by three mesomeric patterns, but two of them have the same energy, and the two borderline mesomeric structures differ significantly in energy. The mesomeric structures are shown in Figure 3. As a result, malachite green can absorb light at wavelengths of 621nm and 425nm, and the resulting solution appears yellow-green with a dominant green color. In an acidic environment, one proton attaches to the dimethylamine group to form an ammonium group, which does not engage in resonance, and the molecule cannot absorb light at a wavelength of 621nm. The resulting solution appears yellow. In alkaline solution, the conjugated π -electron multiple bond system is destroyed, and the compound is colorless (Amann et al., 2000).

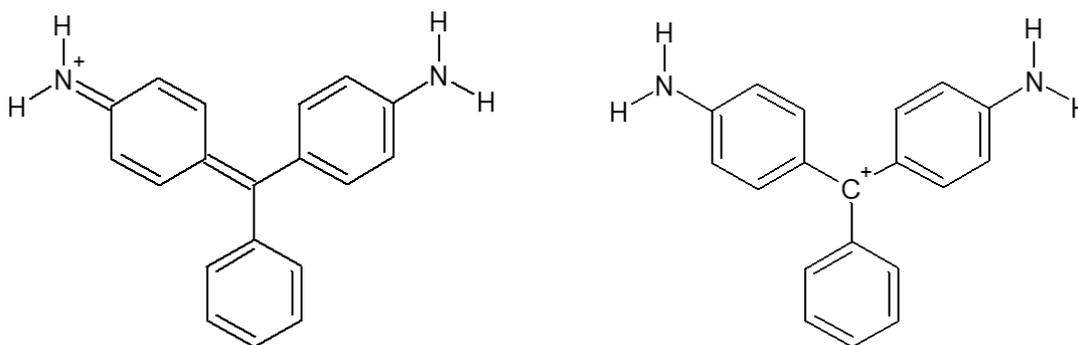


Figure 3. Resonant structures of malachite green in acidic and basic solutions (Holler & Crouch, 2014).

Phenolphthalein is another important representative of commonly used indicators. It belongs to the group of triphenylmethane dyes, but unlike malachite green, the central carbon atom is involved in a lactone ring. The lactone ring opens in strongly acidic or strongly alkaline environments, and this is the cause of the compound's off-color (Záruba et al., 2016).

Another important group of synthetic dyes that are used as pH indicators are azo dyes, which contain a characteristic azo group ($-N=N-$) that is part of the chromophore. The chromophore system of the

molecule usually extends from the electron-donor part of the molecule to the nitrogen atoms of the azos groups. The energies of the different mesomeric groups of the molecule are different and can therefore be effectively balanced by protonation of the azos groups. This results in a color change and is the principle behind the use of azo dyes as pH indicators. Some of the important azo dyes that are used as pH indicators include aniline yellow, methyl orange, and Congo red. The resonance structures of methyl orange are shown in Figure 4. In an acidic environment (protonated form), the solution is red (Holler & Crouch, 2014). In an alkaline environment, the methyl orange solution is yellow. Figure 5 shows the formula in congo red.

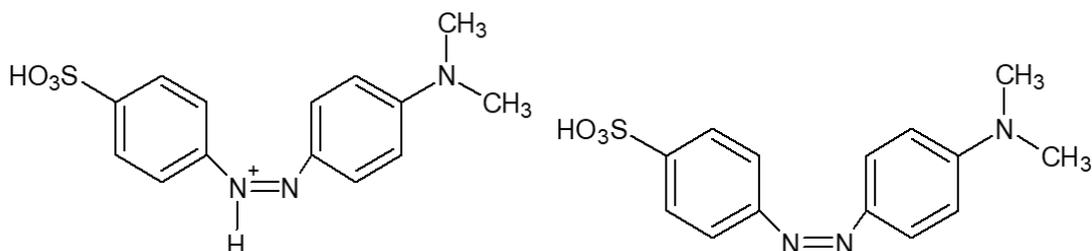


Figure 4. Structure of methylorange in acidic and basic solutions (Holler & Crouch, 2014).

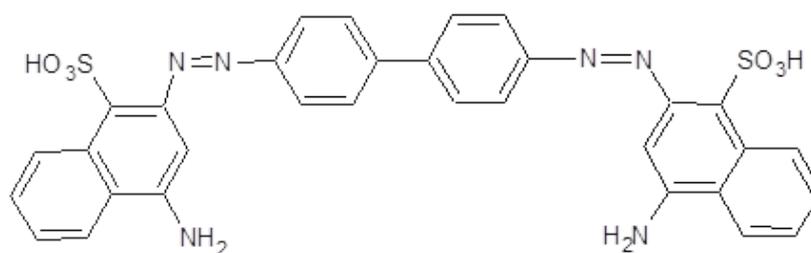


Figure 5. Congo-red indicator (Canov, 2009).

4. Colors as a cross-cutting theme in grammar school education

The project entitled "Colors" was assigned to ninth-grade students at a multi-year grammar school in the subjects of science, physics, and chemistry. The task was to divide the pupils into groups according to their own preference for the subject and to present to the other groups how a physicist, a biologist, and a chemist perceived the topic "Colors".

The groups had two hours from each subject to prepare their project. In total, the project preparation took 6 class lessons. The students could consult their ideas with the teachers of the subject. Two lessons were devoted to presenting the results of the pupils' work.

The group "Colors through the eyes of a physicist" focused on color addition. The pupils prepared a station for their classmates, where each pupil made his/her own rotating disc (a bucket) (Žaludová, 2016). They made a hole in the middle of the paper disc so that the disc could be threaded onto a pencil and attached to it with plasteline. The pupil divided the disc into several equal pieces (the more pieces, the greater the effect) and colored them with different colors. After spinning the disc, the pupils observed the effect of additive color folding. Depending on the colors used to color the pieces, the pupils observed the different resulting colors. Using red and green, they got yellow, blue, and green parts made cyan, and red and blue parts made magenta. If they used red, green, and blue to color the disc, they got the white day color.

The "Colors through the eyes of a biologist" group focused on the extraction and chromatographic separation of plastid dyes (Kubienova & Vinter, 2013). The students prepared a station called "Colors of Autumn" for their classmates, where the students verified the presence of green, red, and yellow dyes in the leaves of green plants using paper chromatography. They compared the chromatogram obtained with

the chromatogram of autumn colored leaves. Technical gasoline was used to extract the plastid dyes. At the end, the pupils illuminated the two chromatograms with a UV lamp and observed the chlorophyll fluorescence.

The group "Colors through the eyes of a chemist" chose pH indicators and their color changes as their topic. The group set up a station for their classmates to test the color change of the indicators phenolphthalein, methyl orange, and methylene red, depending on the pH of the solution. The pupils checked the pH of the solution with a universal pH indicator paper. The second experiment that the pupils could try at the station was the reaction of red cabbage extract to different pH values of the solution (Krejčíková & Richtr, 2009).

After the project, a "roundtable" was organized where pupils asked and answered questions of each other, evaluated the contribution of their own work, suggested changes in procedure and preparation, and formulated a final evaluation of themselves and the other groups. One class lesson was devoted to the final evaluation.

5. Conclusion

Colors and colors of substances is a very broad topic that can be included in primary and secondary school lessons as a cross-cutting theme in physics, chemistry and biology, or more generally in science subjects. Up to 80% of information about the functioning of the world around us is obtained by sight (Holeček et al., 2003). Color perception is not only a complex physiological process, but can be explained from a chemical, physical, biological, or psychological perspective. Everything is related to everything, and understanding of one must be supported by understanding of the other, and thus understanding of the whole.

This topic can be easily adapted to the age of the pupils, their existing knowledge and abilities, and can be designed as a research-oriented task, a problem-based task, a task for active thinking in a social context, or as a project day topic. This is because it can be approached from a variety of angles to support the development of cross-curricular relationships and the linking of pupils' newly acquired and previously acquired knowledge. The color of fabrics and understanding its nature is a topic that should be included in the curriculum, because without it the world would not be so beautifully colorful.

Acknowledgements

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References

- Amann, W., Eisner, W., Gietz, P., Maier, J., Werner, S., & Stein, R. (2000). *Chemie pro střední školy 2b* [Chemistry for upper secondary schools 2b] (Translation: Svoboda, J., & Kratochvíl, B.). Scientia, spol. s.r.o.
- Canov, M. (2009, February 1). *Formy kongačerveně* [Forms conga red]. Retrieved May 10, 2022, from <https://canov.jergym.cz/indikato/formy/kcerven.html>
- Chlorofyl* [Chlorophyll]. (2022, May 12). In *Wikipedie*. <https://cs.wikipedia.org/wiki/Chlorofyl>
- Feynman, R. P., Leighton, B., & Sands, M. (2013). Feynmanovy přednášky z fyziky: revidované vydání s řešenými příklady [Feynman lectures in physics: Revised edition with solved examples]. Fragment.
- Holeček, V., Miňhová, J., & Prunner, P. (2003). *Psychologie pro právníky* [Psychology for lawyers]. Aleš Čeněk, s.r.o.
- Holler, F. J., & Crouch, S. R. (2014). *Fundamentals of analytical chemistry* (9th ed.). Brooks/Cole.
- Krejčíková, A., & Richtr, V. (2009). Barevné experimenty v organické chemii [Color experiments in organic chemistry]. In M. Bílek (Ed.), *Výzkum, teorie a praxe v didaktice chemie XIX = Research, theory and practice in chemistry didactics XIX sborník přednášek 19. mezinárodní konference o výuce chemie: proceedings of the 19th international conference on chemistry education* (pp. 246-252). Gaudeamus
- Kubienová, L., & Vinter, V. (2013). *Experimenty pro přírodovědné kroužky* [Experiments for science circles]. http://www.priroda21.upol.cz/docs/Experimenty_pro_prirodovedne_krouzky_na_tema_rostliny_lecive_latky_drogy.pdf

- MŠMT (2021). Rámcový vzdělávací program pro základní školy [Framework educational program for primary schools]. (Jeřábek, J. & Tupý, J.). <https://www.edu.cz/rvp-ramcove-vzdelavaci-programy/ramcovy-vzdelavacici-program-pro-zakladni-vzdelavani-rvp-zv/>
- Purkyňův efekt* [Purkinje effect]. (2022, June 14). In *Wikisofia*. https://wikisofia.cz/wiki/Purky%C5%88%C5%AFv_efekt
- Smahel, D., Machackova, H., Mascheroni, G., Dedkova, L., Staksrud, E., Ólafsson, K., & Livingstone, S. (2020). *EU Kids Online 2020: Survey results from 19 countries*. EU Kids Online. <https://doi.org/10.21953/lse.47fdeqj01of0>
- Záruba, K. et al. (2016). *Analytická chemie I* [Analytical chemistry I]. VŠCHT.
- Žaludová, N. (2016, July 15). *Fyzikální pokus: Skládání barev* [Physics experiment: Color mixing]. <https://www.matfyz.cz/clanky/fyzikalni-pokus-skladani-barev>

Pilot Study Plan Proposal for a New Professionally Focused Study Program “Chemical Laboratory Technician - Specialist”

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Abstract. The Institute of Chemistry, Faculty of Science of Pavol Jozef Šafárik University (PF UPJŠ) in Košice is preparing a new professionally focused study program for future students. The social situation in Slovakia shows that the connection between young people's education and practical experiences from industry and services is necessary for a prosperous society in the future. Practical training must develop skills important for the workforce living in a technologically advanced economy. If we want to keep up with developed Europe and the world, in Slovakia, it is necessary to provide young people with the opportunities that foreign students use at advanced universities in the surrounding V4 countries, as well as throughout Europe. Our experiences from the solution of the project KEGA 008UPJŠ "Innovation of content, methods and forms of teaching practical exercises of chemical fields with direct participation of potential employers from practice" show that the Slovak industrial and institutional community in chemistry longs for such highly qualified graduates. Graduates are educated by Slovak universities, but with the significant support of foreign and some domestic institutions, which have a high-level instrument infrastructure. In Slovakia, such an instrument portfolio is missing at universities. Based on the above-mentioned fact, it is necessary to create a study program within the field of chemistry in Slovakia, the graduates of which will be directly prepared for practice. However, for a student to see his real readiness for the labour market, he/she must gain vast instrumental experience during his/her studies. With such knowledge and skills, he/she will also shift the state economy based on science and research, which he/she will apply to industry and services. The teachers from the Institute of Chemistry PF UPJŠ, together with experts from practice, involved in the creation of the professionally focused study program "Chemical Laboratory Technician - Specialist", will create materials for the elaboration of an accreditation file for quality education of the young generation ready for practice. The paper will present an initial proposal for the content of the study program, which was created based on cooperation between teachers and experts from practice. Moreover, the results of a survey of employers' requirements for graduates, as well as the connection between education and practice, will be presented.

1. Introduction

In the 21st century, the importance of the teaching of natural sciences and mathematics for economics is emphasized in the growth of countries. The emphasis in education is shifting from the content of teaching to the development of skills and abilities for the 21st century related to learning, as well as the application of young people to the labour market. Education must develop skills important to the workforce that will live in a technologically advanced economy (Hanushek & Woessmann, 2015). The labour market has also changed in Slovakia, and employers' requirements for school graduates have also changed. On the territory of Slovakia, as well as in Eastern Slovakia, there were several secondary schools at the end of the last century (Secondary vocational school of chemistry), which prepared graduates for work in industry and state administration laboratories. (e.g. Duslo a.s. Šaľa, healthcare, SAV, food industry, agriculture etc.). Currently, there is almost no secondary vocational school in Slovakia (mainly Eastern Slovakia), which would prepare students for the "Chemical Laboratory Technician" profession. When we monitored the situation in the surrounding countries, we found out that universities and colleges offer similar study programs at the bachelor's degree for such a profession. Based on the needs of the company and on the reasons mentioned above, we decided to offer a new bachelor's study program for students. In the paper, we deal with the survey analysis of a new study program among potential employers. Moreover, we present the results of the pedagogical survey.

2. Used methodologies

In order to find out the current situation with the implementation of the preparation of the young generation for the profession of "Chemical Laboratory Technician" in secondary schools, we conducted pedagogical research in the form of a questionnaire. The questions were as follows:

1. Which subjects and professional areas do you provide at school? (please choose from the menu)
2. How many students do you have on average per year in these fields?
3. Which chemistry subjects do you teach?
4. What kind of laboratory and equipment does the school have? (please list the laboratories and the devices used in them). What devices do you lack?
5. Which are the matriculation exam subjects that are related to chemistry?
6. Does the school provide education in the form of dual education?
7. How many hours of practice do your students have? (write in which year and the number of hours)
8. Are professional practices implemented in blocks or continuously?
9. Do experts from practice participate in the teaching process at your school? If so, on which subjects?
10. Is an expert from practice a member of the graduation committee?
11. Do students also complete international short-term internships? If so, where and in what form
12. What is the demand for your graduates from the practice side? Try to write in percentages.
13. Which workplaces are "customers" of your graduates (e.g., pharmacies - two graduates, Slovnaft - two graduates, etc.)?
14. How many graduates continue their education at universities (in percentage)?
15. Which universities do your students prefer?

Similarly, with the aim of finding out the requirements and needs of potential employers, we conducted a survey and asked experts from practice in the form of a questionnaire. The questions were as follows:

1. Write: Graduates of which fields are needed for your company?
2. Do you employ chemical graduates in your company?

- Yes
No
3. Are graduates available on the labour market for the job positions that you want?
Yes
No
 4. If yes, write what positions chemistry graduates actually hold in your company?
 5. Which level of completed education do you require for chemical graduates to work in an operational laboratory? Please explain.
BSc.
MSc.
 6. Do chemical graduates have sufficient knowledge necessary for the performance of their job classification?
Yes
No
 7. Do chemical graduates have sufficient skills necessary for the performance of their job classification?
Yes
No
 8. If not, write which knowledge and skills you think graduates of chemistry departments lack? What specific subjects or thematic areas in the teaching of chemistry would you suggest to include or improve, so that a graduate suitable and better prepared for the profession in your company.
 9. Students of chemistry majors should complete theoretical training directly in practice.
Yes
No
 10. What are the biggest shortcomings in the preparation of university graduates for practice?

Graduates lack experience	Yes No
Graduates are not independent	Yes No
They should have experience directly in companies	Yes No
The educational system at universities is outdated	Yes No
Within the study, theory is not connected with practice	Yes No
University studies are too theoretical	Yes No
Other? Fill in please.....	
 11. When looking for a new employee, would you prefer cooperation with the university over advertising? (These two methods represent the most widespread forms of searching for new employees - applications for employment sent by graduates and active advertising; Employer survey from 2015)
Yes
No
 12. What kind/kinds of cooperation between employers and universities do you prefer or would you recommend?

Cooperation in projects	Yes No
Cooperation in the management of final theses	Yes No
Cooperation in organizing professional practice	Yes No
Participation in state fairs, selected lectures	Yes No
Participation in conferences organized by the University	Yes No
Reminder of study programs	Yes No
Other? Fill in please.....	

3. The result of the pedagogical survey

We approached 12 secondary vocational schools. The analysis of teachers' answers to questions in the questionnaire showed:

- Teachers primarily provide the following subjects at schools: Biotechnology, Pharmacology and Technology
- The average number of students per year is 12-20
- The following subjects are taught as part of the preparation: analytical chemistry, chemical calculations, toxicology, pharmaceutical chemistry, biotechnology, chemical and biochemical analyses, applied chemistry, etc.
- School equipment - is insufficient - schools have laboratories, but their equipment is outdated, classic, and insufficient for preparation in the current era. They have the following devices: analytical scales, oven, fume hood, thermometers...
- The matriculation exam consists of a theoretical and a practical part:
Theoretical part - chemical and biochemical analyses, pharmacology, applied chemistry
Practical part - knowledge from practice and from the subject of the chemical laboratory exercises are tested
- Teaching in the form of dual education is not implemented
- Professional internships are implemented in blocks
- International internships are mostly not implemented, in the past, due to the "Covid pandemic" some schools did, but not currently
- The graduation committee rarely includes an expert from practice
- Applicability of graduates in practice – approx. 80%
- List of workplaces that are customers of graduates: pharmacies, laboratories in hospitals, Chemosvit, Slovnaft
- Approximately 80% of graduates continue their studies at universities
- Graduates prefer to study at the following schools:
Faculty of Pharmacy UK Bratislava, Faculty of Pharmacy UVLF Košice, Faculty of Health Sciences Prešov, Faculty of Chemical Technology Bratislava, Czech Universities – in Olomouc, Pardubice, and Prague

4. The result of the survey: Opinions and attitudes of employers towards the preparation of the chemical laboratory technician profession

We carried out research using a questionnaire of our own construction. Five experts from practice were included in this survey. The middle management, with long professional experience, was involved. The questions of the questionnaire were divided into several parts:

1. Current situation with work positions in the field of chemistry in Slovakia
2. Required knowledge and skills for the work of chemical laboratory technicians
 - The research showed that all respondents employ graduates of chemical fields, especially in the following positions: Chemical laboratory assistant, Chemist in chemical production with skills in analytical chemistry, metallurgy, or biology.
 - The Slovak market lacks graduates to fill the following chemical positions: chemical laboratory assistants, who should have basic theoretical knowledge in the field of chemistry, but mainly should have mastered the practical skills of a laboratory technician in performing individual chemical analyses and operating analytical instruments. Theoretical knowledge, practical skills (basic laboratory work), working with a PC, language skills - should be provided by the university. However, some theoretical knowledge could also be gained in practice. Vocational training should be implemented directly in practice. In practice, there are such experts who were trained even before the years 1990-2000.

3. Chemical graduates lack the following knowledge and skills:
 - chemical data processing, use of statistical methods in data processing,
 - practical skills related to the operation of equipment, insufficient skills in laboratory and instrument technology, instrumental methods, measurements, e.g., can be observed among graduates. on analytical instruments, etc.,
 - independence,
 - the ability to connect theory with practice, some respondents see the fact that university training is too theoretical as a problem.
4. In order to improve the training of future chemical laboratory technicians, they would recommend the following cooperation between companies and universities: cooperation in conducting final theses, cooperation in teaching, analysis, and comments on study programs, cooperation in projects, cooperation in contributions to conferences, etc.

5. Draft study plan of a pilot professionally focused study program

Mandatory subjects

1st year

General chemistry
Chemical calculations I
Chemical nomenclature I
Basics of mathematics
Basics of physics
Basic methodologies in the chemical laboratory
Analytical chemistry
Chemical calculations II
Inorganic chemistry
Practical course in inorganic chemistry
Organic chemistry
Practical course in analytical chemistry
Chemical nomenclature II
Basics of chemical technology

2nd year

Practical course in organic chemistry
Biochemistry
Physical chemistry
Practical course in physical chemistry
Practical course in biochemistry
Analytical chemistry in practice
Quality management and good laboratory practice
Instrumental laboratory practice
Basic methodologies in the chemical laboratory II
Basics of chemical engineering

Compulsory elective subjects

Safety regulations in chemistry
STN standards of chemical industry products
Chemical technologies (contribution of all departments)
Basics of electroanalytical methods
Basics of separation methods
Basics of optical methods

Environmental chemistry
Basics of chemical production
Green analytical chemistry and measurement automation
Instrumental practicum (contribution of all departments)
Chemical industry

Elective subjects

Industrial ecology
Biotechnologies
Basics of pharmaceutical chemistry
Nanotechnology
Battery and hydrogen technologies
Basics of mineralogy
Basics of bioanalytical chemistry

3rd year

Instrumental laboratory exercise in practice	block*
Professional stay	block**
Professional stay	block**

* Block exercises in the first half of the semester - (rotating around the contracted laboratories, a different external workplace every week)

**professional internship at contracted workplaces - (each external workplace would have a maximum of two students)

**professional internship at contracted workplaces - (each external workplace would have a maximum of two students)

State final exam (SFE)

Subject SFE	Chemistry
Final thesis	Defence

The proposal for the professional stay educational program was developed in cooperation with experts from practice:

1. Entry training in OSH (Occupational health and safety) and FP (Fire protection)
2. Survey of the company's production and auxiliary facilities
3. Acquaintance with the quality management system according to ISO 9001 and the environment according to ISO 14001
4. Acquaintance with the documentation related to work at the Quality department (guidelines, internal work procedures, internal regulations)
5. Acquaintance with Safety Data Sheets
6. Acquaintance with work on individual analytical devices
7. Learning the methods of the analysis, determining input materials, intermediate products (production process control), and finished products
8. Recording and distribution of the results of individual analyses

Detailed study plans of individual external training workplaces will be set according to their focus.

6. Conclusion

Based on the conducted surveys, it is clear that the profession of “Chemical Laboratory Technician” is gradually disappearing on the Slovak labour market. Experts in this field are of retirement age, and the current education system does not offer studies in this field. Based on a survey among experts in practice, it is necessary to connect the knowledge and experience of higher education and the chemical industry in the education of graduates for the profession of Chemical Laboratory Technician. Experts in practice see their involvement in the teaching process in the form of participation in the educational process (participation in a lecture, cooperation in conducting final theses, cooperation on study programs formation, cooperation on projects and conferences, etc.). In cooperation with practice, a pilot draft of a new study program was created with mandatory and optional subjects, as well as with the implementation of professional practice directly in operating laboratories. As part of the new study program, we consider the practical teaching of students on modern devices and equipment to be crucial, thanks to which they can bring innovations and new ideas into practice.

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References

Hanushek, E. A., & Woessmann L. (2015). *The knowledge capital of nations: Education and the economics of growth*. MIT Press.

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The Impact of Online Teaching on the Implementation of Standard Didactic Methods and Resources in Teaching

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Abstract. The article is devoted to a survey that maps the impact of online teaching on the implementation of standard didactic methods and standard teaching aids in the teaching process. The aim of the research was to find out the possibilities of different online platforms for conducting teaching in this area from the teachers' perspective and to identify the weak points of these tools based on their comments. The findings of the survey then provide a valuable basis for the design and implementation of teacher training courses in this area.

1. Research objectives

The research objective was to map the impact of software tools deployment on the implementation of standard and new didactic methods and means in education, primarily during the COVID-19 pandemic. The expected outcome of this research is the conclusions that will lead to the design of new further education courses that will allow teachers to better apply standard didactic methods, deploying classical aids and tools in a digital learning environment. (hereunder "DLE"). The findings are extended by the implementation of new methods and tools related to the DLE environment.

We introduced the term *digital learning environment* for the purpose of our research, and it is an environment of tools that enable the application of synchronous or asynchronous learning or a combination of both through IT technologies. This term is also used in the international literature. For example, as early as 2000, the issue of the impact of these technologies on the teaching process was addressed by Katzensteiner (Katzensteiner et al., 2022). One of the works considering the COVID-19 pandemic's impacts is Peters (Peters, 2000).

2. Research methodology

The research was divided into two questionnaire surveys. The first questionnaire survey focused on the effectiveness of deploying tools of a digital learning environment in a general sense, considering the teacher's perspective. The survey was actively participated by 241 teachers out of all the addressed respondents. We contacted more than 400 teachers in total. The respondents answered 30 structured questions in an electronic questionnaire. The questionnaire was divided into three parts focused on the acquisition of basic information on the respondent, knowledge and skills of work with these tools in a digital learning environment, and availability of these tools at schools and training support.

The second questionnaire survey was also conducted in the form of an electronic questionnaire. The survey addressed the same set of respondents, 283 of whom took part. The survey included 17 questions. All questions were focused on the possibilities of implementing individual phases of the teaching process and didactic tools.

Both questionnaire surveys were carried out in the second half of 2020, i.e., in the period when the teaching process was hampered by anti-epidemic measures and the work with tools of a digital learning environment was a must and an everyday routine.

3. Structure of the deployed tools of a digital learning environment

In the introductory part of this research, we acquired information on the respondents. The information enabled us to describe the structure of the research sample. It was fundamental to find out what type of school the respondents work at, as well as the scope of activities they perform. Regarding the type of school, we categorised the teachers for easier interpretation, see Fig. 1. The graph depicts 283 completed responses, which is caused by the fact that some respondents worked at more types of schools and completed the questionnaire for each school. The graph reveals that most teachers are from primary and secondary schools.

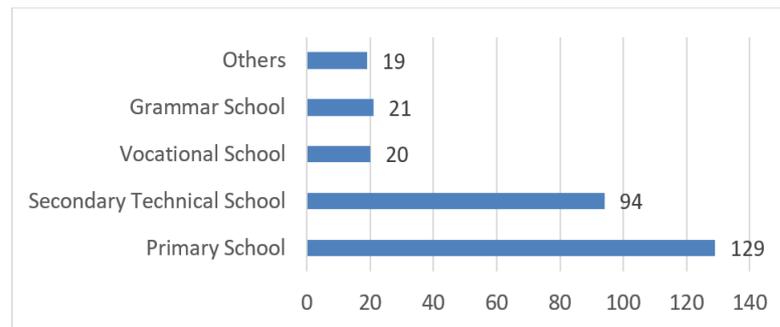


Figure 1. Structure of responses by type of school.

The second parameter, which was fundamental to define the structure of the research sample, was the area of education in which the respondent acted. The structure of responses is depicted in Fig. 2. The structure clearly shows that the prevailing respondents acted in Natural Sciences, Mathematics, and Informatics.

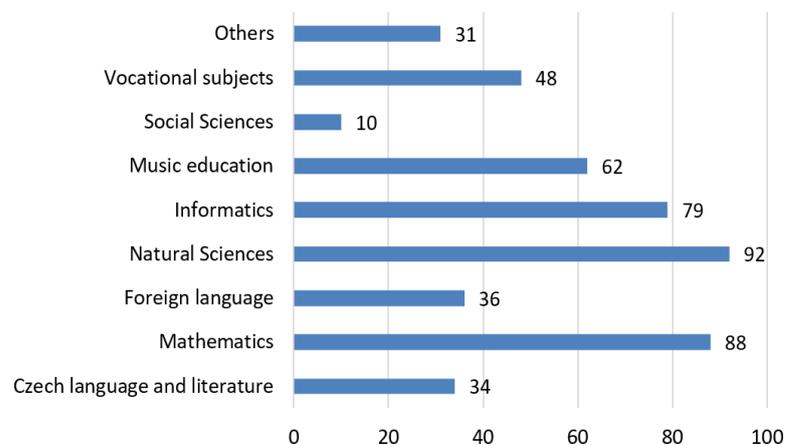


Figure 2. Structure of responses by teaching areas.

The next set of questions was focused on the knowledge of different software environments that can be used as a tool for digital learning environments. This set of questions was designed as closed-response, multiple-choice questions. The knowledge structure of each tool is documented in Table 1.

Table 1. Knowledge of the tools of the digital learning environment.

Software environment	Number of responses declaring knowledge of this tool	Knowledge of DLE tools in %
Microsoft Teams	195	25.8
Webex	16	2.1
Zoom	107	14.1
Google Classroom	164	21.8
Google Meet	133	17.6
LMS Moodle	101	13.4
Edookit	17	2.2
Others	23	3.0

The findings show the prevalence of the Microsoft Teams and Google Classroom platforms, but it is essential to note that a significant group of teachers use more tools in parallel. Similar results are to be found in Lidinillah (Lidinillah, Robandi, Wahyudin, & Dianasari, 2021). This fact is caused by the complexity of these environments from the point of view of available tools and primarily the support of synchronous part of learning in the form of video calls and the possibility to share outputs, which was crucial during the research period. Regarding this trend, it is highly interesting to observe the use of individual components offered in these complex environments. This can be illustrated in the most well-known tool - Microsoft Teams. The research on teachers' preferences in using and preferring individual DLE tools is also to be found in Gavrilova (Gavrilova, 2021; Edelhauser & Lupu-Dima, 2021). These focus on the area of primary education in the region of Eastern Europe.

The complex environment of Microsoft Teams offers its users the following functions: chat, sharing study materials, testing using Forms, and assigning and assessing tasks. Since Microsoft Teams is part of Microsoft 365, users can also share other tools and files of various types. Therefore, we prepared a closed response on these tools. Figure 3 reveals that the most used tools are applications of the office package and cloud. For the purposes of testing students and getting feedback, the respondent frequently used the tools of forms and quizzes (Forms).

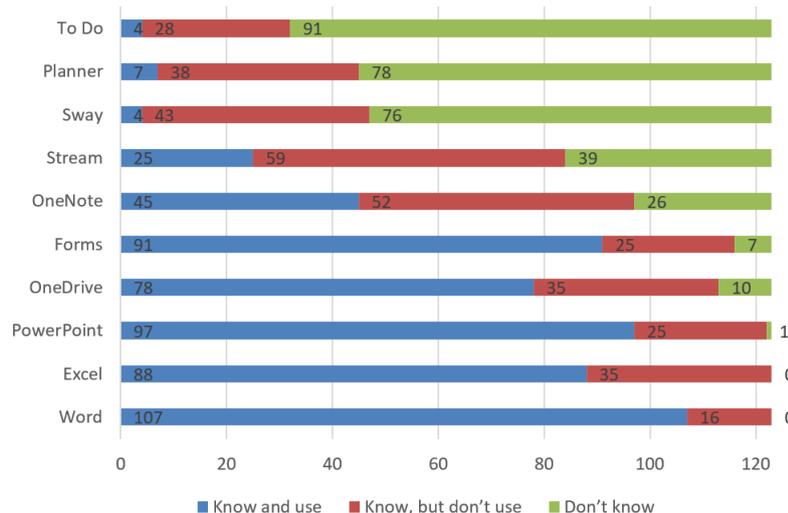


Figure 3. Structure of respondents by tools (programs) of Microsoft 365.

Google's tools were also very numerous, although many teachers did not see them as a single

platform. This aspect is depicted in Table 1, where teachers distinguished Google Classroom from Google Meet, which, although integrated into this comprehensive platform, can also be used separately (for example, Hangouts and Duo). The usability of individual tools is illustrated in the following figure (see Fig. 4).

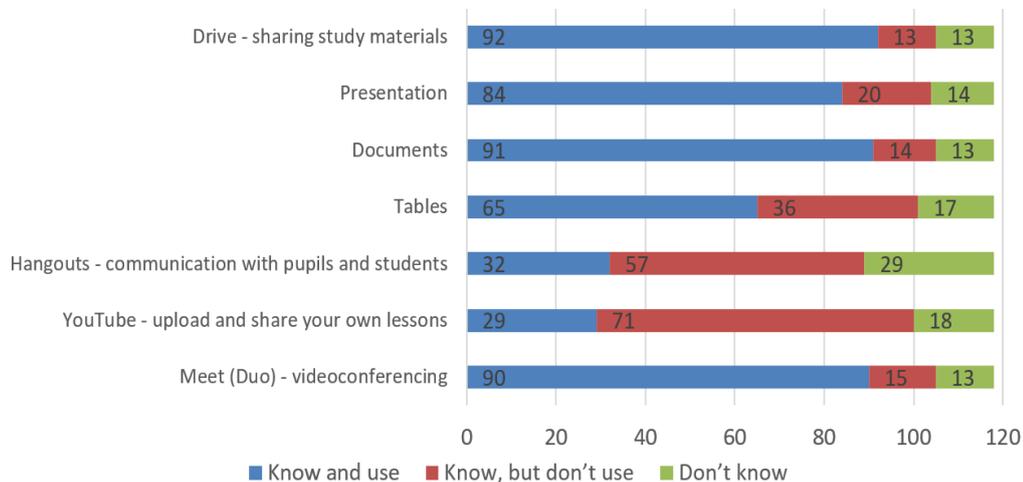


Figure 4. Structure of respondents by knowledge of Google tools (programs).

During the epidemic situation, all teachers across the world were forced to convert to online and distance learning. Concerning the addressed teachers (see Fig. 1), there was a problem with the distance education, which caused numerous troubles due to the unreadiness of the school equipment and the teachers' lack of competencies and knowledge in this area. Only 140 out of 241 respondents participated in the training on distance education during the pandemic, of which 36 were satisfied with the training, 47 respondents were neutral, and 57 respondents were critical. These findings do not correspond with the document of the Czech School Inspectorate, which analysed this issue in the context of the COVID-19 pandemic (Česká školní inspekce, 2021). The technical equipment of schools for online education is depicted in Fig. 5.

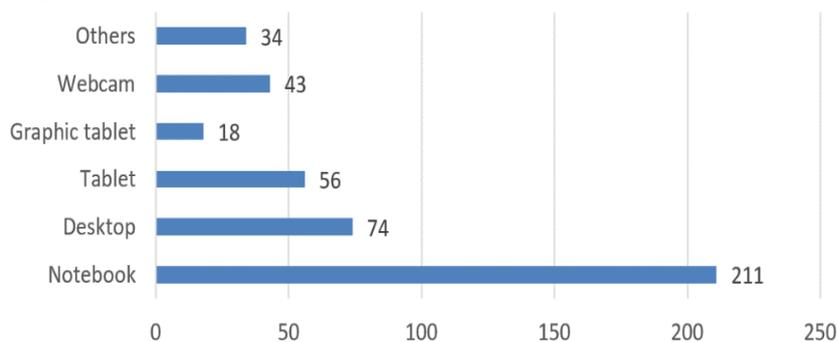


Figure 5. Structure of responses by technical equipment.

In terms of interpreting this data, it should be noted that webcams are integrated into both laptops and tablets. This design fact then implies a relatively small proportion of webcams that are more tied to desktop devices. It is also worth noting the low representation of a graphic tablet, which is a completely new peripheral for many teachers, and it should be mentioned that its use requires some motor training. Undoubtedly, this will be one of the reasons for their relatively low deployment, although we see great potential in them towards interactivity in online learning and the possibility of fully replacing the whiteboard in this environment. The question on the structure of school equipment was complemented by a question on the structure of the use of privately available IT resources. The structure of the responses

on the use of private resources was very similar to those of the school.

4. Impact of a digital learning environment on the implementation of standard didactic methods and tools in education

As already mentioned, this second part of the survey was submitted to the same sample as in the case of the previous chapter. In terms of the number of respondents involved, the structural part was supplemented with an age analysis, as age can be expected to be a significant marker that will influence IT skills. We formulated this hypothesis on the basis of our experience in teaching IT-oriented subjects in lifelong learning studies and refresher courses. From this point of view, we divided the involved teacher-respondents into age bands, represented in Fig. 6. In this sample, we worked with teachers who showed a very similar structure in terms of the DLE tools used. The sample of this part of the research was strengthened in the area of foreign language teachers who were not as involved in the first part. Thus, this group should be considered very important after the science disciplines.

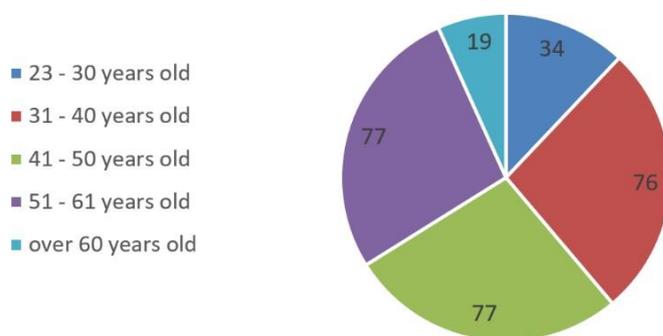


Figure 6. Structure of respondents by age.

In the first part of our research, we asked the respondents whether they prefer distance education with a combination of synchronous and asynchronous tools in the DLE or whether they do well only with asynchronous tools. In this case, 94.7% of respondents stated that it is optimal to combine the DLE with synchronous and asynchronous elements. This finding corresponds with the conclusions of the Ministry of Education, Youth and Sports of the Czech Republic (MEYS, MŠMT in Czech), which were published in a special survey report of the MEYS of the Czech Republic (MŠMT, 2021).

Having identified the key group, we continued asking towards distance education based on a combination of synchronous and asynchronous approaches. Another key research was to evaluate the implementability of individual phases of the learning process in the DLE, see Fig. 7. When classifying the phases, we took grounds in the works in the field of general didactics (Maňák, 1997; Skalková, 2007) despite the fact that the classification of the methods and phases of the learning process are still a live issue.

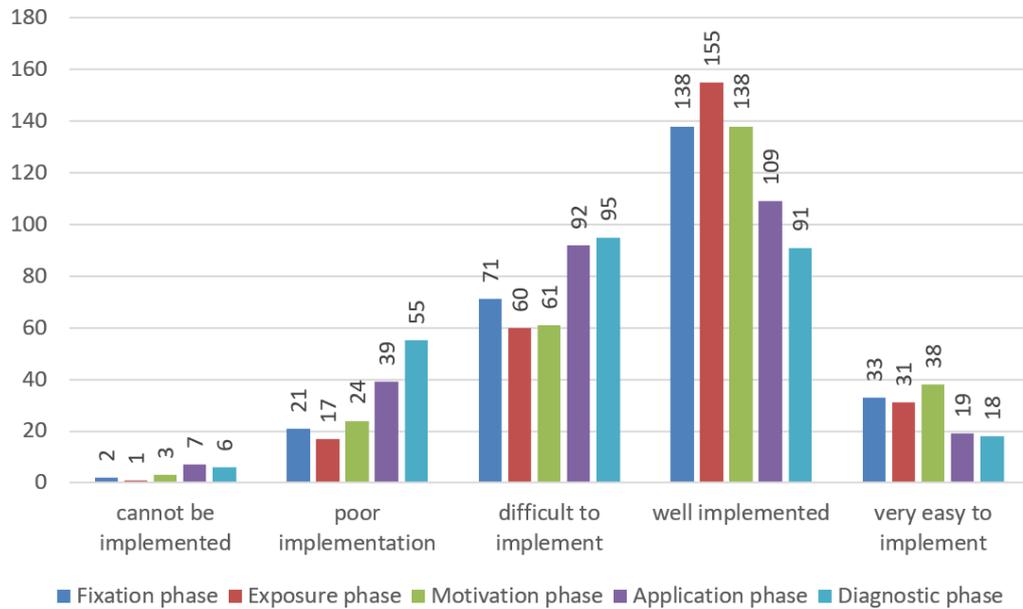


Figure 7. Ability to implement the different phases of the learning process.

Another part of the research was devoted to the required functions that the digital learning environment should offer its users-teachers. The respondent could choose up to 3 responses from a predefined list. Figure 8 depicts the structure of these responses regarding age bands.

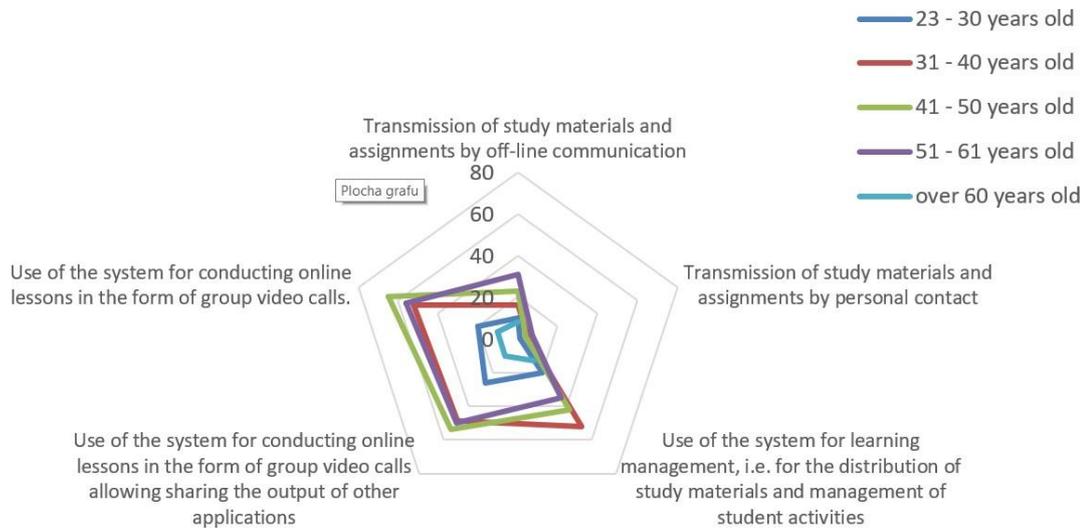


Figure 8. Implementation of didactic methods according to age bands.

The data from the previous graph implies two relevant conclusions. The most sought function of the digital learning environment was a group video call, followed by the implementation of a more complex system to distribute study materials and the management of student activities. The function of sharing the teacher’s screen is also required. The second fact emerging from Fig. 8 is that these preferences are quite balanced regarding teachers’ age bands. Our initial hypothesis that younger teachers would approach the implementation of the DLE differently was not confirmed.

Based on the previous paragraph, we know what the teachers require from a digital learning environment. In the next phase, we focused on the research of the usefulness of individual components with respect to the implementation of individual phases of the learning process in this environment. The

respondents-teachers selected their evaluation on a closed scale responding to whether the given tool enables to implement the corresponding phase or not. The frequency of the responses is depicted in Fig. 9.

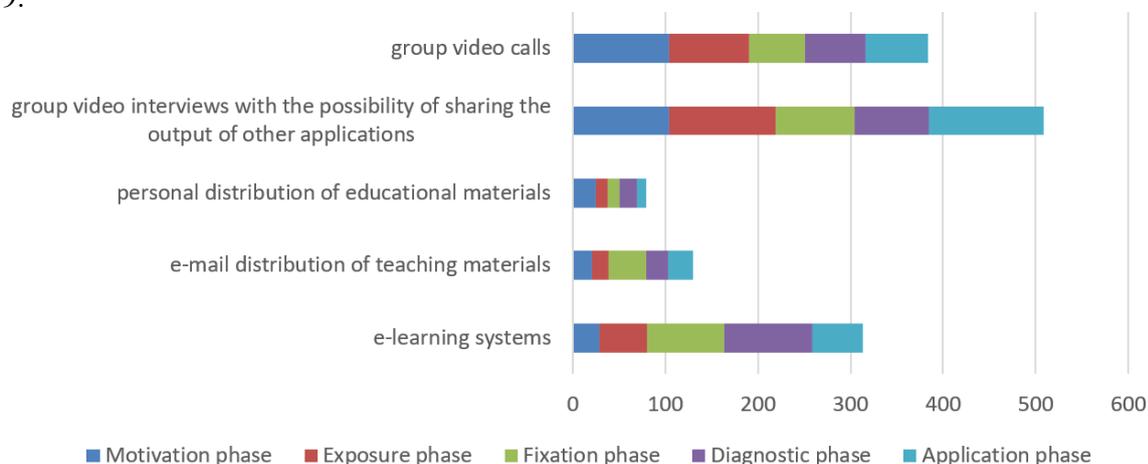


Figure 9. Implementation of learning phases according to individual tools.

The use of didactic tools is an inseparable part of the learning process. The conversion to a digital learning environment results in situations when it is difficult to use certain types of digital aids, or it requires a very creative approach from the teacher. This aspect was the focus of the next research question, where the respondents-teachers evaluated whether the given group of aids is implementable in a digital learning environment. Figure 10 then depicts positive responses.

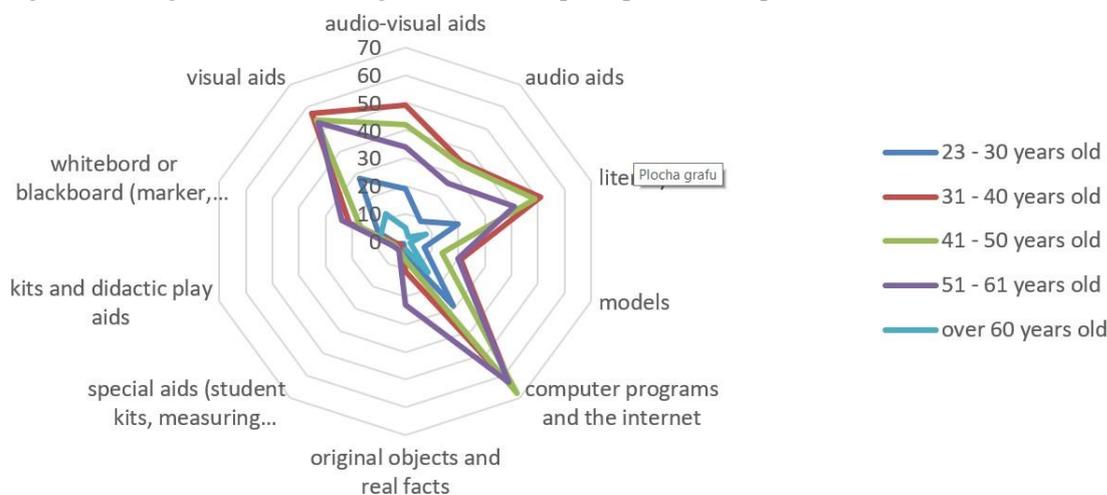


Figure 10. The use of didactic aids in digital learning environments.

The data presented in Fig. 10 reveals that if learning takes place in a DLE, most teachers-respondents prefer aids that can be easily integrated into DLE tools. First, we can include computer programs and internet sources, then visual and audio-visual aids. The use of literary aids is also interesting. The opposite end of this spectrum, viewed by the respondents as difficult, are models, real objects, student kits, and special aids. The structure regarding age bands is also interesting since no age band deviates. A comparison of using aids in a DLE and a standard face-to-face teaching is provided in a table that illustrates the ratios of the use of individual aids in these situations.

Table 2. Structure of involvement of aids in teaching.

Type of aid	Percentage of involvement of aids in standard teaching	Percentage of involvement of teaching aids in DLE
audio-visual aids	10 %	14 %
audio aids	7 %	10 %
literary aids	13 %	16 %
models	6 %	6 %
computer programs and the internet	16 %	22 %
original objects and real facts	7 %	5 %
special aids (student kits, measuring systems)	3 %	1 %
kits and didactic play aids	3 %	1 %
whiteboard or blackboard (marker, chalk)	18 %	7 %
visual aids	17 %	19 %

The results reveal that most respondents coped well with the implementation of all phases of the learning process, including the area of evaluation, which corresponds with the report of the Czech School Inspectorate (Česká školní inspekce, 2021). Regarding the used aids compared in Table 2, there is a significant drop in the use of whiteboard/blackboard and a significant increase in the use of computer programs.

5. Conclusion

The research involved two questionnaire surveys. The first one was oriented on the use of software tools, the second one was focused on the implementation of standard didactic methods and means in education during the COVID-19 pandemic.

The first survey clearly showed that the teachers mostly used Microsoft tools (mostly Teams, Word, Excel, PowerPoint) and Google (Classroom, Meet, etc.). These tools were used both for synchronous and asynchronous learning. At first, the teachers were not ready for this situation at all since they did not have experience with either online (distance) learning or the tools. However, over time, they acquired the knowledge through self-study or various trainings. During the epidemic situation, it turned out that the Czech education system did not have sufficient or outdated IT equipment. Although teachers disposed of school equipment (e.g., notebooks), they preferred their own, more modern equipment. According to the Czech School Inspectorate (Česká školní inspekce, 2021), schools received subsidies for upgrading the technical equipment to carry out distance learning. However, IT products were in short supply at that time. In addition, the internet connection also relates to this topic since schools had a poor internet connection or bad coverage of the buildings. Therefore, some teachers were forced to work from home.

The second survey revealed that teachers using DLE were able to implement all phases of the learning process, although this often required a great deal of creativity. The outcome is somewhat different with regard to the deployment of different types of aids in DLE, where it was rather difficult to replace the traditional aids associated with being in the classroom, which include, for example, a board with a marker or chalk. This was mainly due to low skills in working with a graphic tablet, or its unavailability, and inexperience in working with or the unavailability of touch peripherals. The results in Table 2 also show that a significant part of the learning has moved to standard DLE tools. This is the basis for designing further education courses and developing skills and competencies in these areas.

A positive aspect of the epidemic situation in the Czech Republic, but also in the world, has been the improvement of the technical background of schools and their equipment with digital technology, but also the significant development of digital competences of all teachers.

Acknowledgments

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References

- Česká školní inspekce. [Czech School Inspectorate] (2021). Distanční vzdělávání v základních a středních školách: Přístupy, posuny a zkušenosti škol rok od nástupu pandemie nemoci covid-19 [Distance education in primary and secondary schools: Approaches, shifts and experiences of schools one year after the onset of the COVID-19 pandemic]. https://www.csicr.cz/html/2021/TZ_Distancni_vzdelavani_v_ZS_a_SS/html5/index.html?pn=3&locale=ENG
- Edelhauser, E., & Lupu-Dima, L. (2021). One year of online education in the COVID-19 age, a challenge for the Romanian education system. *International Journal of Environmental Research and Public Health*, 18(15), 8129. <https://doi.org/10.3390/ijerph18158129>
- Gavrilova, L., Beskorsa, O., & Ižutina, O. (2021). Modeling the digital learning environment for primary school teacher training. *Information Technologies and Learning Tools*, 81(1), 180-191. <https://doi.org/10.33407/itlt.v81i1.3401>
- Katzensteiner, M., Vogel, S., Hüasers, J., Richter, J., & Bott, O. (2022). Towards a didactic concept for heterogeneous target groups in digital learning environments: First course implementation. *Journal of Personalized Medicine*, 12(5), 696. <https://doi.org/10.3390/jpm12050696>
- Lidinillah, D., Robandi, B., Wahyudin, W., & Dianasari, D. (2021). Elementary teachers' readiness to implement online learning during the COVID-19 pandemic. *Premiere Educandum: Jurnal Pendidikan Dasar dan Pembelajaran*, 11(2), 172-190. <https://doi.org/10.25273/pe.v11i2.9607>
- Maňák, J. (1997). *Nárys didaktiky* (2. vyd.) [Outline of didactics (2nd ed.)]. Masarykova univerzita.
- MŠMT. (2021). Zpráva z mimořádného šetření MŠMT k distanční výuce žáků v základním vzdělávání [Report from the extraordinary investigation of the MEYS regarding distance learning of students in primary education]. <https://www.msmt.cz/msmt-vydalo-zpravu-z-mimoradneho-setreni-k-distancni-vyuce>
- Peters, O. (2000). Digital learning environments: New possibilities and opportunities. *The International Review of Research in Open and Distributed Learning*, 1(1). <https://doi.org/10.19173/irrodl.v1i1.3>
- Skalková, J. (2007). *Obečná didaktika: vyučovací proces, učivo a jeho výběr, metody, organizační formy vyučování* (2., rozš. a aktualiz. vyd.) [General didactics: teaching process, curriculum and its selection, methods, organizational forms of teaching (2nd ed.)]. Grada.

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The Use of Digital Technologies in the Teaching of Biology at Primary and Secondary Schools

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Abstract. The development of technology is gradually becoming part of human life and is not bypassing schools and education. The implementation of the teaching process according to the existing curriculum in Slovakia does not provide space for the implementation of new trends and innovative strategies with the use of modern teaching aids. It is in science subjects, of which the subject of biology is a part, that it is important to arouse the interest of students. For this reason, it is necessary to change the teaching process so that it actively involves students and attracts their attention. Various visualization aids such as animations, videos, simulations, modeling, but also the use of mobile applications suitably enliven the course of teaching, or make it easier for teachers to explain more challenging topics and allow students to more easily understand the events and phenomena that take place in nature. The paper focuses on the analysis of biology lessons in the form of observation records, through which we wanted to determine the level of use of digital technologies. We performed an analysis of 430 observation records of teacher students during their continuous pedagogical practice in the academic year 2021/2022, who monitored the implementation of digital technologies by practicing teachers. Subsequently, we found out in which years specific digital technologies were most used in primary and secondary schools. Based on the analysis, we can state that digital technologies are rarely used by teachers in biology classes.

1. Introduction

The quality of the school system is one of the criteria that moves the country to the global market. The school system at all levels is a stepping stone that moves the population intelligently in the field of science and research, and, through its influence, interferes with the country's public affairs and public life (European Commission, 2016). Education in mathematics and science plays a crucial role in equipping children and young people with the necessary skills, knowledge, and viewpoints to be responsible and active citizens in our fast-changing and technology-driven societies. However, evidence from international student surveys such as that of the Programme for International Student Assessment (OECD, 2019) carried out by the Organization for Economic Co-operation and Development (OECD, 2020) show that, in the EU-27, a considerable share of 15-year-olds – about 23% in 2018 – do not reach basic levels of skills in mathematics and science.

It was in this pandemic period, COVID-19, that the weakest points of the education system were discovered, which functioned more or less in a distance form, because the full-time form was omitted or kept to a minimum. Many schools were ill-prepared for this situation. They did not know which technologies and methodologies were the most appropriate for teaching, in terms of effectiveness, security, and accessibility (Cachia et al., 2021). Teachers had to rapidly adapt to new modes of delivery of teaching, and students had to rely initially on their own resources to continue learning remotely using textbooks, the internet, television, etc. (Schleicher, 2020). Digitization has come to the fore, and the digital skills of students and teachers have proved to be an essential part of education in the 21st century. It was a challenge that put the teacher in a position in which he must choose a suitable platform for mutual communication with the student (Ambrožová, 2020). Digital education is an

effective way to influence students and adapt to their study needs. The methods implemented in lessons with the use of digital technology increase the activity of students and thus their involvement in the teaching process. By using digital technologies, students acquire a greater range of knowledge, which is produced from various Internet sources and studies, where they exchange knowledge with each other more quickly via social networks, e-mail, or various educational platforms such as Microsoft Teams, Zoom, Messenger, and others. Students can look up information in seconds, so it's understandable that they get impatient if they don't get an immediate answer to their questions. From this point of view, it is expected that teachers will change their approach, start using digital technologies much more, and especially increase interactivity in teaching. Interaction thus becomes more important than communication itself, and teachers will have to focus on developing critical thinking, constructive problem solving, and digital competence (Barnová & Krásna, 2018).

Digital competence (Figure 1) is one of the Key Competences for Lifelong Learning. It was first defined in 2006, and after an update of the Council Recommendation in 2018, it reads as follows: *“Digital competence involves the confident, critical and responsible use of, and engagement with, digital technologies for learning, at work, and for participation in society. It includes information and data literacy, communication and collaboration, media literacy, digital content creation (including programming), safety (including digital well-being and competences related to cybersecurity), intellectual property-related questions, problem solving, and critical thinking”* (Vuorikari et al., 2022).

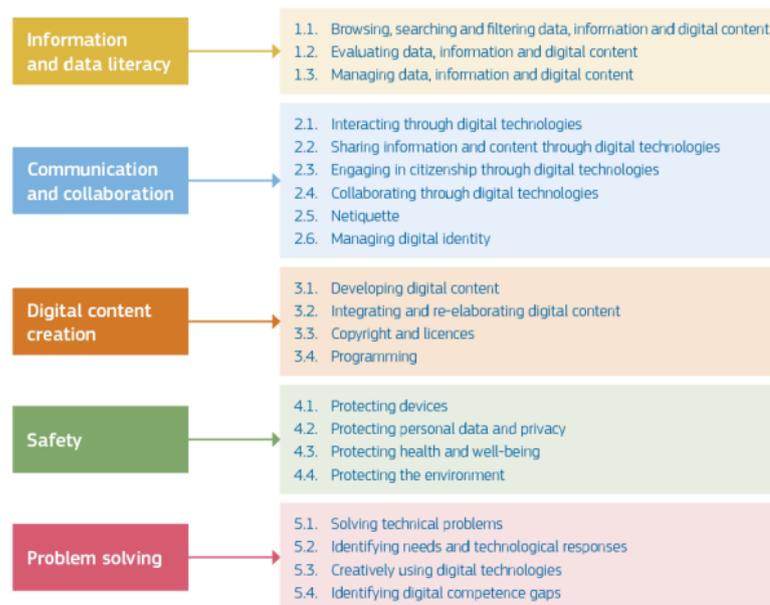


Figure 1. The DidComp conceptual reference model.

Digital technologies support the teaching process and represent a suitable means of ensuring effective teaching. They have their place in the teaching process and bring many advantages. According to the British expert M. Jarvis (in: Sokolová, 2021), digital technologies in teaching:

- significantly save time, there is no need to copy paper materials, which, in addition to time, saves money, or allows teachers to use materials that have already been created,
- they keep the student's attention,
- allow all students to participate in the lesson, including students with various disabilities.

Pasiar (2021) states the following advantages of using digital technologies in teaching: they can become a means to acquire different types of knowledge and skills, education is not dependent on time or space, they can ensure anonymity in communication, they allow one's own pace of teaching, ensure fast, but at the same time, low-cost communication within teaching, availability of a large amount of information.

2. The IT Academy - Education for the 21st century

As part of the IT Academy - Education for the 21st Century project, the innovation of natural science and technical education with a focus on informatics and digital technologies is taking place in Slovak primary and secondary schools. The strategic goal of the project was to create a model of education and training of young people for the current and prospective needs of the knowledge society and the labor market, with a focus on informatics and ICT in the Slovak Republic.

As part of the above-mentioned project (September 1, 2016 – August 31, 2022), science and technical education in primary and secondary schools was innovated with a focus on informatics and ICT, orientation of young people for further study in fields of study and programs with the perspective of application in the IT sector. The innovation of education within the School Educational Programs was aimed at updating the content, methods, and forms of teaching mathematics, informatics, natural science subjects, and professional subjects towards the consistent and meaningful implementation of ICT tools in education. Innovative methodologies were created by the project developers, which are primarily aimed at developing the research competencies of primary and secondary school students. A model of a special class in grammar schools focusing on informatics was created, and part of it was the creation of textbooks for eight new subjects for these classes. Two new motivational subjects, Informatics in Natural Sciences and Mathematics, and Internet of Things, were created to orient secondary school students to university studies in IT study programs and to apply in the IT sector. The project included formal and informal teacher training, clubs, IT camps, seminars, competitions, and other extracurricular activities aimed at motivating primary and secondary school students to study informatics, ICT, natural and technical sciences, the development of digital literacy, personal development, and communication skills. The activities were carried out in close cooperation with IT companies on the basis of a partnership with schools (<https://itakademia.sk/>).

3. Teaching natural sciences

The vision for quality in education includes the mastering of basic skills (in reading, mathematics, and science), but also of transversal skills such as critical thinking, entrepreneurship, creativity, and civic engagement. Mathematics and science education play a crucial role in this regard, as these subject areas have great potential to equip young people with the necessary skills, knowledge, and viewpoints to be responsible and active citizens who are able to think critically and creatively (European Commission, 2022).

The basic goal of how to change students' view of science subjects is to motivate them. The purpose of science education lies in acquiring the feeling that students understand individual sciences and understand their meaning in the world. An important component of the teaching process in science subjects is the interactivity of students and their active involvement in teaching. In science subjects, digital technologies are used to work with information. The student comes into contact with the mentioned information mainly electronically in the form of various simulations, pictures, animations, videos, etc. (Kireš et al., 2016). At the same time, the electronic form of information processing places increased demands on the student to be able to sort, process, and use it. The virtual world is overflowing with information, and for this reason, critical thinking becomes an important skill that students can acquire in the teaching process. The goal is to teach students to assess information sources, to evaluate the relevance of information, and, of course, to work with digital technologies so that students can make their activities more efficient (Pasiar, 2021). The correct sorting of information is related to the level of digital literacy, and its development is also associated

with science education. "*The goal of science education is a scientifically literate person abounding in knowledge, skills, and attitudes, i.e., competent to make full use of their abilities and capabilities in work, social and personal life*" (Kireš et al., 2016). At the same time, within the framework of natural science teaching, it is proposed to prioritize the students' activities and focus on a comprehensive view of nature.

4. Research aim, research questions, and research hypotheses

We carried out the research at secondary and grammar schools in Košice and Prešov regions, while our aim was to determine the use of digital technologies by teachers in biology classes.

The research aims were defined as follows:

1. To investigate the level of use of digital technologies during teaching in biology classes.
2. Focus on specific digital technologies that were used most often (mobile applications, presentations, videos, computer-supported laboratories).
3. Focus on individual grades and find out which digital technologies were used the most and which were used the least.
4. To compare the level of use of digital technologies in secondary and grammar schools.

Based on the sub-aims, we defined the research questions:

1. Which digital technologies did teachers use most often?
2. Are there differences in the use of digital technologies in secondary and grammar schools?
3. In which grades did teachers use digital technologies most often?

The following hypotheses were formulated and tested:

1. We assume that teachers rarely use DT in the teaching process.
2. We assume that presentations will be used most often among the mentioned DTs, followed by video recordings, mobile applications, and computer-supported laboratories will be used the least, while we assume that presentations will make significant progress compared to other DTs.

5. Research methodology

The research was carried out on the training schools that have a contract with the Faculty of Sciences of the University of Pavol Jozef Šafárik in Košice. Students in the second year of their master's degree are required to complete a teaching practice within their approved subjects at schools as part of the continuous practice output, which was implemented in the winter and summer semesters of the academic year 2021/2022. In addition to the outputs, the students also completed internships with their trainee teachers. During the supervisions, they observed the teacher's teaching while also focusing on the use of digital technologies (presentations, videos, mobile applications, and computer-supported measurements). After completing the internship, the students made the supervision records available to us, which we analyzed. The mentioned supervision record is a written record of the supervision, which records the essence of one lesson. We noticed the grades and the type of digital technologies used in biology classes. The research sample consisted of 430 supervision records from 44 schools. The number of individual grades shown in Table 1 and Table 2. We could not influence the mentioned number of grades, because the practice teacher, after agreement with the student, determined in which classes the internships will be practiced, and for this reason, the number of internships in individual grades is different.

Table 1. Number of hospitalizations in secondary schools.

years of secondary school	5. year	6. year	7. year	8. year	9. year	overall
number of hours:	49	54	68	35	27	233

Table 2. Number of hospitalizations in grammar school.

years of grammar school	1. year	2. year	3. year	4. year	overall
number of hours:	46	37	50	64	197

6. Research results

Quantitative analysis of 430 supervision records recording one school year, we tried to find out which digital technologies were used most often by teachers in biology classes. Figure 2 shows that the use of presentations significantly advanced over other digital technologies, while video recording and mobile applications were used to a lesser extent, and a computer-assisted laboratory was used minimally, which could also be related to the topics covered during the implementation practice. From the total number of hours, i.e. 430 teaching hours, teachers used presentations in 201 hours, which represents 47,74 %, mobile applications in 15 hours, which is 3,49 %, we recorded the video analysis in the number of 36, which represents 8,37 % and by computer teachers used the supported laboratory for 3 hours, which amounts to 0,70 %.

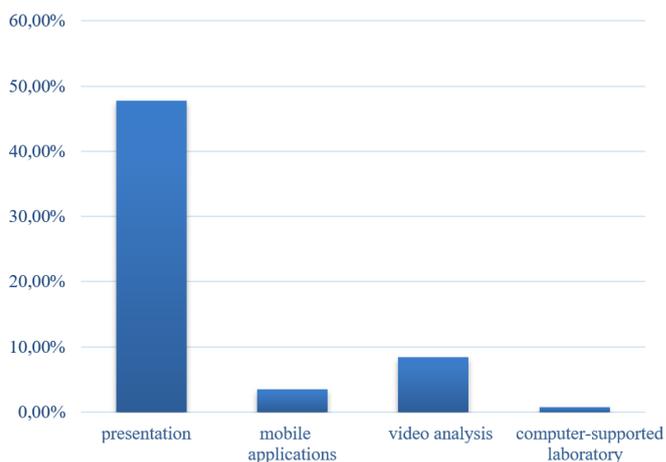


Figure 2. The use of digital technologies in the teaching of biology.

As part of the research, we focused on individual grades of secondary school and analyzed in which grades individual digital technologies are most often used. Figure 3 shows 49 hospital records from the 5th grade, on the basis of which we found that in the fifth grade, presentations were used in 19 hours, which is 38,78 %, and video analysis was used in 7 hours, which is 14,28 %. From the 6th year, we analyzed 54 hospitalization records, thanks to which we found that presentations were used in 22 lessons, which represents 40,74 %, and video recordings were used in 4 lessons, which represents 8,16 %. From the 7th year, we had 68 recordings available, based on which we found that presentations were used in 35 lessons and video recording was used in 4 lessons, which represents 51,47 % and 5,88 %. From the 8th grade, we had 35 records, which show that presentations were used in 12 hours, which is 34,29 %, mobile applications in two hours, and video recordings in two hours, which is 5,71 %. We collected 27 hospital records from the last year of secondary school, on the basis of which we found that presentations were used in 16 lessons, which represents 59,26 %. Other digital technologies were not used in the 9th grade, and computer-supported laboratory were not used in any grade.

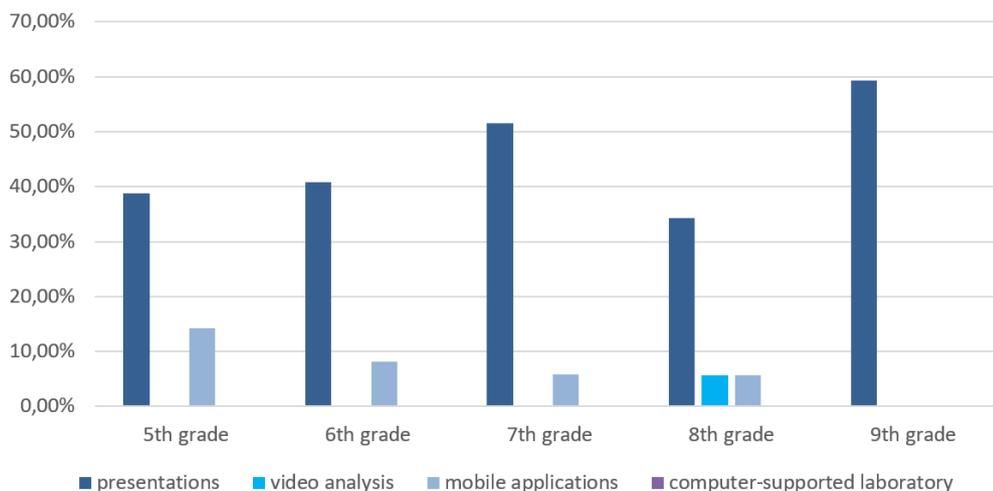


Figure 3. Comparison of the use of digital technologies across all grades in secondary schools.

Figure 3 shows that the presentations were most often used in secondary schools in the 9th grade, followed by the 7th grade. In the 8th grade, presentations were used the least. Video recording was used the most in the 5th grade, then in the 6th grade, and to about the same extent in the 7th and 8th grades. Mobile applications were used only in the 8th grade, and teachers did not implement a computer-supported laboratory at all.

In the next section, we present the research results from grammar schools, see Figure 4. In the 1st year, we analyzed 46 supervision records, from which it follows that presentations were used in 29 lessons, which represents 63,04 %. We found the use of video recordings at 7 hours, which represents 15,22 %, we recorded mobile applications at 2 hours, which is 4,35 %, and at 1 hour, a computer-supported laboratory was used, which represents 17 %. From the 2nd year, we analyzed 37 recordings, from which it follows that presentations were used in 11 lessons, which amounts to 29,73 %, video recordings were used in 5 lessons, which represents 13,51 %, and mobile applications were used in 5 lessons, which also represents 13,51 %. In the 2nd year, a computer-supported laboratory was also used for 2 hours, which is 5,41 %. We had 50 supervision records available from the 3rd year, on the basis of which we found that presentations were used for 24 hours, which represents 48 %, video recordings were used for 4 hours, which represents 8 %, and mobile applications were used for 2 hours, which represents 4 %. From the graduation year, we had 64 supervision records available, which showed that presentations were used in 33 hours, which amounts to 51,56 %, video recordings were used in 3 hours, which represents 4,69 %, and mobile devices were used in 4 hour applications, which represents 6,25 %.

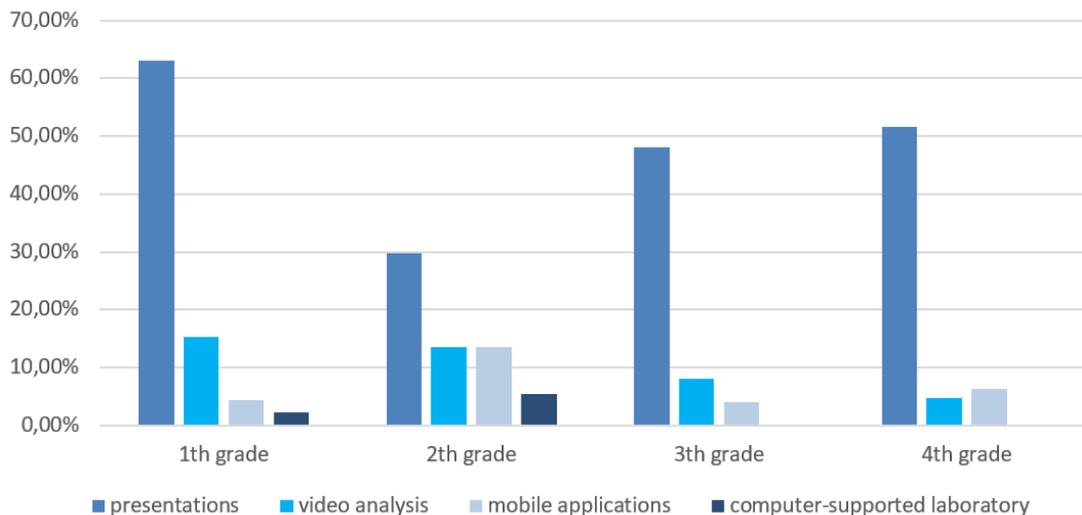


Figure 4. Comparison of the use of digital technologies across all grades in grammar schools.

7. Discussion

Based on our research, we can conclude that digital technologies are rarely used by teachers in the teaching of biology. As part of her research, Habartová (2019) focused on the use of mobile technologies in teaching, while conducting the research through a questionnaire. The research sample consisted of elementary school teachers in Bratislava. She worked on the following results. Out of 111 respondents, representing primary school teachers, 22 teachers always use mobile technologies in teaching, which represents 22,4 %. Most teachers sometimes choose the answer yes. The number of these teachers was 67, which is 60,4 %. The research shows that 11,7 % (13) of respondents do not want, and therefore do not use, mobile technologies in teaching, and 6 respondents do not use, but would like to implement mobile technologies in teaching. Based on the conducted research, Habartová found that 82,9 % of teachers use mobile technologies. Of the mobile technologies, most teachers used laptops in class, followed by smartphones, followed closely by tablets. Laptops are used by 7,8 % of respondents, smartphones by 27 %, and tablets by 22,5 %. Based on the conducted research, Habartová found that mobile technologies are used quite often in teaching. Compared to our research, we observe a significant difference. Our results pointed to the fact that digital technologies are rarely used in teaching. Presentations were used most often, even in only 201 hours out of a total of 430, which is 47,74 %, and thus we observe a significant difference in the results when comparing the researches.

Another research focused on the use of information and communication technologies in the teaching process was carried out by researchers from Olomouc in 2017. Again, a questionnaire was used to collect data, while 260 teachers from kindergarten, primary, and secondary schools filled out the questionnaire. The conducted research shows that 61,5 % of teachers use information and communication technologies and 23,1 % of teachers use them rather than not. The number of teachers not using any information and communication technologies is 2,7 % and 12,7 % of teachers do not use rather than use information and communication technologies. Based on the aforementioned research, the use of information and communication technologies in teaching is high, and more than 50 % of teachers implement them in the teaching process. An interesting fact of this research was that teachers with longer experience use information and communication technologies to a higher extent than teachers with shorter experience. The research shows that the teachers mostly (51,2 %) use a laptop with a data projector in the classroom during face-to-face teaching. Interactive whiteboards are

used by 32,7 % of teachers, and 12,3 % of teachers do not use information and communication technologies when conducting face-to-face teaching.

Kremeňová et al. (2018) conducted research at a selected secondary school in Žilina, while also focusing on the use of teaching aids and didactic techniques in the teaching process. The research sample consisted of 148 respondents representing the students of the given school. The conducted research shows that the most common students (141) use classic textbooks in class, 73 students indicated the option of audio recording, and 31 students indicated that they use videos in class. Another component of the research was the didactic technique used in the teaching process. Based on the research, it was found that the most frequently used didactic technique is the data projector, which was indicated by 117 students, followed closely by the computer, which was indicated by 114 students, 52 students indicated the possibility of using an interactive whiteboard, and 30 students indicated the use of tablets in class. The mentioned researches again have more positive results compared to our research. According to the results of the questionnaires, information and communication technologies are used quite often in the teaching process, while our research pointed out the uniqueness of the use of technologies.

On the basis of individual researches, we can state that the authors used questionnaires to obtain data and also that the questions from the questionnaire were primarily addressed to teachers and pupils respectively. We focused on the lessons themselves and analysed the teaching process. We wanted to find out how often teachers use digital technologies in the classroom, while most research focuses on whether teachers will use digital technologies in general.

8. Conclusion

Digital technologies have their meaningful application in the teaching process, facilitating the work of teachers in all phases of the lesson and keeping the attention of the student. It is important to appropriately implement digital technologies in the teaching process in order to improve the quality of biology teaching. Based on the conducted research, we can state the uniqueness of the use of digital technologies in biology classes. Therefore, it is necessary for teachers to complete training that will be focused on the implementation and practical demonstrations of the use of digital technologies in the teaching of biology.

Acknowledgments

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References

- Ambrožová, P. (2020). *New forms of school cheating and disruption in the context of digital education*. Pavel Mervart.
- Barnová, S., & Krásna, S. (2018). Virtual generation and application of digital technologies in teaching. In *Conference Mental health and well-being of the virtual generation: Proceedings of the International Scientific conference. 21.11.2018*. Bratislava. <https://www.researchgate.net/publication/329117951>
- Bobot, V., & Jakubeková, M. (2012). *Interaktívne vyučovanie v školských vzdelávacích programoch* [Interactive teaching in school educational programs]. Metodicko-pedagogické centrum v Bratislave.
- Cachia, R., Velicu, A., Chaudron, S., Di Gioia, R., & Vuorikari, R. (2021). *Emergency remote schooling during COVID-19: A closer look at European families*. Publications Office of the European Union. <https://data.europa.eu/doi/10.2760/613798>
- COM(2016) 941. *Improving and modernizing education*. European Commission. <https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM:2016:941:FIN>

- European Commission. (2022). *Translations of DigComp 2.0 in the European skills, competences and occupations classification (ESCO)*. Publications Office of the European Union. <https://doi.org/10.2767/316971>
- Habartová, N. (2019). *Primary school teachers' approach to the use of mobile technologies in education*. [online]. Brno, 2019 [2022-05-13]. <https://is.muni.cz/th/fx4t6>
- Kireš, M., Ješková, Z., Ganajová, M., & Kimáková, K. (2016). *Bádatel'ské aktivity v prírodovednom vzdelávaní [Inquiry activities in science education]*. Štátny pedagogický ústav.
- Kremeňová, I., Fabuš, J., & Beňušová, J. (2018). Analysis of the use of ICT in the educational process. *Post, Telecommunications and E-commerce*, 13(1), 18-29. <https://doi.org/10.26552/pte.C.2018.1.3>
- OECD. (2019). *OECD Future of Education and Skills 2030: OECD Learning Compass 2030*. OECD Publishing. https://www.oecd.org/education/2030-project/teaching-and-learning/learning/learning-compass-2030/OECD_Learning_Compass_2030_concept_note.pdf
- OECD. (2020). *PISA 2018 results (Volume VI): Are students ready to thrive in an interconnected world?*. OECD Publishing. <https://doi.org/10.1787/d5f68679-en>
- Pasiar, L. (2021). Attitudes of future teachers to the using of digital technologies in teaching: A case study. In P. Krpálek et al., (Eds.) *Schola Nova, Quo Vadis?* (pp. 66-74). Extrasystem. <http://www.extrasystem.com/9788087570579.pdf#page=66>
- Schleicher, A. (2020). *The impact of COVID-19 on education: Insights from "Education at a Glance 2020"*. OECD Publishing. <https://www.oecd.org/education/the-impact-of-covid-19-on-education-insights-education-at-a-glance-2020.pdf>
- Sokolová, L. (2021). *Digital technologies in interdisciplinary relations*. Univerzita Komenského v Bratislave.
- Vuorikari, R., Kluzer, S., & Punie, Y. (2022). *DigComp 2.2: The Digital Competence framework for citizens: With new examples of knowledge, skills and attitudes*. Publications Office of the European Union. <https://data.europa.eu/doi/10.2760/115376>

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Education of Biology Teachers in the Field of Teaching Innovation

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Abstract. Global trends in a rapidly changing world point to the necessity of transformation in the field of education. The rapid increase in information and digitization raises the question of changing priorities in the teaching of pupils at all levels of education and across different fields of study and subjects. The focus is on improving pupils' literacy and skills for the 21st century (critical thinking, digital and soft skills), which are key to the successful employment of graduates on the labor market and adaptability to changing demands in society and the work field. However, the mentioned changes also point to the necessity of targeted, effective, and up-to-date training of teachers as important actors in the digital transformation of education. The results of the SELFIE survey in Slovak primary and secondary schools indicate that pupils perceive differences in the degree of development of digital skills between different subjects. The development of these skills is the result of the didactic mastery of the teacher, who directs the teaching process to the appropriate and meaningful implementation of digital technologies for the fulfillment of the set goals. With the aim of improving the skills and competence of biology teachers, during the national project IT Academy - education for the 21st century, we implemented several accredited courses of innovative education with the aim of innovating the teaching of biology in primary and secondary schools. We investigated the positive and negative factors that influence the use of digital technologies in the teaching of biology. Based on the experience of biology teacher education, we can conclude that the completion of education focused on specific examples of the practical use of digital technologies in teaching biology is a key element for the innovation of teaching and the shift to digital transformation.

1. Introduction

The changing requirements for the successful employment of graduates on the labor market point to the necessary innovation of the education of pupils in primary and secondary schools. One of the main goals of the European Commission is to increase the level of digital competences of all citizens as a reflection of digitization on a global level, in all areas of life. These digital competences are defined by the European framework of citizens' digital competences DigComp in 5 areas, namely Information and data literacy (I), communication and collaboration (II), digital content creation (III), safety (IV) and problem-solving (V) (Vuorikari et al., 2022). The results of the SELFIE survey in Slovakia point to a different level of digitization in primary and secondary schools (Mišianiková et al., 2021b). Pupils in many schools pointed out significant differences in the development of digital competences in various subjects. The teachers themselves assessed that the material equipment of the school is important for the successful digital transformation of the school, but they also need appropriate education for the meaningful and effective use of digital technologies in education. They see a lot of room for improvement, especially in education, which is focused on ways of using digital technologies in the assessment of students' knowledge and skills.

The digital transformation of school education should be based on a pre-thought-out and targeted school digitization action plan (Hubeňáková et al., 2020). Support for innovation in teaching and learning

and the digital transformation of schools was implemented through the National IT Academy project in 2016 – 2022 (Šveda et al., 2022). A significant shift is the new role of a professional in education - digital coordinator. An important task of the digital coordinator is the development of an action plan for school transformation and responsibility for the implementation of the planned action steps. It turns out that the necessary action steps are also the improvement of the digital competences of educators, which is defined and described by the European framework of DigCompEdu (Redecke, 2017). The success of the school's digital transformation strongly depends on the level of digital competence of school teachers as important actors of education, including biology teachers.

2. Support of biology teachers during the national project

During the duration of the IT Academy national project, biology teachers were supported in several ways, primarily by creating innovative methodologies, providing accredited educational programs, and conducting workshops and webinars. A total of 167 innovative methodologies were created for biology teachers, of which 89 were for primary school teachers and 78 were for secondary school teachers. Innovative methodological procedures represent complex procedures for the teacher with the application of a research approach and the implementation of digital technologies in the teaching of biology in primary and secondary schools. All proposed methodological procedures were verified by several teachers through practice, with the subsequent incorporation of their comments and recommendations. After teaching the lesson according to the proposed procedure, the teachers mainly evaluated the objectives of the lesson in the area of knowledge, skills and abilities and their fulfillment according to the methodology, the degree of application of the research approach, the adequacy of the proposed time allocation for individual activities, the suitability of the proposed didactic aids, including digital technologies, motivation and interest pupils, problems during teaching and pupils' misconceptions. The teachers also suggested improvements to the methodological procedures and listed the most frequent questions of the students, many of which are included in the final version as a source of inspiration for further research questions or to stimulate discussion. The final innovative methodological procedures are part of extensive collections for biology teachers (Lešková et al., 2021; Mišianiková et al., 2021c), which are made available online together with supplementary study materials and worksheets for pupils. In addition to collections of methodologies, a collection of methodologies for teaching a new innovative subject at secondary schools - Informatics in natural sciences and mathematics - was created. To support teaching according to the proposed methodologies, support was provided to teachers through accredited educational programs, face-to-face meetings with teachers, and online webinars. In addition to the mentioned activities, we also provided help to biology teachers in motivating and supporting talented students or students interested in biology and implemented practical exercises in research laboratories, in which biology teachers also participated.

3. Education of biology teachers

The education of biology teachers during the IT Academy project was implemented using a formal and informal approach. Formal education was provided as innovative educational programs accredited by the Ministry of Education, science, research and sport of the Slovak Republic and met the standards established by law for the given type of education. Graduates received a certificate confirming successful completion of the education. Informal education was carried out through discussion meetings with biology teachers, practical workshops with teachers, or online webinars. Many of these meetings were attended by teachers who are active in the Biology Teachers' Club organized under the auspices of the Pavol Jozef Šafárik University in Košice. Teachers received certificates of participation, which can be recognized by the school principal as part of continuous teacher education.

4. Accredited innovative educational programs

The main goal of the educational programs was to expand the knowledge and professional competences of biology teachers necessary for the meaningful and effective use of digital technologies and in the field of applying methods of active natural science research in teaching. 3 accredited educational programs were provided to biology teachers as part of innovative education:

1. Educational program Teaching biology in primary school with a focus on the development of digital and scientific literacy (B - PS).
2. Educational program Teaching biology in secondary school with a focus on the development of digital and scientific literacy (B - SS).
3. Informatics in natural sciences and mathematics, part of biology (INSaM).

All educational programs were implemented in a combined form, namely face-to-face and distance learning, while the face-to-face form took place online during the pandemic. The implementation of distance education was ensured with the support of an e-learning environment, where teachers had access to supplementary materials for self-study. The main part of distance education was the development of a distance assignment, while teachers were provided with consultations if they were interested. The output of the distance assignment was formatively evaluated as part of ongoing feedback. After completing at least 80% of the prescribed number of hours for the face-to-face form and preparing all the outputs of the distance part, the teachers finished their education by preparing and defending an original final presentation before the examination board. The final presentation of 15 minutes represented the level of acquired knowledge and skills of the graduate. The teachers presented the proposal and experience with the implementation of the lesson, which was a synthesis of research-oriented education and meaningful implementation of digital technologies (B - PS, B - SS) and/or informatics (INSaM). The teachers documented the students' activities and evaluated the contribution of the implemented activity to the development of the students' science literacy and digital competences.

4.1 Programs focused on the development of digital and scientific literacy

Educational programs focused on the development of digital and scientific literacy were implemented in the range of 40 (B - PS) and 50 (B - SS) hours. The specific goals of these programs were to deepen the knowledge and skills for applying the research approach in teaching (I), to expand knowledge and skills in the field of computer-supported measurements as part of the research approach in the teaching process (II), and to expand the knowledge of biology teachers about the principles of image and video analysis biological objects and events.

The content of the programs was divided into 4 (B - PS) and 5 modules (B - SS), namely inquiry-based science education (IBSE) (I), Computer-supported laboratory (CSL) - school measurement systems (II), computer image processing (III), video analysis (IV) and additional module field work using school measurement and recording systems (V) for secondary school teachers (B - SS). The level of knowledge and skills from the given module was demonstrated by the teachers by preparing the output from the distance learning part. The output of the distance task was the design and implementation of a lesson with active student research. Teachers created preparation for 1 teaching unit in the form of a Word file in the scope of at least 2 pages of A4 format and documented examples of student work from the lesson conducted by the teacher in the form of a presentation in the scope of at least 8 slides. Table 1 shows the content of individual modules, the form of education, the time allowance, and the specifics of the teacher's output from the distance part.

Table 1. The content and scope of the educational programs are focused on digital and scientific literacy.

Module	Content	Form of education	Subsidy (hours)
1	Subject of education: Inquiry-based science education (IBSE)		
	Introduction to IBSE, levels of research in IBSE, research cycle.	in person/online	2
	Practical demonstrations of IBSE on the example of the biology curriculum for primary (B – PS) and secondary schools (B – SS), interactive demonstration.	in person/online	2
	Practical research in the role of a pupil – application of selected innovative methodologies created for (B – PS) and secondary schools (B – SS).	in person/online	2
	Assessment of pupils' research skills. Examples and use of assessment tools.	in person/online	2
	Preparation and implementation of a sample lesson on a chosen topic with IBSE. Output specification: observation notes, research plan, etc.	distance	2
2	Subject of education: Computer supported laboratory (CSL) - school measurement systems		
	School measurement systems. Use of school measurement systems on selected topics (heart - measurement of heart rate and blood pressure, etc.).	in person/online	2
	Processing of measured data by computer and their interpretation.	in person/online	2
	Mobile applications and their possibilities of use for measurement in teaching biology.		
	IBSE with computer supported laboratory. Work in the role of a pupil according to selected innovative methodologies for teaching biology at primary (B – PS) and secondary schools (B – SS).	in person/online	4
	Preparation and implementation of a sample lesson on the chosen topic. The lesson is research-oriented and uses measurement, data processing, and their interpretation. Output specification: measured data, graphs, etc.	distance	2
3	Subject of education: Computer image processing		
	Obtaining information about biological objects and phenomena based on computer measurement of objects in digital photography. Options and tools for working with digital photography. Examples.	in person/online	2
	Acquisition of records from a digital microscope and their modification.	in person/online	2
	Practical research in the role of a student according to selected methodological procedures (detecting the size of cells, counting blood cells, etc.).	in person/online	4
	Preparation and implementation of a sample lesson on the chosen topic using computer processing of the image of a biological object. Output specification: photograph of a biological object and its analysis.	distance	2
	Subject of education: Video analysis		
	Video recording as a source of information on biological objects and phenomena. Making a camera recording and its digital processing.	in person/online	4
	IBSE with analysis of selected video recordings, processing, and interpretation of obtained information. Examples.	in person/online	2

4	Practical demonstration of innovative methodologies using video, created for biology teachers at primary (B – PS) and secondary schools (B – SS).	in person/online	2
	Preparation and implementation of a sample lesson on a chosen topic using a video recording of a biological event or phenomenon and its analysis. Output specification: a video recording of a biological event or phenomenon made by a teacher or a pupil.	distance	2
Subject of education: Field work using the school measurement and recording system			
5	Assessment of air and water quality. Data measurement and processing. Use of CLS outdoors.	in person/online	4
	Manifestations of animals. Video recording, audio recording, and their digital processing and evaluation. Innovative methodologies were created for secondary school biology teachers.	in person/online	4
	Preparation and implementation of a lesson on a chosen topic with work in the field (in the schoolyard, in the park, etc.) and the use of measuring and recording devices. Output specification: a video or audio recording of a biological object or event made by the teacher, examples of pupil products from the lesson (pupil recording of measurement, graph, calculation, pupil recording of an observed biological object or event, etc.)	distance	2

The aim of Module 1 was to know the current trends in the field of science education at primary (B - PS) and secondary schools (B - SS), especially in the field of education oriented towards active student science research. The activities were chosen to make teachers aware of different levels of inquiry and principles important for planning and designing activities, as well as effective inquiry-based teaching of biology. Biological observations, trials, and experiments were an important part of this module. The teachers solved research questions linked to everyday life or questions that stimulate the curiosity and motivation of students (Where does fat go if we lose weight? Is it possible to drown in the Dead Sea? Is it possible for a spider to get caught in its own web? Why do fish in the Arctic won't the seas freeze? Why is Katka after her mother? and others). The teachers found themselves in the role of a student who observes biological objects and discovers the regularities of biological events and phenomena through his own investigation. After this module, teachers should be able to apply the acquired knowledge and skills in teaching using the proposed innovative methodological procedures, as well as according to their own proposals for research activities appropriate to the age of the students, with an emphasis on developing students' research skills in accordance with the principles of constructivism and the objectives of the lesson. Teachers should be able to critically evaluate the quality of available educational materials aimed at the implementation of research activity. An important part of the module was the assessment of students' research skills with concrete examples and the use of evaluation tools for formative assessment of students' knowledge and abilities.

In the module focused on the computer-supported laboratory, teachers were presented with measurement systems, as well as research activities focused on counting and measuring with the use of digital technologies. Teachers in the role of pupils looked for answers to research questions using measuring systems and sensors, websites in the form of online calculators, but also mobile applications with the possibility of measuring and calculating. For example, the teachers investigated whether/how it is possible to influence the activity of the heart, how respiration and photosynthesis of plants take place under different conditions, what their carbon footprint is, how many years they will live and how long they will live in health, they calculated the age and value of the tree (according to the type of tree, age and location),

investigated the consequences of using the phone behind the wheel by simulating different situations and using a mobile application to measure reaction time. The module also included modelling of biological events and phenomena, for example, the relationship between predator and prey using the Coach software, and investigating the consequences of a disturbed biological balance.

In module 3, teachers became familiar with the possibilities of image processing in biology classes. Using freely available Fiji software, teachers analyzed digital photographs, counted biological objects (red blood cells), measured the content of objects or different parts in photographs (black and white zebra stripes), and indirectly counted volume (hypericin in dark and hyperforin in transparent nodules on St. John's wort leaf). The teachers observed the objects using a digital microscope (e.g., pollen grains), a stereo magnifier (the structure of a bird's feather, a carp scale), and made records for their further analysis. The module also included research activities using mobile applications using shape or color analysis, for example an application for the analysis of artificially prepared and differently colored urine samples, analysis of marks on the skin and evaluation from the point of view of the risk of malignant changes, an application for examining the color sensitivity of a healthy window or for identification fungi, plants, insects, etc. A special part consisted of activities using interactive online keys to identify trees and plants, 3D models, simulations and also biological databases, where the results are displayed visually, for example the representation of bird migration and their occurrence in a selected area, forest monitoring, air quality in a given area or occurrence of endemic bird species, etc.

The part of the program focusing on the analysis of the video recording aimed to familiarize teachers with the importance of video from the perspective of neuroscience knowledge, as well as practical examples of valuable video recordings with recommendations for their effective inclusion in teaching. The teachers mastered the principles of video analysis using the Coach software, which they can apply, for example, when analyzing a video of a person's breathing with visible movements of the diaphragm, recording the movement of animals, etc. Mobile applications with analysis of audio recordings were used for bird species identification. Teachers can take advantage of the fact that the creation, processing, and analysis of video footage by the students themselves has a significant effect on their learning. Therefore, within the module, the teachers created and then processed their own video recording on the selected topic. It was interesting to create records with subsequent analysis during the examination of living biological objects, e.g., snails, earthworms, lichens, etc. The teachers were also introduced to the possibilities of creating animations through freely available applications.

The education of biology teachers at secondary schools (B – SS) was extended by a module in which teachers became familiar with research activities that can be implemented directly in the field. In the role of a student, they analyzed the quality of various water sources using measuring systems with sensors for measuring conductivity, pH, dissolved oxygen concentration, and litmus papers specialized for the analysis of several water parameters in ponds, lakes, and aquariums, as well as the analysis of drinking water. It included the use of mobile applications for the assessment of air quality in selected locations, documenting the occurrence of observed bird species, and participation in the census of birds in the world. Depending on the weather, the teachers also participated in the collection of manure in the botanical garden, which they later documented and researched.

4.2 Program informatics in natural science and mathematics

The biological block of the educational program Informatics in natural sciences and mathematics (INSaM) was implemented during 3 academic years in the scope of 25 hours as part of a larger educational program, which made up 50 hours together with a general block of informatics and a block focused on the teacher's second approval subject (informatics, mathematics, physics, chemistry or geography). In the last 2 academic years, the biology block was taught as part of a separate innovative educational program in the range of 50 hours. The specific goal of the program was to expand the knowledge and skills of biology teachers with

the implementation of informatics and digital technologies in solving biological research questions and problems, namely by analyzing the image of biological objects (I), modeling biological events and phenomena (II) and using available biological databases (III).

The education was designed so that biology teachers have the knowledge and skills necessary for teaching the biology block of the innovative optional subject INSaM in secondary school. The content of the modules was aimed at introducing innovative methodological procedures, the name of which presents a research problem solved using informatics. Table 2 presents the subject of the education modules, the name of innovative methodologies, the form of education, and the time allowance within the educational program in the range of 25/50 hours (more details in Kimáková et al., 2020; Mišianiková et al., 2021a).

Table 2. Content and scope of the educational program Informatics in natural sciences and mathematics (INSaM).

Module	Content	Form of education	Subsidy (hours)
	Subject of education: Image processing		
1	Organism and environment: How many birds fly in a flock?	in person/online	2/4
	Blood, blood elements: How do we know how many blood cells are in the blood?	in person/online	2/4
	Cell: What does light reveal about cells?	in person/online	2/4
	Subject of education: Modeling		
2	Organism and environment: Rabbits and foxes.	in person/online	2/4
	Cell proliferation: When is the surgeon busy?	in person/online	2/4
	Organism and environment: When is the forest healthy?	in person/online	2/4
	Virology, bacteriology, prophylaxis: Will you get vaccinated?	in person/online	2/4
	Subject of education: Database system		
3	Biodiversity: Get to know the plants.	in person/online	2/4
	Organism and environment: Where do migratory birds fly?	in person/online	2/4
	Structure of nucleic acids, genetic code: It is not a virus like a virus.	in person/online	2/4

Distance output: Preparation for 1 teaching unit in the form of a Word file in the scope of at least 2 pages of A4 format, a photo of the biological object and samples of the pupil's record of the lesson conducted by the teacher in the form of a presentation in the scope of at least 8 images. Subsidy: 5 hours/10 hours, including self-study and consultation of the final presentation.

4.3 Participation of biology teachers in accredited educational programs

The University of Pavel Jozef Šafárik in Košice implemented the accredited education of biology teachers during the period of 5 academic years as part of the IT Academy project. In the beginning, teacher training took place face-to-face (in person), but for the last 2 academic years, all implemented programs took place in an online environment due to the pandemic. Figure 1 shows the participation of teachers in accredited programs, which were successfully completed by the defense of the final thesis by 127 teachers, of which 53 teachers graduated from the Educational program Teaching biology in primary school with a focus on the development of digital and scientific literacy (B – PS, biology primary school teachers), 50 teachers completed the Educational program Teaching biology in secondary school with a focus on the development of digital and scientific literacy (B – SS, biology secondary school teachers) and 24 teachers completed the innovative education Informatics in natural sciences and mathematics, part of biology. Teachers showed

the greatest interest in participating in programs focused on the development of digital and scientific literacy, especially at the beginning of education.

The interest of teachers in these programs during the academic year 2020 – 2021 decreased significantly. Since the training of teachers in the academic year 2019 – 2020 was completed before the start of the pandemic, we believe that the decrease in interest in education was caused by the pandemic, when teachers participated in online webinars to support the teaching of students online. On the contrary, in the case of innovative education Informatics in natural sciences and mathematics, part of biology, we noticed the opposite trend. The increased participation of teachers in the academic year 2018 – 2019 was probably caused by the fact that this educational program was not opened in the previous academic year for organizational reasons. The teachers' interest in this education was approximately the same, even in the last year of the project. The availability of online education meant that in the last 2 academic years, teachers from all over Slovakia and from more distant locations participated in the education. During the project, the education of biology teachers was also carried out by the partner universities, Matej Bel University in Banská Bystrica and Constantine the Philosopher University in Nitra, with the exception of the educational program Informatics in natural sciences and mathematics, part of biology.

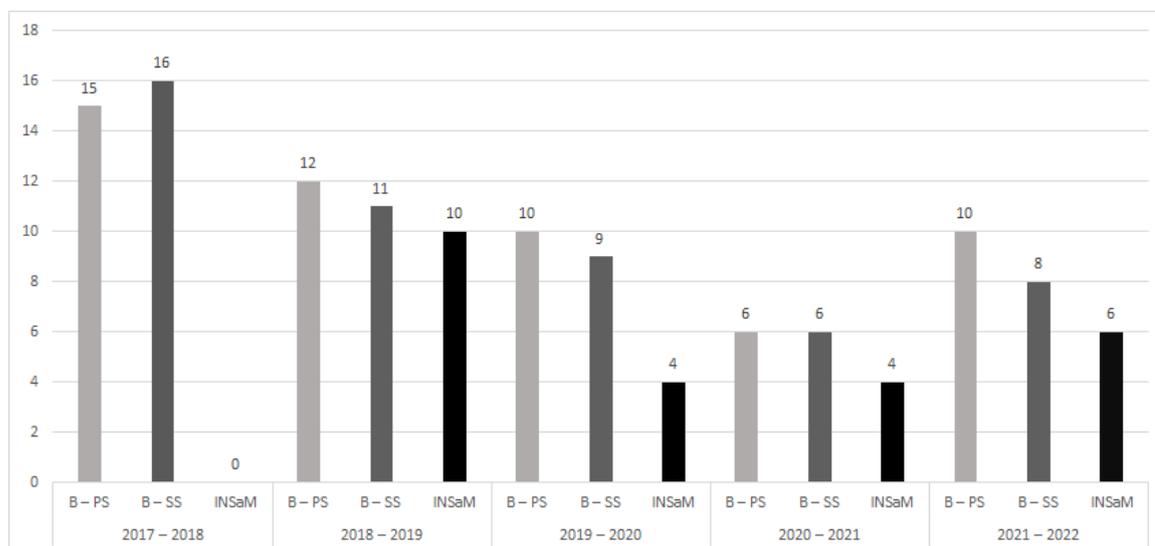


Figure 1. Participation of biology teachers in educational programs (B – PS: Educational program Teaching biology in primary school with a focus on the development of digital and scientific literacy, B – SS: Educational program Teaching biology in secondary school with a focus on the development of digital and scientific literacy, INSaM: Informatics in natural sciences and mathematics, part of biology).

4.4 Evaluation of educational programs by teachers

Primary and secondary school biology teachers spoke positively about the contribution of education to their professional development at the final defense. After the final defense, we sent an online questionnaire to teachers for the evaluation of accredited education. We sent the questionnaire to graduates of all accredited educational programs.

We asked the teachers to evaluate each module of the given educational program according to 3 criteria, in the context of usefulness, applicability, and the level of knowledge and skills achieved. In the questionnaire, it was explained that usefulness means that the knowledge and skills are new for teachers or

presented in a new way and have the potential to innovate the teaching of pupils in the area related to the given module. Applicability represents the possibility of using the knowledge and skills acquired in biology classes in relation to the conditions of the school, the material provision of classes, as well as in relation to the school's educational program for biology. Finally, the teachers also commented on how, after completing the program, they evaluate the level of their own knowledge and skills in relation to the given module, where their level of self-confidence is high and where, on the contrary, they see the potential for improvement and the suitability of further education. Each criterion was rated by teachers using a scale of 1 – 5, where 1 means the lowest level of usefulness/applicability/level of knowledge and skills, and 5 the highest rating for that criterion. In the questionnaire, there was also space for justifying the evaluation of the module, recommendations, and evaluation of the benefit of meetings held in person compared to online.

The evaluation questionnaire was filled out by 89 biology teachers, which represents 70% of the total number of education graduates. Of the teachers involved in the programs focused on the development of digital and scientific literacy, 42 elementary school biology teachers (B - PS) and 33 secondary school teachers filled out the questionnaire, which represents 79% and 66% of the number of graduates of the given educational program. Of the graduates of the educational program Informatics in natural sciences and mathematics, part of biology, 14 teachers participated in the survey, which corresponds to 58% of the graduates of this program. Tables 3 and 4 show the evaluation of the modules of the educational programs by the biology teachers who successfully completed the training. Table 3 illustrates the proportions of biology teachers (%) of primary/secondary schools (B – PS/B – SS, %) who evaluated the module according to the given criterion on a scale of 1 – 5.

In general, primary school and secondary school teachers rated the innovativeness and usefulness of education most prominently in module 2, which focused on computer-assisted measurements, the use of measurement systems, and mobile applications for measurement. The teachers evaluated that this part of the program helped them to realize the importance of measurement in regular biology lessons and that measurement can be part of several practical exercises. High school teachers indicated that students' work with graphs to interpret results could be useful in developing critical thinking and data analysis, and these skills could also be useful for students interested in studying medicine. On the other hand, it is precisely in this area that even after training, teachers perceive great room for improvement and the suitability of further education. Several teachers stated that their uncertainty is related to the lack of measurement systems at the school, the insufficient number of sensors, or other limitations. It is also the reason why teachers perceive a lower degree of applicability of knowledge in practice. On the rating scale, the teachers rated usefulness and innovativeness lower in module 1, where the teachers adopted the principles of research-oriented teaching of biology. The teachers justified this by saying that some of the information was familiar to them. Nevertheless, they commented on the validity of the given module and stated that they mastered the principles of research-oriented teaching mainly thanks to practical research activities during the entire education in the role of a student, distance learning assignments from each module, and the realization of lessons with the application of IBSE. Secondary school biology teachers evaluated the module in terms of applicability lower than elementary school teachers, which they explained by time constraints in regular biology lessons. The survey also showed that teachers also see potential for further education in this area. When evaluating all modules, teachers positively perceived practical demonstrations of the use of digital technologies in teaching biology. Primary and secondary school teachers were interested in websites and mobile applications that can be used directly in school, but also as part of student research in preparation for teaching. Most of the presented sites and mobile applications were unknown to the teachers until then, and they considered the presented ideas to be an important source of innovation in teaching biology.

Table 3. Evaluation of educational programs focused on digital and scientific literacy (%; B – PS/B – SS).

	1	2	3	4	5
Module 1: Inquiry-based science education (IBSE)					
Usefulness	0/0	0/0	40.5/45.5	42.8/30.3	16.7/24.2
Applicability	0/0	0/0	7.2/12.1	33.3/48.5	59.5/39.4
Level of knowledge and skills	0/0	14.2/6.1	26.2/18.1	54.8/57.6	4.8/18.2
Module 2: Computer supported laboratory (CSL) - school measurement systems					
Usefulness	0/0	0/0	0/0	16.7/24.2	83.3/75.8
Applicability	0/0	16.7/24.2	28.6/3	45.2/57.6	9.5/15.2
Level of knowledge and skills	0/0	28.6/3	50/63.6	21.4/27.3	0/6.1
Module 3: Computer image processing					
Usefulness	0/0	0/0	0/0	52.4/42.4	47.6/57.6
Applicability	0/0	4.8/3	23.8/27.3	28.6/57.6	42.8/12.1
Level of knowledge and skills	0/0	4.8/9.1	23.8/15.2	45.2/60.5	26.2/15.2
Module 4: Video analysis					
Usefulness	0/0	0/0	0/0	50/54.5	50/45.5
Applicability	0/0	4.8/0	4.8/3	23.8/24.3	66.6/72.7
Level of knowledge and skills	0/0	4.8/0	42.8/27.2	26.2/57.6	26.2/15.2
Module 5: Field work using the school measurement and recording system					
Usefulness	0	0	0	30.3	69.7
Applicability	6.1	12.1	54.5	21.2	6.1
Level of knowledge and skills	6.1	27.3	21.2	24.2	21.2

The evaluation of the biological block of the educational program aimed at preparing teachers to teach the innovative subject informatics in natural sciences and mathematics at school is demonstrated in Table 4 (%). Education graduates highly rated the usefulness of all modules, which is connected to the innovative character of the given subject. The survey indicates that teachers perceive the applicability of the developed methodological procedures in teaching the subject. According to this criterion, they rated databases and image processing the highest, while solving biological problems through modeling was the lowest. The assessment of modules by teachers from the point of view of applicability and their knowledge and skills has the same trend. The teachers also stated that they perceived as a limitation the low level of digital competences needed in the teaching of module 2. However, several teachers demonstrated during the final presentation that, in cooperation with the informatics teacher, they had successfully designed and implemented lessons using modeling with the Python programming language. Most often, however, teachers choose image analysis through the Fiji application for the final work.

When evaluating the form of education, up to 76% of teachers would choose a combined form of face-to-face and online meetings supplemented by distance tasks, 15% of teachers would prefer to conduct all meetings online, and 9% would prefer face-to-face.

Table 4. Evaluation of educational program Informatics in natural sciences and mathematics, part of biology (%; INSaM).

	1	2	3	4	5
Module 1: Image processing					
Usefulness	0	0	0	7.1	92.9
Applicability	0	0	0	14.29	85.71
Level of knowledge and skills	0	7.1	35.7	42.9	14.3
Module 2: Modeling					
Usefulness	0	0	0	0	100

Applicability	0	0	0	78.6	21.43
Level of knowledge and skills	7.1	35.7	35.7	21.5	0
Module 3: Database system					
Usefulness	0	0	0	14.29	85.71
Applicability	0	0	0	7.1	92.9
Level of knowledge and skills	0	0	7.1	57.2	35.7

5. Informal education of biology teachers

During the IT Academy national project, 23 in-person and online meetings with biology teachers were held, in which a total of 345 teachers participated. Teachers showed the greatest interest in this form of education during the pandemic, when several webinars were held focused on the possibilities of research-oriented teaching of biology online and the presentation of available digital tools, mainly in the form of websites and mobile applications.

6. Conclusion

The continuous education of biology teachers is of enormous importance in the era of rapid development of digital technologies and the related need for digitization of education. Primary and secondary school biology teachers perceive the need for innovative education focused on practical demonstrations of the implementation of digital technologies in teaching. It is the alternative possibilities of digital tools, which are freely available for teachers and students, that offer a way of meaningful innovation in teaching biology. The use of mobile applications during student research supports the motivation of students and the connection of education with everyday life. In addition, the effective use of digital technologies contributes to the well-thought-out development of pupils' digital competences, as well as 21st-century skills. Biology teachers are also supported by digital coordinators at schools, who are the leaders of the school's digital transformation. Newly established regional teacher support centers offer individual support to teachers through a mentor who accompanies the teacher in his professional and personal growth.

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References

- Hubeňáková, V., Šveda, D., Mišianiková, A., & Kireš, M. (2020). Digital Transformation of Education at School. *ICETA 2020: 18th IEEE International Conference on Emerging eLearning Technologies and Applications*, 187-193. <https://doi.org/10.1109/ICETA51985.2020.9379221>
- Kimáková, K., Mišianiková, A., & Andrejková, G. (2020). *Informatika v prírodných vedách a matematike - zošit biológia* (1st ed.). Centrum vedecko-technických informácií SR.
- Lešková, A., Mišianiková, A., Kimáková, K., Boberová, Z., Slepáková, I., Schubertová, R., Malina, R., Sandanusová, A., Vondráková, M., Schlarmanová, J., Strejček, F., Čipková, E., Fridmanová, A., Panigaj, L., Kotlárová, K., Fialková, L., Šmajdová, V., Petnuchovej, V., Mitíľová, V., Vavreková, J., Bystrá, B., Žideková, K., Radvanský, M., Fuchs, M., & Fančovičová, J. (2021). *Zbierka inovatívnych metodík z biológie pre základné školy* (2nd ed.). Centrum vedecko-technických informácií SR.
- Mišianiková, A., Kimáková, K., & Lešková, A. (2021a). Implementation of interdisciplinary elements in biological education at secondary. *EDULEARN21: 13th annual International Conference on Education and New Learning Technologies*, 7061-7067. <https://doi.org/10.21125/edulearn.2021.1422>

- Mišianiková, A., Hubeňáková, V., Kireš, M., Babinčáková, M., & Šveda, D. (2021b). Assessment of digitalization in primary and secondary schools by SELFIE survey as a part of school leaders training. *ICETA 2021: 19th IEEE International Conference on Emerging eLearning Technologies and Applications, Proceedings*, 252-258.
- Mišianiková, A., Lešková, A., Kimáková, K., Boberová, Z., Slepáková, I., Schuberová, R., Malina, R., Sandanusová, A., Lengyelová, L., Matejovičová, B., Morovič, M., Strejček, F., Čipková, E., Fuchs, M., Panigaj, L., Bruňáková, K., Mock, A., Kisková, T., Škarbeková, L., Čornaničová, S., Luczyová, P., Prokaiová, M., Procházková, B., Greňová, A., Šoltéssová, S., Skičková, Š., Prokaiová, M., & Nagyová, S. (2021c). *Zbierka inovatívnych metódik z biológie pre stredné školy* (2nd ed.). Centrum vedecko-technických inovácií SR.
- Redecke, Ch., editor(s), & Punie, Y. (2017). *European Framework for the Digital Competence of Educators: DigCompEdu*. Joint Research Centre. <https://doi.org/10.2760/159770>
- Šveda, D., Hubeňáková, V., Babinčáková, M., Kireš, M., Kozelková, K., Lukáčová, K., Mišianiková, A., & Ondová, V. (2022). Digital transformation of education with the support of the national project IT Academy. *20th Anniversary of IEEE International Conference on Emerging eLearning Technologies and Applications*, 640-646. <https://doi.org/10.1109/ICETA57911.2022.9974646>
- Vuorikari, R., Kluzer, S., & Punie, Y. (2022). *DigComp 2.2: The Digital Competence Framework for Citizens*. Publications Office of the European Union. <https://doi.org/10.2760/115376>

Nucleic Acids – Educational Animations and Their Use in Practice

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Abstract. Nowadays, finding new strategies for students' learning is discussed by many authorities in the research field as well as through state curricula. The need for transfer from traditional education to student-activating methods is widely emphasized. One of the possible tools enabling the achievement of the above objectives is an animation. This article presents a set of newly created animations on the topic of nucleic acids and their use in teaching at a Czech high school. A total of 18 interactive and interdisciplinary 2D subanimations were created. They were used in an action research (realised with a questionnaire survey) for graduate students. According to the answers, the students evaluated the animations positively. They appreciated the clarity, sufficient professional level, and simple handling.

1. Introduction

Pupils' motivation has been a very strongly discussed topic recently (Ikwuka et al., 2017). Today, many professionals report the necessary transition from traditional frontal education to a more attractive form for students and, as a result, for teachers. This transition is in great demand, especially in the natural sciences. The fields of chemistry, physics, but also biology are often very abstract and demanding on understanding and the student's imagination (Szarka & Juhász, 2014). According to many authors, it is possible to reverse this perception by using visualization tools that will simulate or at least animate complex events (Barak & Ashkar, 2011; Nodzyńska, 2012; Schönborn & Anderson, 2006). One of the visualization tools that can be used for this purpose is an educational animation.

This article summarizes the methodology and results of action research, which addressed the possible increase in teaching effectiveness through the use of educational animations. It was performed in the subject of chemistry at a Czech high school, and the animations focused on the structure and metabolism of nucleic acids were used for it.

2. Theoretical background

The following paragraphs will describe the theoretical background on which the whole survey is based. The main emphasis is on animation as one of the possible dynamic visualization tools, teaching effectiveness, and action research theory.

2.1 Animation

Animation can be classified as a dynamic visualization tool, which includes, among other things, simulations and videos (Ainsworth & van Labeke, 2004). It is now widely accepted that animation leads to more efficient teaching (Barak & Ashkar, 2011; Szarka et al., 2016; Tarmizi, 2010). Animations have the potential to illuminate concepts that are otherwise very abstract and difficult to understand. This is also confirmed by Barak & Ashkar (2011), who argue that animations are applied to support the transition from abstract to concrete thinking. In this way, they help to develop the student's comprehensive understanding. In an educational context, animation is particularly effective when it visualizes processes that cannot be observed or are difficult to explain (Ikwuka et al., 2017). Understanding such complex,

abstract concepts results in better memorization, and animation can also prevent misconceptions or get possible preconceptions to the right level (Tarmizi, 2010).

A meta-analysis by Berney et al., who analysed 140 pair-wise comparisons in 61 studies (a total of 7036 respondents) comparing the effects of static (images, texts, ...) and dynamic models (animations) in teaching, pointed to a long-running conflict between researchers. Of the 140 studies, 43 (30.7 %) pointed to more positive effects of the use of animations compared to static models, while according to the results of 14 studies (10 %), static objects are more effective than dynamic ones. A large number of surveys (a total of 83, i.e., 59.3 %) did not find any significant difference between teaching using static and dynamic models. The authors' conclusions, therefore, speak of a positive effect of animations in comparison with static models. The authors state that animations, unlike static objects, provide a more comprehensive view of the problem simply because several solo static objects (eg. images) must be used to express for example structural changes in a certain chemical process, while in the case of an animation, change is more clearly represented by a single dynamic object (Berney et al., 2015). As a result, animations reduce students' cognitive overload.

Other authors argue that animation can lead to increased motivation, increased academic achievement, reduced learning time, gaining student attention, and support for cognitive processes (Barak et al., 2011; Ikwuka et al., 2017; Kainz et al., 2013; Stith, 2004; Szarka et al., 2016).

Among the negatives of educational animations, we can include, for example, the transience of the presented information. Thus, animation does not offer permanent, but temporary information. From this, it is evident that the given information can remain in the working memory of the pupils for only a few seconds, and subsequently, other information can be displaced (Bétrancourt & Tversky, 2000).

Another negative factor may be the so-called "split attention effect", which in many animations may be caused by their excessive complexity. Some objects may move at the same time, and students are then forced to divide their attention, which can lead to imperfect capture of the required information (Lowe, 1999).

The above conclusions of the studies show that animations can be a tool that strengthens the understanding of complex processes, increases students' motivation, and thus improves their learning outcomes.

However, on the other hand, many studies have not found the correlation between the use of animation and better understanding or motivation of students (Bétrancourt & Realini, 2005; Hegarty et al., 2003; Rebetez & Bétrancourt, 2007). However, the relevant reasons have still not been identified.

2.2 Effectiveness of the educational process

Given that each person spends a substantial part of their childhood or adolescent life at school, it is useful for education to be as effective as possible. Very often, the term "teaching effectiveness" refers to the expression of the success of students, teachers, or entire schools in various subjects, competitions, entrance exams, etc. Among the many definitions of teaching effectiveness, we can mention, e.g., "It is the ratio between spent resources, time, effort, intensity of psychological processes in learning activities, and achieved results of learning activities (mastered knowledge, applicable working procedures, adopted attitudes)." (Kolář, 2012).

Many authors have been dealing with the effectiveness of teaching for a long time. Surveys in this area also include a meta-study by Seidel and Shavelson, which summarizes the results of research into teaching effectiveness in 1996-2006. As a basic research method, the authors used a meta-analysis of research studies that looked at the effects of the teaching process on students' learning. The basic result of the meta-study is the fact that the effectiveness of teaching is complex. The management of learning activities related to a specific curriculum has the greatest effect on pupils' cognitive outcomes. The subject-related activities, social and personal experience, time for learning, management, and monitoring had the greatest effect on motivational-affective outcomes. Again, learning material, activities, learning time, and social experience had the greatest effect on learning processes (Seidel & Shavelson, 2007).

From this and other research, it is clear that the right variation of learning activities, personal

experience, teacher and student work management and their expertise contribute to greater teaching efficiency (Brandsford et al., 2000; Floden, 2001; Seidel & Shavelson, 2007; Wang et al., 1993).

2.3 Action research

According to the Pedagogical Dictionary, action research is characterized as: "A type of pedagogical research, the purpose of which is to directly influence or improve a certain part of educational practice, addresses the current needs of the educational institution" (Průcha et al., 2003). Action research is seen as a tool that helps teachers solve problems in school practice and, at the same time, implement innovations in this practice. The teacher appears here in the difficult dual role of researcher and active participant at the same time. This type of research may differ from academic research, but it is no less significant or less relevant. Its results correspond to immediate activities, but have limited use and are more subjective. Action research is focused on both the pupil and the teacher; it has the potential to improve the teacher's procedures and methods, and at the same time, in the broader context of the whole school.

In action research, action, reflection, and revision are essential elements. According to Whithead (1993), action research is practical to be divided into five steps:

- a) a problem that has arisen in practice,
- b) the idea of solving the problem,
- c) activity for the chosen solution,
- d) evaluation of the results of activities,
- e) modification of the problem.

The objectives of action research have already been described in general terms above, but in summary, their essence is to increase the teacher's professionalism, develop his pedagogical thinking and skills, and improve his decision-making processes. Overall, therefore, this type of research leads to an improvement in the teacher's practice. A very important point is also that action research supports the improvement of pupils' results and the overall level of their work at school. Also, a sense of personal responsibility for one's own growth of professionalism, efforts to improve teaching, leading to better educational results of students, are not negligible possible results of action research (Nezvalová, 2003).

In terms of types of action research, we distinguish two basic types (Schmuck, 1997):

- a) Proactive action research - when the action itself takes place before data collection and processing. The teacher first develops activities, the effectiveness of which he then studies. This type of research inspires teachers to implement new approaches, methods, or tools used in teaching. This inspiration can be based on the teacher's previous experience, from colleagues, or the students themselves. Proactive action research begins with an attempt at new approaches that bring better results, then the teacher gathers students' reactions to the changes, then evaluates the information obtained, and tries other new approaches (alternative approaches are also possible).
- b) Reactive action research - here, teachers gather information before trying to innovate practice. The teacher's activity is based on the assumption that each pedagogical situation is unique and it is necessary to first understand it, then respond to it. The steps of this type of research are as follows: collect information about the situation, evaluate this information, define the changes that will follow, try new approaches and implement them, then monitor reactions and collect data, then evaluate and possibly modify selected procedures and methods.

The survey described in this article used a proactive type of action research.

3. Aim of the study, research questions, and hypothesis

It is evident that the conclusions from the studies described above are inconsistent. For this reason, there is a need for more investigations that focus on the use of animations in teaching, respectively, on their impact on pupils' motivation and learning outcomes. The action research described in this article aims to validate nucleic acid-related animations. The results of previous studies show that this topic is considered one of the difficult topics in chemistry (or biology) (Marbach-Ad et al., 2007; Rotbain et al., 2008), so the use of animations for its teaching is offered. At the same time, the students from the research class mentioned that the topic of nucleic acid metabolism was discussed in biology during the same school year, but without the use of dynamic visualization tools. For the pupils, the whole curriculum was difficult to understand; they were confused by a lot of information, or did not understand the basic principles of these events. The following objectives of the research survey were set:

- a) verify the quality of the created animations on the topic of nucleic acid and modify these animations according to any student comments,
- b) to find out the attitude of pupils to the use of educational animations in teaching in order to make teaching more efficient.

Based on the above objectives, the following research questions were formulated:

RQ1: Are the created animations on the topic of nucleic acids of sufficient quality for use in teaching this topic?

RQ2: According to students, can the use of educational animations in teaching lead to its greater effectiveness?

4. Methods and study design

4.1 Participants and learning environments

The action research presented in this paper was carried out at a secondary level of the grammar school type in Slaný (Central Bohemian Region). It was attended by 9 high school graduates in the subject of chemistry. It was a proactive action research. The educational animations used presented the topic of nucleic acids. The whole process is described by the following schedule:

- a) creation of a new teaching aid,
- b) setting the main goal,
- c) carrying out the research itself,
- d) obtaining feedback,
- e) evaluation of feedback and drawing conclusions.

The animations used were created in Adobe Animate 2022, in the javascript coding language. In total, the animation application contained 18 partial animations, which covered basic high school topics related to nucleic acids (e.g., animal cell structure, replication, transcription, translation, PCR). The animations were created on the basis of a search of already available thematic materials and according to criteria that are discussed, for example, in the author's diploma thesis (Šarboch, 2018).

Figure 1 shows the desktop of the animation program. The creation is based on inserting specific objects into different layers. Objects in individual layers can then be animated independently of the others. In addition to various drawing tools, the workspace also contains a library of already created objects, as well as an overview of individual layers, and of course, the drawing canvas itself.

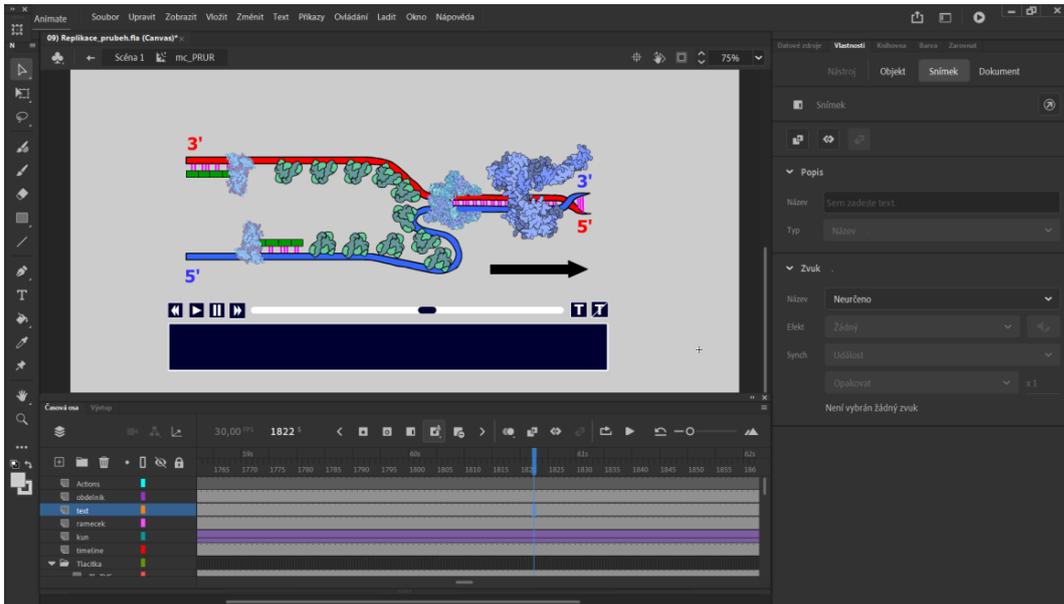


Figure 1. Sample desktop of the animation program Adobe Animate 2022. In the lower part, you can see the individual timelines, and in the middle is the drawing canvas itself. On the left is a column of drawing tools, on the right is the library and options for working with objects.

Figure 2 then represents the final animation itself, respectively. animation window. It consists of an ongoing animation, under which there is an accompanying text describing the animated processes. The text can be turned off and on again. Above the text box is the timeline of the animation, to the left of it, the individual interactive animation buttons ("go back", "play", "pause", "go forward").

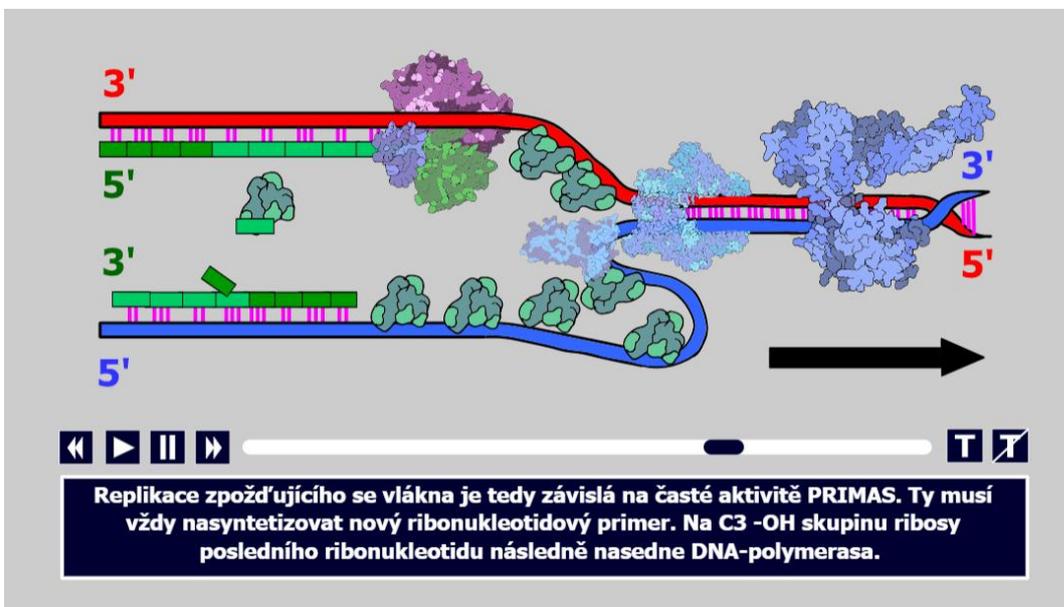


Figure 2. Example of the animation itself. Here you can see a part focused on the replication process.

4.2 Research tools

The tool that was used to obtain data on the basis of which it was possible to answer the research questions was a student questionnaire. It contained three items. The first of them presented pupils with several statements with which respondents had to agree or disagree to varying degrees (a five-point scale from "strongly agree" to "strongly disagree"). In the second item, students were asked questions, to which they responded with a short open answer. In the third item, the respondents had to create hashtags that would describe the work with the animations. After completing the questionnaires, an additional interview between the teacher and the students followed, during which some answers were supplemented or clarified. The results of the survey are discussed in a chapter below.

4.3 Schedule of implementation of the action research

The first step was to create interactive, educational animations on the subject of nucleic acid (for more details, see the paragraphs above). The research itself was conducted continuously during three lessons. Specific topics were the processes of replication, transcription, translation, and maturation of proteins (a total of 4 partial animations were used). Teaching animations served as a basic teaching tool, which was always used in most classes. Among the methods used during the survey, frontal teaching with the method of asking questions, cooperative learning, and finally, the description of animated events by the pupils themselves prevailed. The animations were used mainly during the exposure, fixation, and diagnostic phases of the lesson.

The penultimate part of the whole process was to get feedback from the students themselves. This was done by a short questionnaire, which found out the attitude of students to the use of specific educational animations and at the same time their impression of the research tool itself.

Based on the reflection with the pupils, the animations used in the teaching were finally partially modified. The main change was the conversion of the blue background to light grey and the subsequent necessary change in the colour of some texts. Due to the fact that some students found the accompanying texts to be less informative, a study text was created with static visualization material, which specifies and possibly expands the animated topics.

5. Results of the action research

The questionnaire that the students filled in after using the animations in the lesson was divided into three parts. This division also reflects the following summary of the results of the action research.

The answers from the first part, which mainly concerned the appearance and use of specific animations, are summarized in Tab. 1. Pupils had to evaluate individual statements with a grade from 1 to 5 (i.e. 1 - strongly agree, 5 - strongly disagree).

Table 1. The results of the first part of the questionnaire summarize the appearance and use of the animations.

Evaluation criterion (statement)	Amount of „1“	Amount of „2“	Amount of „3“	Amount of „4“	Amount of „5“	Average grade
The animations have good graphics.	2x	7x	---	---	---	1,78
The complexity of the professional content corresponds to the educational level.	9x	---	---	---	---	1,00
The animations are illustrative.	6x	3x	---	---	---	1,33
The inclusion of similar animations in other topics would lead to a better understanding of teaching.	6x	3x	---	---	---	1,33
The inclusion of similar animations in other subjects would lead to a better understanding of teaching.	5x	4x	---	---	---	1,44

The results presented in Tab. 1 show that the students evaluated the animation very or rather positively in all the above criteria. During the additional questioning of individual statements, the pupils

mentioned, for example, that the video used to explain the given topics in biology was too complex, from a professional level, it did not correspond to their previous knowledge, and at the same time, it did not match the knowledge required by the teacher. On the contrary, the educational animations seemed to the pupils to be quite suitable for use at the secondary school level.

In terms of clarity, the students pointed out the blue background of the animation and the blue colour of some enzymes, which sometimes led to poor visibility of the ongoing events.

Among other topics that could be elaborated within the animations, the pupils mentioned in particular cellular respiration, photosynthesis, van der Waals interactions, hydrogen bonds, or lipid emulsification. Pupils would also be able to imagine the use of animations in biology subjects (especially in the topic of cell metabolism and genetics), in physics (animation of various physical processes), and then in mathematics, for example.

The second part of the questionnaire was represented by five open-ended questions. Below are the individual items and summaries of the students' answers:

a) *"Which elements were disturbing in the animation?"*

Most of the students did not observe any disturbing elements in any of the animations used. However, some mentioned the use of a blue background and blue moving objects, which sometimes merged with the surface.

b) *"Did you use the above animations for home study as well?"*

Three students wrote that they actually used the animations at home. The rest of the respondents stated that they did not know where to find them, so they used videos used in biology, but nevertheless used notes from chemistry lessons during their home preparation.

c) *"Write the 3 pros of the animations used."*

Here, the captions that accompany the individual animations were very often mentioned, as well as the possibility of moving or stopping the animation (and possibly re-reading the accompanying commentary). There have also been comments on the very nature of the use of animation in teaching: "You get a better idea of what's really going on than just looking at the pictures."

d) *"Write the 3 cons of the animations used."*

The answers in this task were mainly related to a small accompanying text, or the need to add more information to the text. The fact that animation needs to be explained by teachers was also mentioned as a negative. This observation is very closely related to the generally accepted thesis that animations are not self-supporting, and the role of the teacher is very important here.

e) *"Write at least 1 other way of using animations in the class in addition to the classic presentation by the teacher."*

Pupils mainly mentioned group work (cooperative teaching), they also mentioned a certain form of peer learning, and the flipped classroom method.

In the last part of the questionnaire, the students had the task to come up with at least one hashtag that would relate to the animations used. Here are some specific answers: #chemistryunderstandably, #Ivegotit, #creativelearning, #animationineducation, #illustrativeteaching, #playwithchemistry, #easybiochemistry.

The results above show that students perceive the implementation of animations in the educational process as a positive step that leads to increased efficiency and attractiveness of teaching. Of course, due to the very small sample of respondents and the very nature of the action research, the results cannot be generalized. On the other hand, thanks to the research, it was possible to adjust the entire animation set according to the pupils' observations, and valuable suggestions were also obtained for further work in the field of creating and using animations in teaching.

6. Conclusion

The action research described in this paper followed the pupils' opinion on the use of educational animations in teaching, and at the same time, its aim was to obtain feedback on the created animations as one of the possible didactic tools.

It should be mentioned that action research usually concerns only a small sample of respondents, who often subjectively evaluate, for example, the demonstrated method. Therefore, its results cannot be generalized to the entire population. However, it can be argued that the use of educational animations on the topic of nucleic acids was found by students to be positive. According to the respondents, the understanding of the given processes increased significantly, and the presented curriculum was more comprehensive and clear for the pupils. The answer to the second research question is therefore positive, yes, the use of educational animations can lead to greater teaching efficiency. The question arises of whether this positive effect was not caused by previous teachings on the topic of biology. It is possible that the students who had already encountered the topic had some basics, so the topic was not completely foreign to them, some knowledge was supportive for them, and therefore they understood the teaching in chemistry better. However, the aim of this research was not to compare the teaching of biology and chemistry, but to find out a specific attitude on a particular topic taught by a specific method. From this point of view, the use of animations can be considered effective.

According to the first item of the questionnaire, the first research question can also be answered. Pupils rate the created animations as high quality, but with minor shortcomings. Based on their comments, the most mentioned shortcomings were adjusted. In particular, it involved changing the background colour and editing some text. It would be interesting to use the discussed animations once again with other students and follow their specific answers and reactions. However, this research step was not implemented due to time constraints.

References

- Ainsworth, S., & van Labeke, N. (2004). Multiple forms of dynamic representation. *Learning and Instruction*, 14(3), 241-255. <https://doi.org/10.1016/j.learninstruc.2004.06.002>
- Barak, M., & Ashkar, T. (2011). Learning science via animated movies: Its effect on students' thinking and motivation. *Computers and Education*, 56(3), 839-846. <https://doi.org/10.1016/j.compedu.2010.10.025>
- Berney, S., Bétrancourt, M., Molinari, G., & Hoyek, N. (2015). How spatial abilities and dynamic visualizations interplay when learning functional anatomy with 3D anatomical models. *Anatomical Sciences Education*, 8(5), 1-11. <https://doi.org/10.1002/ase.1524>
- Bétrancourt, M., & Realini, N. (2005). Faut-il vraiment laisser le déroulement d'une animation sous le contrôle de l'apprenant ? *Communication à la 11ème journée d'étude sur le traitement cognitif de systèmes d'informations complexes*, 1-7.
- Bétrancourt, M., & Tversky, B. (2000). Effect of computer animation on users' performance: A review. *Le Travail Humain*, 63(4), 311-329.
- Bransford, J. D., Brown, A. L., & Cocking, R. R. (2000). *How people learn: Brain, mind, experience, and school*. National Academy Press.
- Hegarty, M., Kriz, S., & Cate, C. (2003). The roles of mental animations and external animations in understanding mechanical systems. *Cognition and Instruction*, 21(4), 209-249. https://doi.org/10.1207/s1532690xci2104_1
- Ikwuka, O., Nkiru, N., & Chigozie, S. (2017). Effect of computer animation on chemistry academic achievement of secondary school students in Anambra state, Nigeria. *Educational Research*, 8(2), 98-102.
- Kainz, O., Jakab, F., & Kardos, S. (2013). The computer animation in education. In *2013 IEEE 11th International Conference on Emerging eLearning Technologies and Applications (ICETA)* (pp. 201-206). <https://doi.org/10.1109/ICETA.2013.6674428>
- Kolář, Z. (2012). *Výkladový slovník z pedagogiky, 583 vybraných hesel* [Explanatory dictionary of pedagogy, 583 selected entries]. Grada Publishing, a.s.
- Lowe, R. K. (1999). Extracting information from an animation during complex visual learning. *European Journal of Psychology of Education*, 14, 225-244. [https://doi.org/10.1016/S0959-4752\(02\)00018-X](https://doi.org/10.1016/S0959-4752(02)00018-X)
- Marbach-Ad, G., Rotbain, Y., & Stavy, R. (2007). Using computer animation and illustration activities to improve

- high school students' achievement in molecular genetics. *Journal of Research in Science Teaching*, 45(3), 273-292. <https://doi.org/10.1002/tea.20222>
- Nezvalová, D. (2001). Intercultural competencies towards interactive professionalism: A challenge for leadership training. *International conference*, Slovenija, pp. 23-31.
- Nodzyńska, M. (2012). Vizualizace v chemii a ve výuce chemie [Visualization in chemistry and in the teaching of chemistry]. *Chemické listy*, 106, 519-527.
- Průcha, J., Walterová, E., & Mareš, J. (2003). *Pedagogický slovník* [Pedagogical dictionary]. Portál.
- Rebetez, C., & Bétrancourt, M. (2007). Video game research in cognitive and educational sciences. *Cognition, Brain and Behavior*, 11(1), 131-142.
- Rotbain, Y., Marbach-Ad, G., & Stavy, R. (2008). Using a computer animation to teach high school molecular biology. *Journal of Science Education and Technology*, 17, 49-58. <https://doi.org/10.1007/s10956-007-9080-4>
- Schmuck, R. A. (1997). *Practical action research for change*. SkyLight Professional Development.
- Schönborn, K. J., & Anderson, T. R. (2006). The importance of visual literacy in the education of biochemists. *Biochemistry and Molecular Biology Education*, 34(2), 94-102. <https://doi.org/10.1002/bmb.2006.49403402094>
- Seidel, T., Shavelson, R. (2007). Teaching effectiveness research in the past decade: The role of theory and research design in disentangling meta-analysis results. *Review of Educational Research*, 77(4), 454-499. <https://doi.org/10.3102/0034654307310317>
- Stith, B. (2004). Use of animation in teaching cell biology. *Cell Biology Education*, 3(3), 181-188. <https://doi.org/10.1187/cbe.03-10-0018>
- Szarka, K., & Juhász, G. (2014). Model učenia interaktívnym molekulovým modelovaním na ZŠ. *Mezinárodní konference o výuce chemie a IX. Regionálního IOSTE symposia pro Střední a Východní Evropu*, Hradec Králové, 362-373.
- Šarboch, D. (2018). Trávení jako mezioborové téma ve výuce přírodovědných předmětů / Digestion as an interdisciplinary topic in science education [Master's thesis, Univerzita Karlova, Přírodovědecká fakulta]. <https://dspace.cuni.cz/handle/20.500.11956/98659>
- Tarmizi, R. A. (2010). Visualizing student's difficulties in learning calculus. *Procedia-Social and Behavioral Sciences*, 8, 377-383. <https://doi.org/10.1016/j.sbspro.2010.12.053>
- Wang, M. C., Haertel, G. D., & Walberg, H. J. (1993). Toward a knowledge base for school learning. *Review of Educational Research*, 63(3), 249-294. <https://doi.org/10.12691/education-4-2A-4>
- Whitehead, J. R., & Corbin, C. B. (1991). Effects of fitness test type, teacher, and gender on exercise intrinsic motivation and physical self-worth. *The Journal of School Health*, 61(1), 11-16. <https://doi.org/10.1111/j.1746-1561.1991.tb07850.x>
- Wilson, S., Floden, R., & Ferrini-Mundy, J. (2002). Teacher preparation research: An insider's view from the outside. *Journal of Teacher Education*, 53(3), 190-204. <https://doi.org/10.1177/0022487102053003002>

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Motivation of Students Through Play

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Abstract. Currently, many teachers struggle with students' negative attitudes towards school. Students are reluctant to learn, bored at school, and reject some subjects because they consider them unnecessary. Distance learning in schools also made a significant contribution to the situation. We decided to address this unfavorable situation within the „Student Grant Competition“ (SGS) project by preparing activities leading to game-based learning. The article presents educational games (a card game, a memory game, and tasks from the worksheet) with a simple design, which emphasizes the remembering of facts. Due to the fact that these "stereotypical" activities can no longer attract students so much, they were transferred to the environment of online applications (LearningApps, Flippity, Wordwall) and they were created into fun games to support meaningful learning. During the solution of online games, students are motivated through a competitive challenge, curiosity, ongoing control, and the provision of immediate feedback. Students' motivation is positively influenced by the theme of the game connected with everyday life, the impressive story taking place in the background of the game, and the evaluation of learning progress.

1. Introduction

The goal of every teacher is to attract the student's attention and interest in learning. Make learning more attractive, captivating, and effective (Ott & Tavella, 2009). To support students' external and internal motivation, student involvement, critical thinking, and social interactions (Alsawaier, 2018). To enable learning to take place individually, at the students' own pace, and be linked to experience (Challco et al. 2015; Perryer et al. 2016). All these aspects are covered by the online didactic game.

Gaming is associated with trial and error, failure, and eventual success through practice, experience, reasoning, and learning (Buckey & Doyle, 2014). Many educational games have a simple design and emphasize memorizing facts by practicing tasks. When students are provided with regular explanatory feedback, this fun teaching leads to deep learning and improved learning outcomes (Erhel & Jamet, 2013). Over the last decade, gamification has been increasingly implemented in full-time and online teaching. The modern trend is the introduction of online applications in all phases of teaching. Digital learning tools have considerable potential in providing immediate feedback in the form of formative assessment. Students have the opportunity to self-control and identify weaknesses, which leads to better learning outcomes.

2. Aim and methodology

The aim of the authors was to design game activities using selected online applications, then to include them in the exposure and fixation phase of teaching, to verify the effectiveness of fun learning using the activation method of didactic games with an open-ended test. Furthermore, during action research, factors that can influence the results of testing must be identified. The research questions were defined as follows: “Does the game activity used affect the test results?”, “Does students' academic average affect test results?”

Prepared online game activities using LearningApps, Flippity and Wizer.me were tested at three schools (A, B, C), using three different tools 1-3 (1 - individually assigned tasks, 2 - escape games and 3 - interactive worksheet). Testing at the school took place in two parallel classes, taught by one teacher, and the subject matter, Natural substances connected with everyday life, was selected for the research. The research sample included a total of 126 students in the 9th grade of primary school, of which 58 were girls and 68 were boys. The activities included 82 students, including 38 girls and 44 boys, and at School B, 44 students, including 20 girls and 24 boys, participated in the fixation phase. The success of solving individual test items was determined from the testing results. Subsequently, Pearson's test of independence was applied to verify the hypothesis.

3. Research organization

3.1 Selection of curriculum for research

First, a suitable subject, Natural Materials, with an interdisciplinary overlap in biology and health education, was selected. This curriculum covered these topics as carbohydrates, lipids and proteins. Subsequently, an analysis of terms occurring in the most frequently used textbooks in the Czech Republic for primary schools from the publishing house Fraus and Nová škola was performed (see Table 1).

Table 1. Didactic analysis of concepts on the topic of natural substances.

Topic	Important concepts
Carbohydrates	Photosynthesis, occurrence, function, composition, and significance of selected carbohydrates. Monosaccharides: glucose (grape sugar), fructose (fruit sugar). Disaccharides: sucrose (beet sugar, cane sugar, table sugar), maltose (malt sugar), lactose (milk sugar). Polysaccharides: cellulose (pulp), starch (vegetable starch), glycogen (animal starch).
Lipids	Higher saturated and unsaturated fatty acids, glycerol, fats of vegetable and animal origin, simple and complex lipids, solid fats and liquid oils, waxes, formation of fats, oils, and waxes (esterification), fat solubility, soap production.
Proteins	Peptide (peptide bond), precipitation (denaturation) of proteins, protein functions (construction, transport, movement, protective and defense, control and regulation, accelerating chemical reactions, energy sources). Representatives of proteins: keratin, collagen, casein, albumin, hemoglobin, immunoglobulins, hormones (adrenaline, insulin), enzyme (pepsin).

3.2 Selection of a suitable online application

Suitable freeware applications were selected for the compilation of game activities, which can be used in synchronous online teaching as well as in traditional full-time teaching. It has been found that there are two basic types of applications:

- Applications that provide students with immediate feedback, the student has the opportunity to immediately correct their incorrect answers, and the teacher does not receive results on the performance of the activities. We include LearningApps, Wordwall in this group of applications.
- Applications that provide students with automatic evaluation of closed answers. The evaluation of tasks requiring an open answer is performed by the teacher. Feedback, including the correct answers, is sent by the teacher. We include Wizer.me, Socrative, and Quizizz in this group of applications.

The selection of applications took into account the offer of activities enabling short-answer items (cloze text, crossword, open question), true-false items (group assignment, sorting), and matching items (matching pairs, matching). Another selection criterion was the number of activities that can be compiled in the free version. The possibility of connecting the application with the Flippity application was also considered, which includes the Scavenger Hunt activity, in which all links to the prepared activities can

be inserted, linked to the motivational story, and used as a tool for preparing an online escape game.

Although Wordwall has very attractive graphics, offers a variety of task designs for a compiled game activity, and allows you to collect student responses, it has been excluded due to the limited number of five free game activities. LearningApps, Flippity, and Wizer.me applications were selected to prepare for game motivational activities. The online tool LearningApps is available as a web application in several languages, including Czech. It allows the preparation of several types of exercises, and the link to the prepared exercises can be opened in any web browser. This application can be linked to the Flippity application to create an escape game. The only downside to LearningApps is its old-fashioned design. Wizer.me interactive worksheets are modern, allow you to choose from a wide range of backgrounds and themes, and allow you to add multimedia (video, audio, slides). However, this tool cannot be used for automatic self-checking.

3.3 Preparation of game activities for testing

A total of eight game activities were compiled in the LearningApps application, of which three are on the topic of carbohydrates, three on lipids, and two on proteins. Three worksheets on the same topics covering identical game activities were compiled in Wizer.me, with one exception: open-ended questions were used instead of a crossword puzzle (see Table 2, Fig. 1-4).

Table 2. Three tools for testing game activities (1 - individually assigned tasks, 2 - escape games, and 3 - interactive worksheet).

Topic	1. Separate activities in the LearningApps application	2. Escape game in LearningApps and Flippity	3. Worksheets in Wizer.me
Carbohydrates	Matching Pairs Groups assignment Crossword	The Scavenger Hunt from Flippity includes all links to activities compiled in LearningApps.	Matching Sorting Open Question
Lipids	Cloze text Groups assignment Matching Pairs		Blanks Sorting Matching
Proteins	Crossword Cloze text		Open Question Blanks

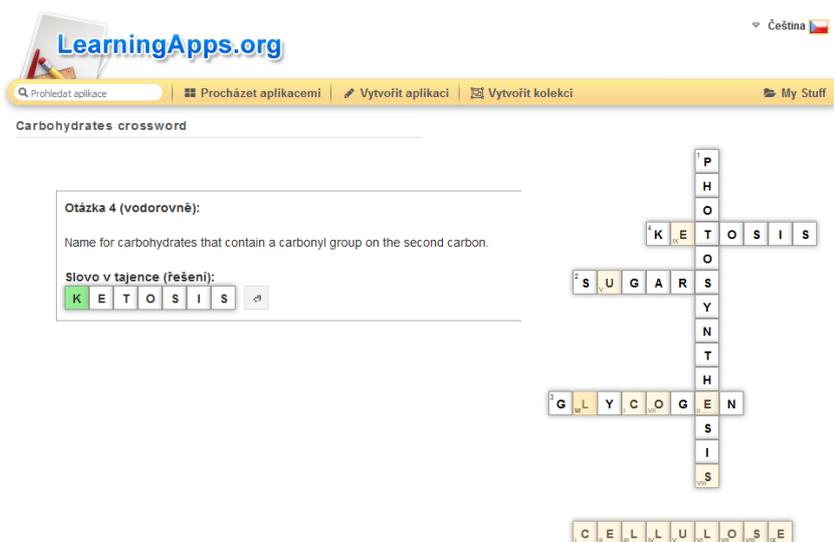


Figure 1. Crossword on the topic of Carbohydrates in applications, LearningApps.

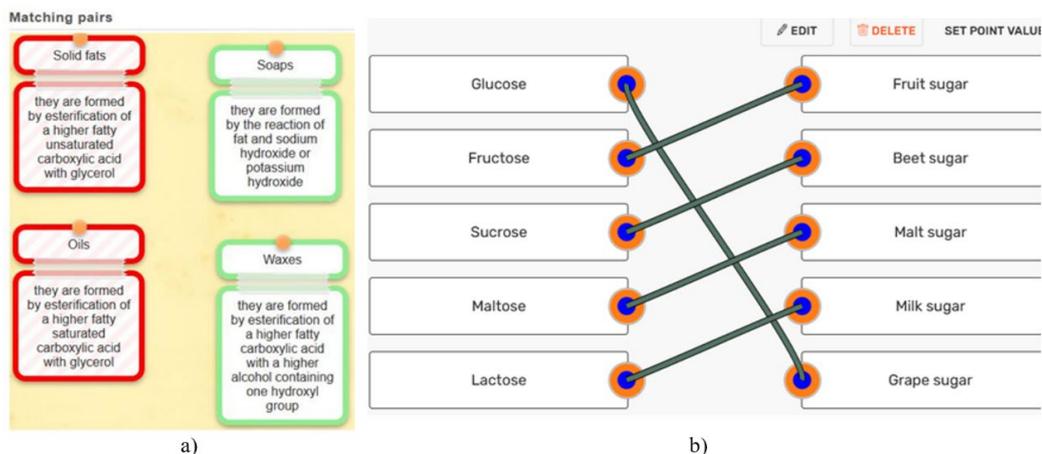


Figure 2. Matching Pairs a) on the topic Lipids in applications LearningApps, b) on the topic Carbohydrates in applications Wizer.me.

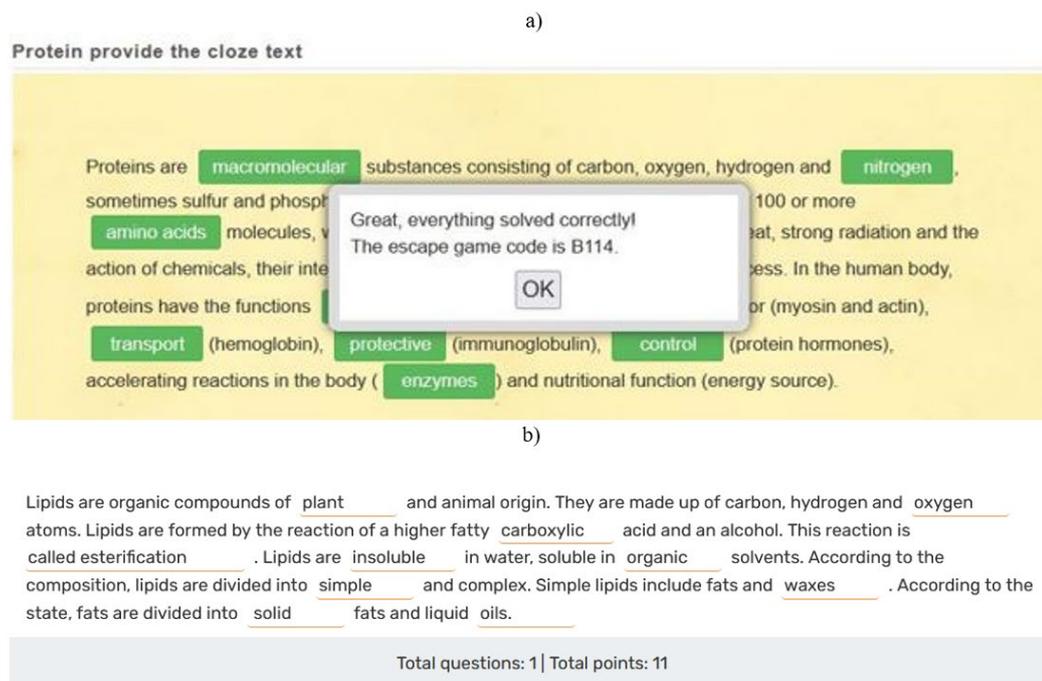


Figure 3. Cloze text a) on the topic Proteins in applications LearningApps, b) on the topic Lipids in applications Wizer.me.

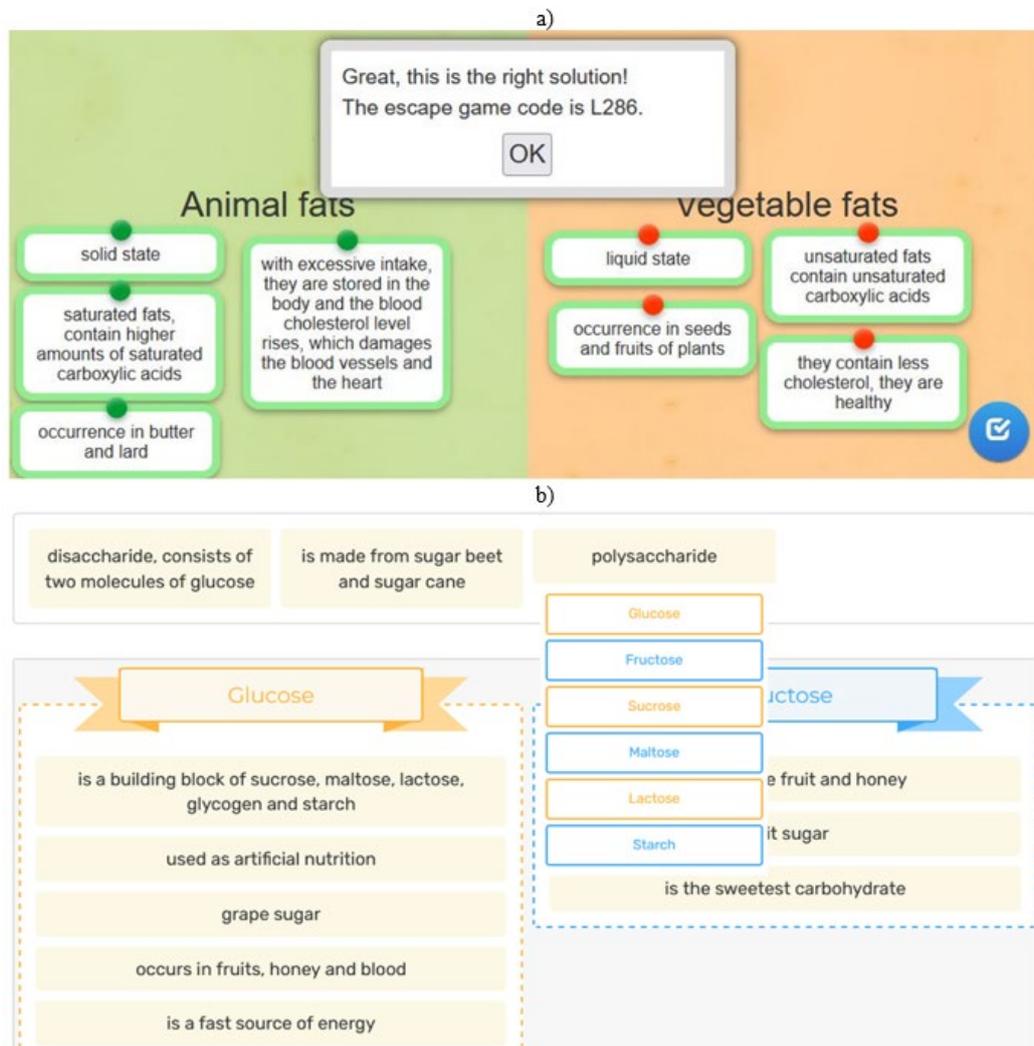


Figure 4. Groups assignment a) on the topic Lipids in applications LearningApps, b) on the topic Carbohydrates in applications Wizer.me.

3.4 Test preparation

In order to verify the learning outcomes through play activities, a test was compiled, which included a total of 12 questions, of which four questions on the topic of carbohydrates (questions 1-4), lipids (questions 5-8), and protein (questions 9-12), see Table 3. The table also shows what type of game activity included the term, which is the answer to the given test question.

Table 3. Test questions and the occurrence of answers in game activities.

Test questions	Short-answer items	Cloze text	True-false items	Matching items
1. Which carbohydrate serves the body as a fast source of energy?			+	
2. Which carbohydrate performs a storage function in plants?			+	
3. Which disaccharide contains the sweetest sugar, fructose?			+	

4. Give a name for the complex biochemical process of converting inorganic substances (carbon dioxide and water) to glucose in the presence of light and the green dye chlorophyll.	+	
5. What is the name of the reaction of a higher fatty carboxylic acid with an alcohol?		+
6. In what solvent do we dissolve the fat?		+
7. What are the names of unsaturated fats that are less cholesterol and healthy?		+
8. What are the reaction products of fat and sodium hydroxide called?		+
9. What is the name of a complex protein that occurs in the blood and has a transport function?	+	
10. What is the name of the protein hormone that is produced by the adrenal medulla and is responsible for the body's reactions to stressful situations?	+	
11. What is the name of an important property of proteins, which is manifested by heating or the action of chemicals? This property is the basis for the production of yogurt, cottage cheese, and some cheeses.		+
12. What is the name of the bond that connects amino acids to the protein chain?		+

4. Results and discussion

After the implementation of online play activities at schools A, B, and C, the learning outcomes of the students were tested. From the testing results, the impact of game activities (1 - independently assigned tasks, 2 - escape games, and 3 - interactive worksheet) and the type of question used in the didactic game on the learning outcomes were analyzed. The success of answers to individual questions from the test was compared. A hypothesis was established and subsequently verified using the Pearson test of independence.

H₀: There is no significant difference between the evaluation of the test answers of individual groups of students.

4.1 Results of testing groups of students A and C after the implementation of the game in the exposure phase

Testing took place at two schools, A and C. Students at school A tested independently assigned tasks in the LearningApps application (class A1) and an escape game (class A2). Class A1 has a study average in chemistry of 2.33 (boys 3.18 and girls 1.62). They solved the test with an average gain of 4.92 points (boys 3.55 and girls 6.08), i.e., with an average success rate of 40.92%. Class A2 has a study average in chemistry of 2.08 (boys 2.54 and girls 1.55). They solved the test with an average score of 5.79 points (boys 5.23 and girls 6.45), i.e., with an average success rate of 48.26%. The results of testing show that they are influenced by the study's average of students.

Figure 5 shows that the students dealt with the most successful issues on the topic of carbohydrates. With the lowest success rate (< 50%), the students solved questions 11, 8, 10, 5, 3, and 7. Of the six questions solved with the lowest success rate, three were on the topic of lipids (5, 7, 8), two on the topic of protein (10, 11), and one on carbohydrates (3). In terms of the questions used in the didactic game, it is clear that students have difficulty reading with comprehension and subsequent completion of the text. They err in answers incorporating concepts they have learned in the cloze text activity (11, 5). A

statistically significant difference at the level of significance ($p < 0.05$) was demonstrated between students of groups A1 and A2 for questions 3, 5, and 12.

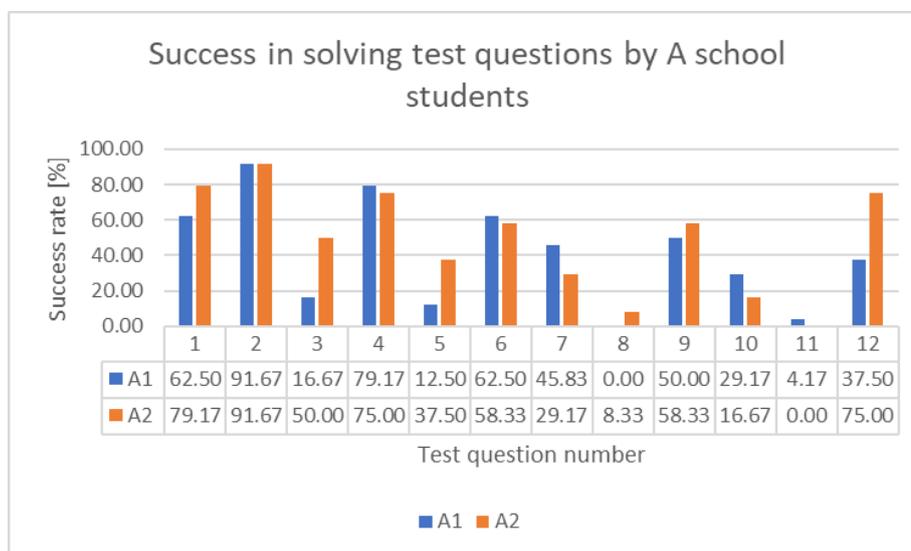


Figure 5. Success in solving test questions by A school students.

School C students tested independently assigned tasks in LearningApps (class C1) and an interactive worksheet in Wizer.me (class C3). Class C1 has a study average in chemistry of 1.82 (boys 1.82 and girls 1.83). They solved the test with an average gain of 5.71 points (boys 5.82 and girls 5.50), i.e., with an average success rate of 47.55%. Class C3 has a study average in chemistry of 1.82 (boys 1.89 and girls 1.75). They solved the test with an average score of 4.06 (boys 4.44 and girls 3.63), i.e., with an average success rate of 33.82%. The test results show that the results are affected by the type of application used. Students taught by the same teacher, with the same study average, are more successful in solving game activities from the LearningApps application, which provides immediate feedback. Using this application in the exposure phase is more efficient than using interactive worksheets. In the free version of the Wizer.me application, an access code for the worksheet was generated for each student, followed by sending the generated codes for three worksheets (Carbohydrates, Lipids, and Proteins) to the student's email. Then the students solved the worksheets. For some worksheet tasks, the students automatically received immediate feedback in the form of points for correct answers. The remaining tasks (answers to open questions, cloze text, and correct answers to all activities) are sent by the teacher after evaluation.

Figure 6 shows that the students dealt with the most successful issues on the topic of carbohydrates. With the lowest success rate ($< 50\%$), the students solved questions 3, 11, 12, 5, 6, 2, and 8. Of the seven questions solved with the lowest success rate, three were on the topic of lipids (5, 6, 8), two on the topic of protein (11, 12), and two on carbohydrates (2, 3). In terms of the questions used in the didactic game, it is clear that students have difficulty reading with comprehension and subsequent completion of the text. They err in answers incorporating concepts they have learned in the cloze text activity (11, 5).

It is evident from Fig. 6 that students C1 and C3 had the biggest problem in solving questions 3 and 11. Question 3 is not just about reproducing knowledge; it requires simple thought operations. The student must list all the disaccharides they know and then identify their ingredients. As was the case with school A, students have difficulty reading with comprehension and then completing the text. Understanding the meaning of the text and finding the right answer is difficult for students (Ema, 2019). Students make mistakes in the concepts they have learned in the game activity cloze text (11, 12, 5, 6). In questions 9 and 10, C3 students are less successful, answering the questions in the worksheet with a short answer. At the same time, C1 students complete the terms in the crossword puzzle. It has been shown

(Pearson, 2020) that this self-learning tool allows students to easily identify gaps in understanding concepts and make learning more fun. Based on our research, we believe that activities providing immediate feedback in the form of formative assessment are more appropriate to include in the exposure phase of teaching. A statistically significant difference at the level of significance ($p < 0.05$) was demonstrated between students of groups C1 and C3 for questions 2, 4, 8, and 9. Significant residuals (deviations) were found here, which show that there are many C1 students who answered the 2nd question correctly, and at the same time, few C3 students who answered the 2nd question correctly. Furthermore, there are many C1 students who answered the 8th question correctly, and at the same time, a few C3 students who answered the 8th question correctly.

The use of the LearningApps application with the provision of immediate feedback in the crossword and matching activity positively affects the test results for questions (2, 8, and 9).

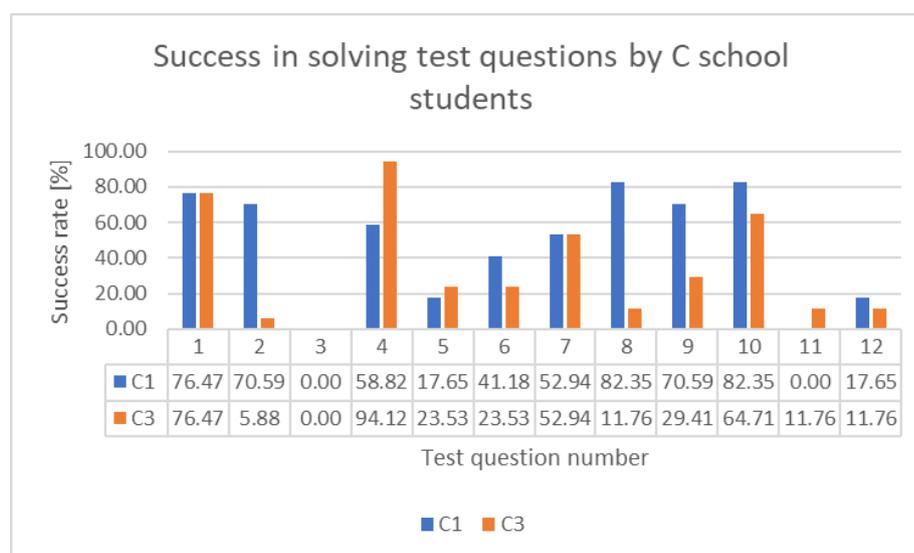


Figure 6. Success in solving test questions by C school students.

4.2 Results of testing of groups of B students after the implementation of the game in the fixation phase

Testing took place in school B in two classes, students of this school tested independently assigned tasks in the LearningApps and Flippity escape game (class B2) and an interactive worksheet in the Wizer.me application (class B3). Class B2 has a study average in chemistry of 2.04 (boys 2.25 and girls 1.67). They solved the test with an average gain of 8.52 points (boys 7.75 and girls 9.89), i.e., with an average success rate of 71%. Class B3 has a study average in chemistry of 2.05 (boys 1.75 and girls 2.27). They solved the test with an average score of 7.00 (boys 8.25 and girls 6.09), i.e., with an average success rate of 58.33%. The results of testing show that they are influenced by the study average of students and the type of application used. Students taught by the same teacher, with the same grade point average, pass the test more successfully because they consolidated the concepts through learning activities with LearningApps, which provides instant feedback.

It is evident from Figure 7 that the students dealt with the issues on the topic of lipids with the greatest success. Students (B2 and B3) solved questions 2 and 11 with the lowest average success rate ($< 50\%$). Students B3 solved five questions with a success rate of less than 50%, of which three questions were true-false decision-making activities from the worksheet (2, 1, 7), one for the text (5), and one for the short answer (9). Question 2: "Which carbohydrate has a storage function in plants?" The common answer was polysaccharide or cellulose. This question was thus formulated intentionally with the possibility of a divergent starch or sucrose answer. The true-false activity for the carbohydrates topic includes 21 items that need to be categorized into six groups. Because Wizer.me does not provide students with immediate

feedback with the correct answers to questions, it would be more appropriate to divide the activity to sort properties and use carbohydrates into three separate activities. Based on our research, we believe that it is more appropriate to include activities compiled in the LearningApps application and in the fixation phase. Links to activities compiled in LearningApps stored in the Scavenger Hunt application of Flippity make it easier for students to control their game activities. This escape game has a greater motivational charge. A statistically significant difference was found between students of groups B2 and B3 for questions 1, 2, and 10 ($p < 0.05$).

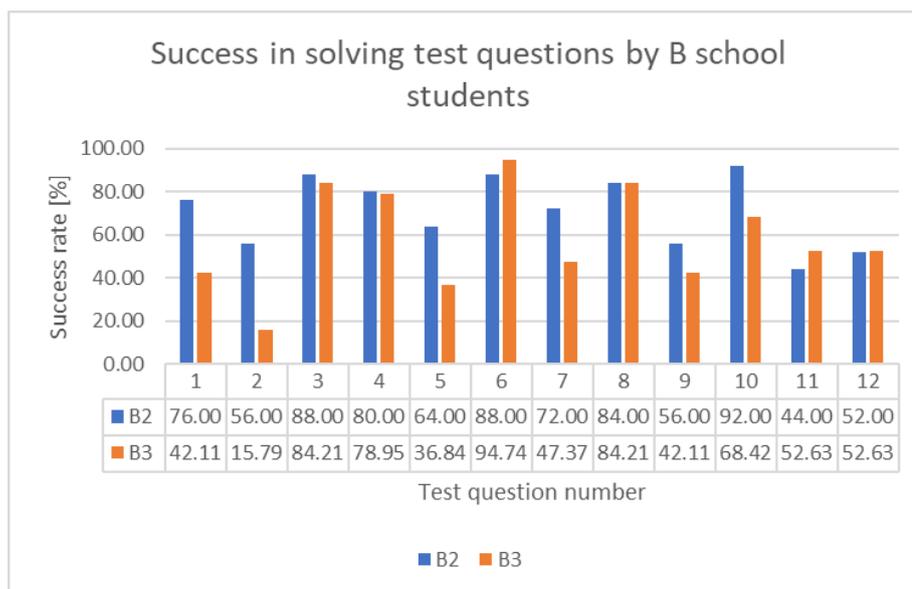


Figure 7. Success in solving test questions by B school students.

5. Conclusion

The analysis of the research has shown that it is more appropriate to introduce online applications into teaching, which provide students with immediate feedback and allow students to work with their own mistakes. Separate activities of the LearningApps application and connected these activities into an escape game are suitable for implementation in the exposure and fixation phase of teaching. In order to streamline the learning process, it is appropriate to divide activities involving a large number of concepts into several sub-activities. For students in the 9th grade of elementary school, it would be appropriate to include various activities so that playing games does not become boring and stereotypical. We recommend enriching your game activities with Multiple-Choice Quiz, Guess the word or The Millionaire Game.

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References

- Alsawaier, R. S. (2018). The effect of gamification on motivation and engagement. *International Journal of Information and Learning Technology*, 35(1), 56-79. <https://doi.org/10.1108/IJILT-02-2017-0009>
- Buckley, P., & Doyle, E. (2014). Gamification and student motivation. *Interactive Learning Environments*, 24(6), 1162-1175. <https://doi.org/10.1080/10494820.2014.964263>

- Chalco, G. C. , Moreira D. A., Bittencourt, I. I., Mizoguchi, R., & Isotani, S. (2015). Personalization of gamification in collaborative learning contexts using ontologies. *IEEE Latin America Transactions*, 13(6), 1995-2002, <https://doi.org/10.1109/TLA.2015.7164227>
- Ema, E. T. (2019). Effectiveness of test design between of cloze test and multiple choice test for reading comprehension. *Journal of Education, Linguistics, Literature and Language Teaching*, 2(2), 53-68. <https://ejurnalunsam.id/index.php/ELLITE/article/view/1782>
- Erhel, S., & Jamet, E. (2013). Digital game-based learning: Impact of instructions and feedback on motivation and learning effectiveness. *Computers & Education*, 67, 156-167. <https://doi.org/10.1016/j.compedu.2013.02.019>
- Ott, M., & Tavella, M. (2009). A contribution to the understanding of what makes young students genuinely engaged in computer-based learning tasks. *Procedia - Social and Behavioral Sciences*, 1(1), 184-188. <https://doi.org/10.1016/j.sbspro.2009.01.034>
- Pearson, R. J. (2020). Online chemistry crossword puzzles prior to and during COVID-19: Light-hearted revision aids that work. *Journal of Chemical Education*, 97(9), 3194-3200. <https://doi.org/10.1021/acs.jchemed.0c00645>
- Perryer, C., Celestine, N. A., Scott-Ladd, B., & Leighton, C. (2016). Enhancing workplace motivation through gamification: Transferrable lessons from pedagogy. *The International Journal of Management Education*, 14(3), 327-335. <https://doi.org/10.1016/j.ijme.2016.07.001>

Observation of 3 Years Changes in the Chemistry E-learning Process Focused on Solving Calculation Tasks during the Periods of Forced Distance Learning

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Abstract. There is an analysis of the e-platform based on the Genexis platform in three countries that have been in demand during the continuous distance learning obstacles in 2020 and 2021. On the example of teaching chemistry concentrated on solving calculation tasks in a basic school in Latvia and Ukraine, the peculiarities of changing the teaching load of students are revealed. It is shown that the mass transition of students to e-learning in a short time does not lead to a deterioration (in the formal indicators) of their level of training.

1. Introduction

In the context of the sudden changes that occurred in the spring of 2020 due to the forced transition of many schools to remote learning, the need to find and apply tools that could ensure the successful implementation of distance learning came to the fore. One of the ways to implement distance learning is to teach students using various electronic platforms.

Since a unified approach to the choice of such a platform for the implementation of the learning process in conditions of remote access, for many reasons, has not been developed even within each individual state, and is hardly possible, then an attempt to make a comparative analysis of how effective the decisions made in conditions of an emergency situation like lockdowns.

In 2008, Data Pro Group Ltd. (Latvia) launched a research project "Computer system for generating and evaluating exercises for subjects of mathematics, physics, and chemistry - GenExis". The system is based on a randomiser and calculator that allows for generating a lot of versions of the same task with different conditions for calculation tasks. The research methodology was developed at Daugavpils University (Latvia), and 21 organizations from Great Britain, Latvia, Lithuania, Slovakia, and Estonia participated in the development and testing of materials for the electronic distance learning platform being created.

The development of the details of the project was based on the results of research that demonstrated an urgent need for tools and methods that could increase the motivation and interest of students in science and mathematics, as well as improve their performance through the use of the GenExis e-learning platform in the educational process (Nikitin et al., 2011).

Currently, e-learning portals have been created and are already operating on this platform in such countries as Armenia, Austria, India, Latvia, Ukraine, and Finland. Initially, the GenExis platform was used to create content and teach subjects in the natural sciences and mathematics; now it is used to teach all subjects included in the curriculum of various educational institutions using the capabilities of this program.

The study of the data accumulated during the period of the mass transition of schools to distance education makes it possible, using the example of the GenExis computer program, to clarify the possibilities of using electronic educational platforms, as well as the features of using such platforms in conditions of their increased demand.

2. Materials and methods

A portal with materials for implementing e-learning opportunities based on the GenExis platform was created in Latvia (www.uzdevumi.lv) in 2009 initially (Gorskis & Nikitins, 2010) and in 2013 in Ukraine (www.miyklas.com.ua). Tasks on the topics offered here are randomly retrieved from the database, which can significantly increase the efficiency of the learning process and avoid mechanical memorization of educational material.

Each of the developed tasks is supplied with an auxiliary comment in the form of solution steps, which may or may not be visible to the student. Therefore, the material posted on the portal can be used both for learning by doing, and for self-control or control of the knowledge and skills of an individual student or a group of students, for example, a whole class, and in all cases each student receives his own set of tasks, different from a similar set of other students generated by GenExis platform.

In addition, both sections of the theory and training tasks obviously contain excess material (tasks and theories) in order to meet the needs of advanced students, too. Tasks for each topic of the section are arranged in order of increasing complexity, so the student using the simulator has the opportunity to choose his own educational trajectory, try to solve tasks and receive support corresponding to his own level of mastering the educational material at this stage. The results of the progress of each student in the study of the material of the subject are stored on the server, and besides the student himself, parents and the subject teacher have access to them (Gorskis, 2012).

On each of these portals, the content of the materials meets the relevant state standards and approved programs, so for a number of subjects it is very different, however, in the content of some subjects, there is a significant similarity. One of these subjects is the basic school chemistry course, which provides for the study of initial chemical concepts, the variety of chemicals and chemical reactions, the structure of the atom and the periodic law, the simplest calculations related to the amount of substance, mass fractions, calculations using the equations of chemical reactions, etc. Therefore, for a comparative analysis of how education process been changed by COVID-19 pandemic and nature of the use of materials offered by e-learning portals created on the basis of the GenExis platform, the accumulated statistical data related to the teaching of chemistry concentrated on solving calculation tasks in the basic school (class 7 to 9) of the above three selected countries were collected in 2019, 2020 and 2021.

3. Results and discussion

Portals created on the basis of the GenExis platform and containing materials from a basic school chemistry course were used by 330,025 students in Latvia and 145,157 students in Ukraine each month in 2019. Due to very large differences in the total number of inhabitants and for some other reasons the number of users of training portals varies greatly in different countries when analyzing, we will pay attention not to absolute indicators, but to the dynamics of their change compared to the 2020 and 2021 years. This will make it possible to draw general conclusions concerning all the above-mentioned countries.

Firstly, it should be noted the high growth of all indicators regarding the number of users of such portals and the intensity of their use. The large differences in the change in the number of users (Figure 1) are explained by the fact that Latvia was the first country where the introduction of e-learning began and by the 2020 year, students in most schools had already used the materials posted on the Uzdevumi.lv web portal. The materials of the e-learning portal were intensively used by students in preparation for tests, as well as by high school students in preparation for exams.

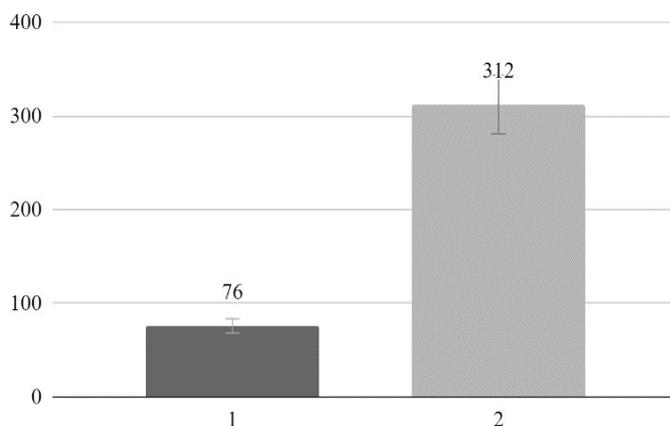


Figure 1. Number of schoolchildren using educational portals created on the platform of the GenExis program (in%) 2020 compared to 2019 (1 - in Latvia, 2 - in Ukraine).

The growth in the number of users by 76% in Latvia in 2020 is explained by the fact that in the absence of alternative electronic platforms for remote learning and for improving acquired skills and abilities, when switching to remote learning, schools and individual students studying chemistry were forced to connect to the portal "Udevumi.lv" almost without exception and now number of registered pupils is close to the number of pupils in whole country.

As for Ukraine, the explosive grow of 312% in 2020 can be explained as, firstly, before the sudden onset of a period of forced transition to distance learning, insufficient attention was paid to this area, and that, secondly, when such a period came, due to the first reason turned out to be that there are practically no alternatives. Both countries' growth stopped after the first year of lockdowns which means user base peaking, there is only 1% grow during year 2021.

The second parameter, which may indicate how responsibly the schoolchildren reacted to self-training in calculation tasks in chemistry at a distance, is how successfully the schoolchildren completed the tasks posted on the portal. Statistical data (Figure 2) indicate that in the conditions of a forced transition to remote learning, the students in their mass showed better results in 2020 and came down in Latvia and Ukraine in 2021.

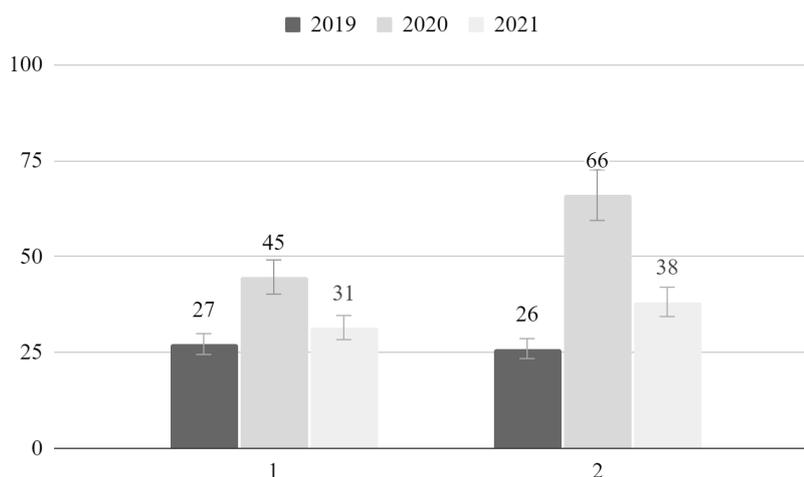


Figure 2. Change in successful attempts to complete a task (in %) in 2021, 2020 compared to the 2019 (1 - by users in Latvia, 2 - in Ukraine).

Another characteristic indicator is the number of tests assigned by teachers. In most cases, the

volume of Homework has increased by 2,5-3,5 times in 2020 but decreased in Ukraine in 2021. This may indicate that teachers in Ukraine who use this electronic platform for teaching have changed their approach for test distribution after the first hard year of a lot of distance learning.

It should be noted that in the context of the forced limitation of face-to-face methodological support from teachers, the time spent by a student on one calculation task increased in 2020 in Latvia but decreased in Ukraine (Figure 3).

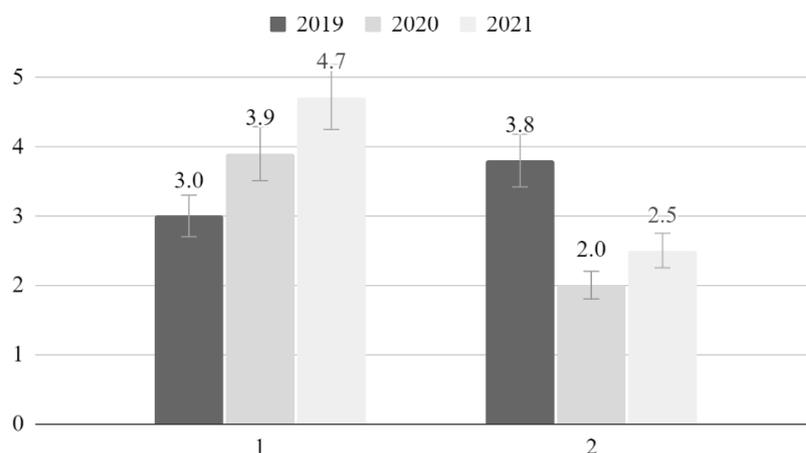


Figure 3. Change in the average amount of time (in minutes) spent by a schoolchild on completing one task in 2020, 2021 compared to the 2019 (1 - users in Latvia, 2 - in Ukraine).

If in 2019 the differences in the amount of time spent on completing one task can be explained by the differing average level of complexity of tasks posted on web portals of different countries, then a significant increase in this indicator in 2020 and 2021 in Latvia and is largely due to the unavailability provide methodological support to schoolchildren in the context of distance learning. Therefore, a lot of new users in Ukraine changed these statistics down in 2020 and started to increase in 2021.

In the conditions of a forced mass transition to distance learning, teachers in all countries began to use portals created on the basis of the GenExis platform much more intensively to organize the assessment of schoolchildren. The growth in the number of tests offered to students is shown in Figure 4.

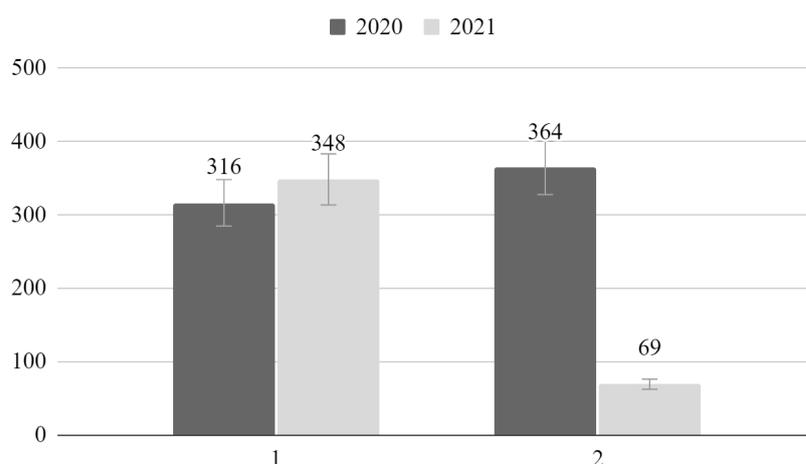


Figure 4. Growth in the number of tests (in %) in chemistry in basic school classes conducted on the basis of the GenExis electronic platform in 2020 and 2021, compared to 2019 (1 - users in Latvia, 2 - in Ukraine).

The final indicator of portals' effectiveness is the average success rate of tests containing calculation tasks (Figure 5).

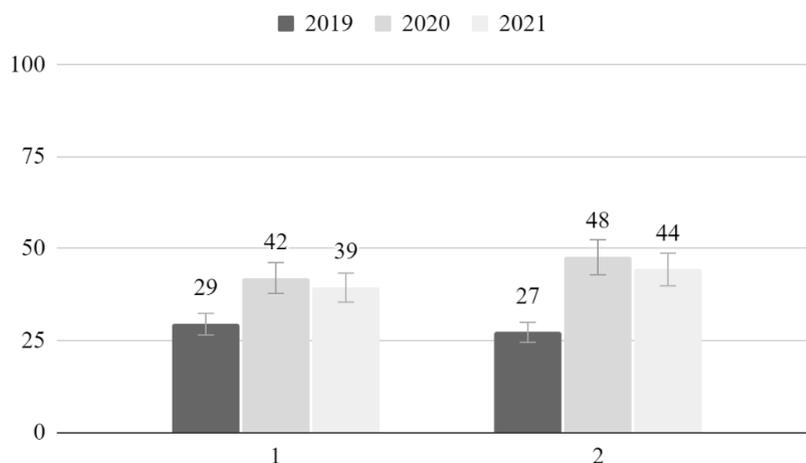


Figure 5. The average success rate (in % of the maximum possible number of points) of the test on portals created using the GenExis electronic platform, conducted in 2020 and 2021, compared to 2019 (1 - users in Latvia, 2 - in Ukraine).

It makes it possible to judge how effective the portals created on the basis of the GenExis platform turned out to be an effective tool for organizing e-learning processes trusted by each country's pedagogical society.

It is obvious that in all countries, despite the previously noted (significant in some indicators) differences, the final indicators of mastering the sections of the basic school chemistry course material by schoolchildren in 2020 and 2021 grew up and now stay stable compared to 2019.

4. Conclusion

A preliminary analysis of the results of the process of teaching chemistry in the basic school, implemented against the backdrop of a forced transition to distance learning, showed a sharp surge in the intensity of access to the electronic platform during 2020 and 2021. Even through this transition occurred largely spontaneously, without careful preliminary training of a large number of teachers, in the end, during few last years did not lead to a decrease in the formal indicators (such as successful attempts to complete a task and average success rate to complete tasks) of the level of training of schoolchildren. This happened because e-learning technology meets modern trends in education, provides process flexibility, free access to educational materials, and the opportunity to receive methodological support at a convenient time for the student.

For a number of reasons, e-learning cannot completely replace other approaches to organizing the educational process. However, the opportunities that were identified in the situation of a mass transition to distance learning, as well as the changes identified in the practical activities of teachers and schoolchildren (for example, an increase in the number of tests, the amount of time spent by a student at the monitor, etc.) should be taken into account in the future when developing advanced learning technologies.

References

- Gorskis M. (2012, July 15-20). *Integration of virtual environment for chemistry students and educators in Latvia* [Paper presentation]. Stimulating Reflection and Catalyzing Change in Chemistry Education: 22nd International Conference on Chemistry Education & 11th European Conference on Research in Chemistry Education, Rome, Italy.
- Gorskis M., & Nikitins V. (2010, July 4-7). *New educational environment to realize e-learning in chemistry*

[Paper presentation]. 10th European Conference on Research in Chemistry Education (ECRICE), Krakow, Poland.

Nikitin V., Gorskis M., & Mazurs V. (2011, November 30 - December 3). *New e-learning platform for science education* [Paper presentation]. International 8th IOSTE Symposium for Central and Eastern Europe: Trends and Main Tendencies in the 21st Century, Riga, Latvia.

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