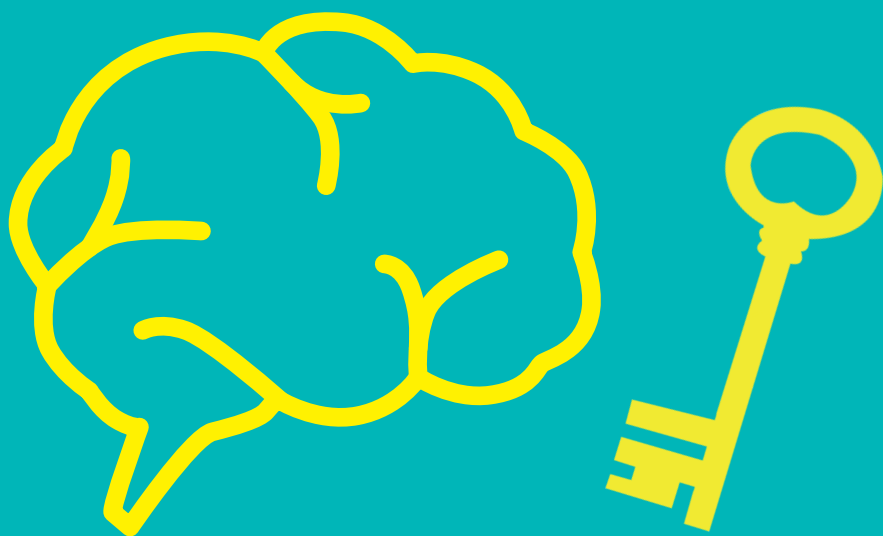


# Developing key competences



Uniwersytet  
Komisji Edukacji Narodowej  
w Krakowie  
Kraków 2024



# **Developing key competences**

**University of the National Education Commission, Krakow  
2024**



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## Introduction

In the dynamic landscape of education, the role of teachers has transcended the traditional boundaries of information delivery to becoming architects of meaningful learning experiences. As we navigate the evolving needs of education, the book “Developing Key Competences” delves into a comprehensive exploration of various facets in the realm of education. This compilation addresses the challenges and aspirations of future educators, offering insights into their reflective practices and the essential competences they need to hone.

The chapters in this book serve as a multifaceted lens, each focusing on a specific aspect of education and shedding light on its intricacies. From the reflective contemplation of the future teacher to the innovative methodologies for engaging Generation Z learners, the book traverses diverse terrains to provide a holistic view of the contemporary challenges and opportunities in the field.

The initial chapters set the stage by examining the challenges and needs that prospective teachers encounter in the preparation of lessons. They explore the complexities of integrating different subjects, examining the viewpoints of teachers regarding the opportunities and obstacles associated with this approach. Furthermore, the book delves into the fundamental question of why we teach science, offering valuable insights into the considerations that future educators bring to this crucial aspect of their profession.

A significant portion of the book is dedicated to practical strategies for effective teaching. From the meticulous preparation of experimental activities to the development of algorithmic thinking through mathematical tasks, the authors provide actionable approaches that resonate with the needs of both teachers and learners. The exploration extends to innovative strategies for assessing geology in secondary education, highlighting the importance of adaptive evaluation methods.

In a rapidly advancing technological era, the book critically examines the readiness of the school environment for the implementation of computational thinking principles, emphasizing the need for aligning educational practices with contemporary demands. Furthermore, the authors unravel the practical applications of pedagogical approaches such as the TASC method in teaching carbohydrates in lower secondary school and the flipped classroom method in the context of applied chemistry.

Addressing the broader societal relevance of science, the book also poses thought-provoking questions about the necessity of chemistry knowledge in everyday life. Additionally, it explores the intersection of chemistry teaching with learning differences, particularly focusing on the challenges posed by dyslexia.

“Developing Key Competences” seeks to be a guiding beacon for educators, providing a rich tapestry of insights, strategies, and reflections that will empower them to navigate the complexities of teaching chemistry. As we embark on this intellectual journey, we invite readers to explore and engage with the diverse perspectives presented within, fostering a community dedicated to enhancing the quality and impact of chemistry education.

Małgorzata Nodzyńska-Moroń



# Development of algorithmic thinking through mathematical tasks

Tomáš Bezouška, Petra Konečná, Martin Žáček

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## Abstract

This paper aims to show how the development of algorithmic thinking can be supported through mathematical tasks. How they can be utilized is illustrated through selected examples. The solution to the problem is always analyzed from a Mathematical point of view, but also in comparison with Computer Science, and then the solution procedure is shown using a flowchart. The tasks are designed to be understandable for both mathematics and computer science teachers. The tasks can be applied to the teaching of both subjects without the teacher necessarily having a mathematics and computer science qualification at the same time. The application of this type of tasks in teaching was pilot tested in two groups of high school students. Two tasks were selected, one easier and one more complex.

## Keywords

computational thinking, algorithmic thinking, algorithm, flowchart

## Introduction

Computational thinking is becoming an increasingly important element of modern education in primary and secondary schools, where the Ministry of Education, Youth and Sports and within the framework of changes to the Curriculum Framework Basic Education (for elementary schools – ISCED 1 and 2) (“Rámcový vzdělávací program pro základní vzdělávání”, 2023) and G (Grammar schools – ISCED 3) (“Rámcový vzdělávací program pro gymnázia”, 2021) introduces the subject of Computer Science into general education subjects. This concept does not mean only learning to program but rather developing the ability to think abstractly, analyze problems and find systematic solutions. One of the critical components of Computational thinking is Algorithmic thinking, which is a necessary tool for analyzing a problem and creating a procedure for solving it.

Computational thinking in elementary and high schools emphasizes the development of algorithmic thinking. Pupils are taught to break down complex problems into simple steps to define conditions and procedures for achieving a goal. In this way, they learn a systematic way of thinking and solving problems, which is a crucial skill not only for the field of computer science but also for many other disciplines and life situations.

Developing algorithmic thinking in primary and secondary schools prepares pupils for the modern world, which is increasingly connected to technology and digitalization. The ability to analyze problems, propose effective procedures and solve complex tasks becomes a key competence for success in scientific, technological and professional fields and everyday life. Thus, Algorithmic thinking prepares students for a possible future career in IT and strengthens their ability to think critically, collaborate and creatively solve problems, whether in everyday life or during work deployment.

### ***Computational thinking***

Defining the term Computational thinking is not simple given the rapidly developing field.

The first author to define this term was Wing (Wing, 2011):

Informally, computational thinking describes the mental activity in formulating a problem to admit a computational solution. The solution can be carried out by a human or machine, or more generally, by combinations of humans and machines.

Computational thinking for everyone means being able to:

Understand which aspects of a problem are amenable to computation,

Evaluate the match between computational tools and techniques and a problem,

Understand the limitations and power of computational tools and techniques,

Apply or adapt a computational tool or technique to a new use,

Recognize an opportunity to use computation in a new way, and

Apply computational strategies such divide and conquer in any domain.

There are currently several definitions of Computational Thinking, for example (Aho, 2012), (Angeli & Giannakos, 2020), (Lyon & J. Magana, 2020), (Selby & Woollard, 2013), (Haseski et al., 2018), (Shute et al., 2017), (Pinheiro et al., n.d.).

Computational thinking involves several curial elements, as shown in several literatures (Khandagale, 2022), (Cetin & Dubinsky, 2017), (Lee et al., 2011), (Lewis Presser et al., 2023), (Liu et al., 2021):

Decomposition: Breaking down a complex problem into smaller, more manageable parts, making it easier to find solutions.

Abstraction: Simplifying a problem by focusing on essential aspects and ignoring irrelevant details.

Algorithmic Thinking: Designing step-by-step instructions or procedures to solve a problem or accomplish a task.

Automation: The ability to automate processes or tasks using programming or automation tools.

Data Analysis: Working with data to identify patterns, relationships, and information, using them to make informed decisions.

Data Representation: Understanding how data can be organized and represented in various formats, and how to manipulate this data.

Generalization and Application: Applying concepts and approaches learned from solving one problem to similar problems.

But the main contribution of Computational thinking to the real life is Collaboration, which means working in a team, sharing ideas, and adapting to various viewpoints and approaches, which may be essential in Computer Science.

From other references (Kong & Abelson, 2019), (Allsop, 2019), (Magana & Silva Coutinho, 2017) we can define three more points, namely:

Evaluation: Assessing solutions and algorithms to determine how well they work and identify any issues or need for further refinement.

Simulation: Using models to mimic the real world or potential scenarios to better understand systems or predict behaviour.

### ***Algorithmic thinking***

As mentioned above, algorithmic thinking is an important element of Computation thinking. We see the ability to think algorithmically primarily in the ability to design algorithms. However, it is no less important to be able to absorb the algorithm, to be able to convince yourself of its functionality, to be able to find possible errors, to be able to determine the effectiveness of the proposed algorithm as well as to propose a sufficiently effective solution.

Algorithm is one of the basic concepts of mathematics and logic. It is a primordial concept, like the concepts of point or set. This means that it cannot be formally defined through simpler terms. Intuitively, we understand it as an instruction on how to perform a certain activity. However, not every instruction can be considered an algorithm (Bezouška, 2023).

The algorithm is characterized by the following properties (Uspenskij, 1963):

Elementarity. The algorithm consists of a finite number of simple (also elementary) steps, which do not allow any specific interpretation of the potential executor.

Finality. The algorithm must terminate at some point, i.e. it always terminates after a finite number of steps.

Determinality. In each step of the algorithm, the next step is clearly defined.

Colectivity. The input data of the algorithm are variable within certain limits. The algorithm does not solve only one or a few cases of a given problem but a whole (large) group of tasks.

Resultativity. The algorithm must always arrive at the desired result. Moreover, due to determinism, the result of the algorithm must always be the same for the same input.

Thus, we will consider as an algorithm here any such instruction that has the above properties. In different sources, then, one may encounter different strict notions of this term. Some people require more of these properties to be satisfied, others less.

Designing these algorithms is no longer straightforward. We need to understand the problem we are trying to solve well in advance and consider everything that could go wrong or wrong - a proper algorithm must never reach any dead ends or get stuck in an infinite loop. Moreover, we require that it apply to any case (we also call it an instance) of the problem. This is the previously mentioned colectivity of the algorithm. It means that, for example, an algorithm for adding two natural numbers, can really add any two natural numbers, and not just a finite number of some selected pairs of natural numbers.

Algorithmic thinking and algorithms offer us another way of knowing and understanding the world around us. While traditional sciences often rely on various experiments that they perform in real environments, on animals or even on humans, with the help of computers and algorithms, we can create models and simulate the phenomena we are interested in and then use them to test our theories. (Curzon & Mcowan, 2017)

### ***Flowchart in Computational thinking***

An algorithm is an unambiguous procedure to solve a problem. There are several notations for writing algorithms:

Natural Language,

Flowchart,

Programming languages - we classify these in a separate group - programming,

Pseudocode.

Flowcharts are one of the most widely used means of creating algorithms due to their simplicity and intuitiveness. A flowchart consists of nodes (symbols), where the shape of the node determines what component of the algorithm it is (for example, a command or a condition). The shapes of the nodes and their meaning are given by the ISO standard (Taufers, 2009). We will not follow this standard in this article precisely, although we will retain the standard node shapes, for example. The usual way of drawing flowcharts is from top to bottom.

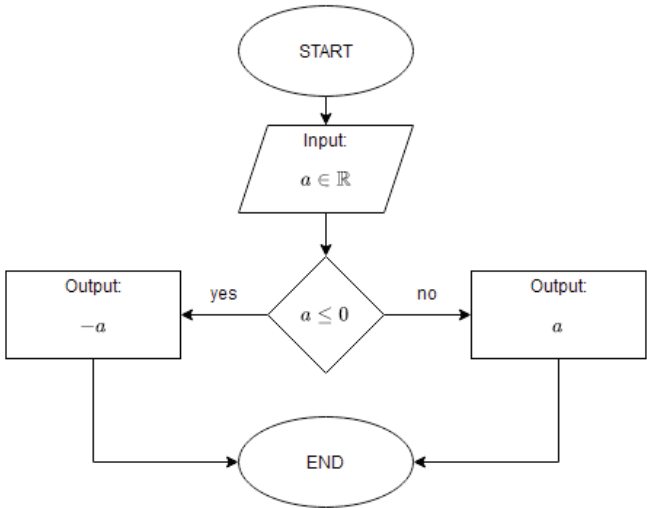


Figure 1. The sample of flowchart of absolute value

The algorithm, written in the form of a flowchart, always starts with a node labelled “START” and ends with a node labelled “END”. The flow of the algorithm is represented by unidirectional arrows between nodes. Immediately after the start of the algorithm, there is a node that defines the inputs of the algorithm. In our case, this is an arbitrary natural number denoted by the letter n. This is followed by a decision node with a condition. Since, in the case of algorithms, we usually work with two-valued logic, the statement written in the condition must be either true or false. Therefore, there must be exactly two new branches leading from each decision node with a condition. One for when the condition is satisfied (here labelled “yes” or “+”), and one for when it is not satisfied (labelled “no” or “-”). The rectangle-shaped nodes represent the instructions to be executed. OPTIONAL: All that remains are the connection nodes, marked with a small colour-filled circle, which we use for clarity when one branch connects to another, and the nodes that determine the algorithm’s output, i.e. the desired result for the specified input.

From the mentioned diagram, its great advantage should be apparent, which is the aforementioned clearer algorithm flow, especially in the case of conditions and cycles where flow branching occurs. This leaves no doubt as to which next step the algorithm should take, and overall the diagram is quite intuitive. The disadvantage is the laboriousness of creating such a diagram and its rapidly increasing size even for relatively simple algorithms. If we want to change the algorithm, it will probably give us more work to change its flowchart. Therefore, it is not very suitable for writing more complex algorithms, where it would not be as clear, but it should still be as easy to follow.

Mathematically minded people and computer science-minded people may have different perspectives on algorithm generation, reflecting differences in their disciplines. The problem can be illustrated by the following example, the output of which is the  $n + 1$  terms of the Fibonacci sequence, see Figures 2 (Mathematically minded people) and 3 (Computer science minded people). A mathematician may focus primarily on the theoretical side, analysing the complexity of the algorithm and finding the most optimal mathematical solutions with a well-defined numerical domain for the variables. For him, precision and generality are key. The computer scientist, on the other hand, maybe more influenced by practical needs and constraints such as computational speed, memory efficiency and integration with existing technologies. He is often concerned with how best to implement and optimize an algorithm for a particular computing environment and a particular programming language. It is not necessarily about how to find the most efficient theoretical solution. These different approaches (which can also be seen in the definition of the problem itself) can lead to different strategies in creating the algorithm, which can have consequences for its final form or performance.

In any case, both approaches for creating algorithms must be independent of any implementation, or the algorithm must be general.

### ***Example of Fibonacci sequence***

Our task is to design an algorithm whose input is  $n \in \mathbb{N}_0$  and whose output is the first  $n + 1$  terms of the Fibonacci sequence.

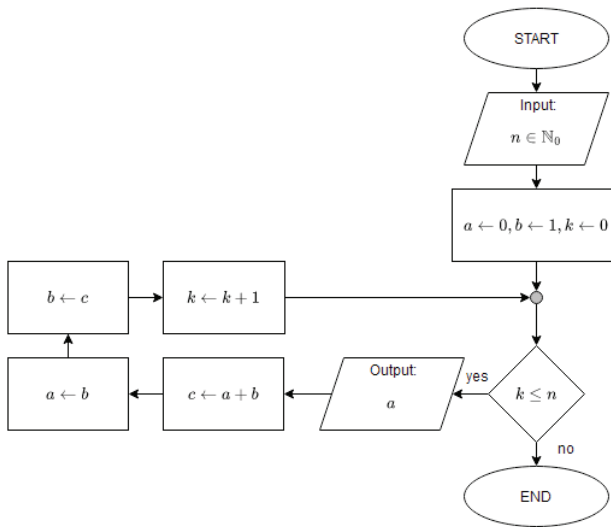


Figure 2. Algorithm of Fibonacci sequences created by mathematician

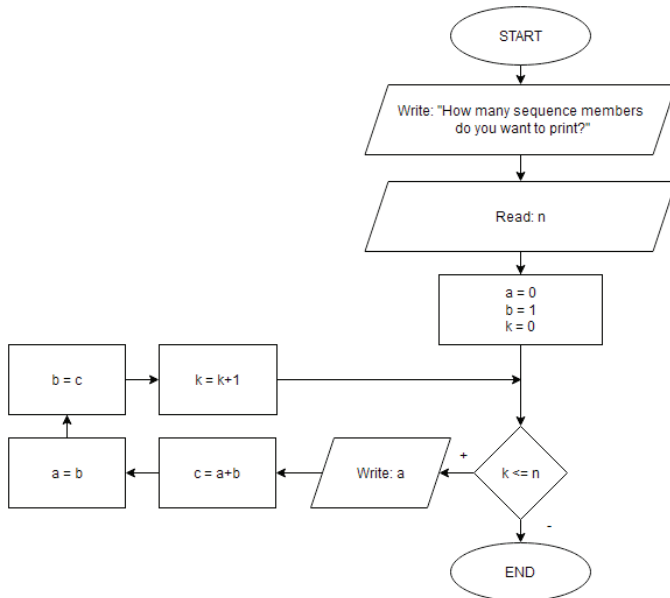


Figure 3. Algorithm of Fibonacci sequences created by informatician

## **Pilot verification of tasks**

### ***Description and methodology of pilot verification***

The pilot validation was carried out in secondary industrial schools with a focus on computer science. Testing was conducted on two groups of third-grade students from two different classes. The first assumption was that the first group would perform better as they had better grades in mathematics and programming. The second assumption was that the students in both groups had already encountered flowcharts during their studies at school, so there was no need to explain the basic elements and principles of flowcharting.

Two examples were chosen, an easier and a more challenging one, based on consultation with the teacher of those classes. The simpler task consisted in designing an algorithm in the form of a flowchart that would sequentially list the members of the Fibonacci sequence (see figures 2 and 3) (“Fibonacciho posloupnost”, 2001). The second selected task consisted in designing an algorithm for the bisection method. As this was a more challenging example, which the students were not familiar with, unlike the Fibonacci sequence, the students had to study it themselves first. To help them, the algorithm was a verbal description of the reference (“Půlení intervalů”, 2001).

### ***Results of pilot verification***

According to the analysis of the success rates of both groups, it was found that the first assumption did not hold, or there were no significant differences between the two groups of students, which is contrary to our assumption that there should be a “worse” and a “better” class. Even the supposedly worse pupils performed slightly better. The success rate for the Fibonacci sequence was approximately 50 % for both groups, but we include in this figure all solutions that correctly identified the terms of the Fibonacci sequence, even if they did not fully meet all the conditions of the assignment (specifically the specification for the inputs and their outputs, see below). Only one pupil out of 27 got Bisection completely correct (13 pupils in one group and 14 in the other). However, approximately 25 % of the pupils in both groups got reasonably close to the correct solution, but they either made an error somewhere in the structure (flow) of the algorithm or made a mathematical error.



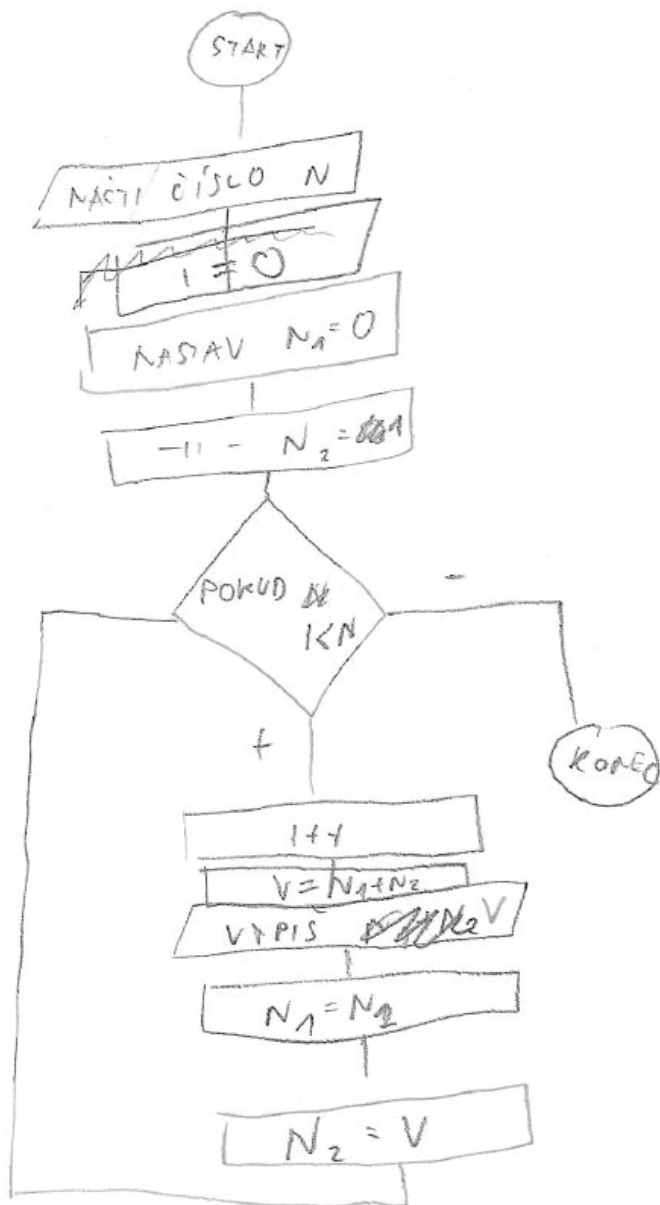


Figure 4. An example of a student's solution that correctly calculates the members of the sequence, but does not fulfill the assignment.

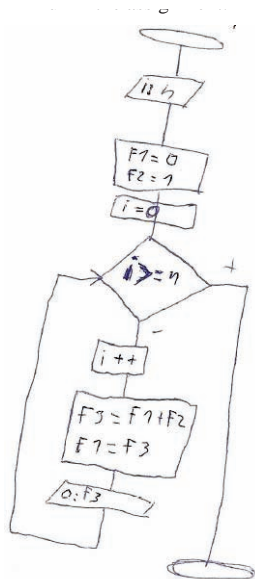


Figure 5. A sample of the student's algorithm, which does not count the members of the sequence correctly.

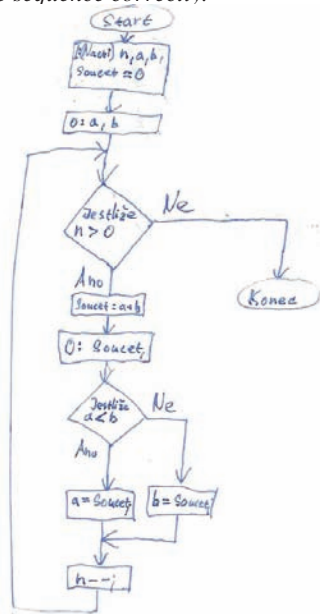


Figure 6. A demonstration of an unconventional algorithm solution.

## **Conclusion**

The goal of the article is the development of algorithmic thinking, which together with analytical thinking and logical thinking, forms the basis of Computational thinking. Computational thinking becomes an integral part of Informatics teaching (Computer Science) at elementary and high schools in the Czech Republic, but also around the world.

Algorithmic thinking is a way of solving problems, where the problem is divided into smaller, more easily solved parts, and the solution is formulated as a sequential series of steps that follow each other. Algorithmic thinking is the foundation of programming, but it is useful in many other areas as well. We're used to using flowcharts as a means of creating algorithms here, which they are very simple, as they consist of several elements, but mainly their greatest advantage is ease of understanding.

The practical part of the work was pilot tested on two selected tasks in teaching at a high vocational school with a focus on informatics (Computer science). The difficulty of the tasks was chosen so that one example was easier and the other harder. The resulting student's comprehension was a bit worse than expected, even though they were pupils who already had experience with algorithm development. Likely this is due to the fact that algorithmic thinking, as the case may be to think like informatician or mathematician, is not easy to master, so it is necessary to constantly develop and practice this thinking.

## ***Acknowledgment***

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## ***Ethics Statement***

The ethics committee confirmed to the corresponding author that this research did not require ethics approval because of the full anonymization of the publicly available data and because the data are not sensitive.

## ***Conflicts of Interest***

The authors declare no conflict of interest.

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# Teaching the subject Applied Chemistry using flipped classroom method

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## Abstract

We have changed the method of teaching the subject Applied Chemistry at Faculty of Education, Masaryk University, Brno, Czech Republic. Instead of a classic lecture, elements of a flipped classroom method are used. We brought the curriculum closer to the STEM concept. Our text discusses our first experiences with this way of teaching. An interesting finding, among other things, is that students with different life experiences perceive this method of teaching differently. Older students, who already work as teachers at lower secondary school, appreciate it and perceive it clearly positively. On the contrary, younger students claim that the teaching was worse prepared.

## Keywords

Education, Chemistry, Flipped Classroom, STEM

## The context and purpose of the framework

Our primary aim was to receive first experiences with teaching via flipped classroom at the upper undergraduate level of university study of chemistry teaching. In addition, our changes in the teaching of the Applied Chemistry course also aimed to include elements of the STEM concept into the education. We believe that the subject Applied Chemistry is well suited for this purpose.

It is widely known that physics and chemistry belong to the least popular subjects in primary schools and lower secondary schools in the Czech Republic. However, at the same time, these are subjects devoted to technically oriented fields, the graduates of which are highly desirable for employment in industry. Many advanced industrial countries are struggling with the outflow of people interested in these fields. In an effort to solve this situation, a number of strategies have been created, among others also the STEM.

The STEM concept originated in the USA in the 1990s to denote education in the fields of science, technology, engineering and mathematics. These fields are understood as decisive for the development of economies and for maintaining competitiveness. The main goal of the STEM concept is the preparation of

graduates of these fields and the provision of a workforce in prospective areas. As a result of its growing importance, this modern educational concept is gradually gaining ground on an international scale and is beginning to play a key role in the field of education as one of the possible solutions to the changing needs of our technologically advanced society.

The aim is to teach the subjects mentioned above in an interesting way, in mutual contexts and with connections to everyday life. However, teachers from practice point to the fact that they themselves have not been brought up in this way and that it is difficult for them to educate their pupils or students in a way that they have never experienced. In a very similar sense, also our students of chemistry didactics speak to us (their teachers). They wish to be taught at least part of their university in terms of new, modern methods. However, it is necessary to realize that the use of each teaching method must be adapted to the specific characteristics of the educated group of pupils or students (age, interests, professional focus etc.).

Anywhere, we consider the aforementioned wishes of students and teachers from practice to be justified and legitimate. We have therefore decided to modify the content of the course Applied Chemistry (taught in the second semester of upper undergraduate level of chemistry teaching courses) to suit the STEM concept. At the same time, we tried to adjust the way of teaching of the course Applied Chemistry to be close to so called flipped classroom method. We were interested in the question how the students would react to this change. Our text discusses our first experiences with this way of teaching.

The first mentions about flipped classroom are from the beginning of the 21<sup>st</sup> century (Lage & Platt, 2000; Lage et al., 2000).

In recent years, it flipped classroom approach became a popular alternative to traditional teaching methods. Using this approach, students or pupils obtain the study materials in advance before the time of class teaching. They study the materials in advance at their own speed. As a result, they gain time to solve more complex tasks than memorization and understanding during their formal class time (Seery, 2015). This procedure is inverted in comparison with classical teaching, when information is delivered to the students or pupils at the lecture and afterwards the students or pupils have to solve tasks, focused on the application of the lectured material, at home.

To bring clarity to discussions about flipped learning, the following definition has been issued (Flipped Learning Network (FLN), 2014):

Flipped Learning is a pedagogical approach in which direct instruction moves from the group learning space to the individual learning space, and the resulting group space is transformed into a dynamic, interactive learning environment where the educator guides students as they apply concepts and engage creatively in the subject matter.

Using the flipped classroom approach, the teacher can help students individually (Prober & Khan, 2013) and he/she has a better opportunity to detect (and correct) errors in thinking.

O'Flaherty and Phillips (2015) have carried out a large review that was focused, among others, on educational outcomes of flipped classroom approach. They have found that a large number of articles, using surveys with Likert scale and free text responses, reported an increased students' satisfaction with the flipped approach and the active learning methods that were used (O'Flaherty & Phillips, 2015 claim this, as a result of a detailed study of the following publications: Butt, 2014; Critz & Knight, 2013; Davies et al., 2013; Forsey et al., 2013; Hoffman, 2013; Lage et al., 2000; Mason et al., 2013; McLaughlin et al., 2013; Pierce & Fox, 2012; Prober & Khan, 2013; Strayer, 2012; Yeung & O'Malley, 2014; Young et al., 2014;). Similarly, the flipped approach showed increased academic performance as measured by improved examination results and/or overall improvement in pre-test to post-test scores, and/or course grades compared with historical controls (O'Flaherty & Phillips, 2015 claim this, citing Ferreri & Connor, 2013; Mason et al., 2013; McLaughlin et al., 2013; Missildine et al., 2013; Pierce & Fox, 2012). Also an increased attendance (from 30 to 80%) was reported, when the flipped classroom model was used (Prober & Khan, 2013, cited by O'Flaherty and Phillips (2015)). O'Flaherty and Phillips (2015) also write (with citation of Ferreri & Connor, 2013; McLaughlin et al., 2013; Yeung & O'Malley, 2014):

Qualitative feedback from student course evaluations suggested improved opportunities for developing communication skills, preferences for working in teams in the flipped model and increased teacher encouragement of active student engagement and learning compared with a traditional class. However the same studies, despite an improvement in student grades, found that students were quite negative towards the introduction of flipped class.

We studied also a review made by Seery (2015), focused on flipped learning in higher education chemistry. Among others, Seery gives examples of both positive and negative feedback given by students. In the cited work, the author writes that some of the students mention difficulties to organize their own time outside the lectures or that some of them have preference for receiving information in lecture. This kind of information is written also in the article of Yeung and O'Malley (2014, p. 62): "Personally, I find it much easier, for want of a better word, to learn through being spoken to in a lecture, rather than being left alone to work it out".



## Methods

Our teaching experiment concerned the approach to teaching the subject Applied Chemistry. This subject is included in the second semester of the first year of the Master's degree program Teaching Chemistry for Lower Secondary Schools (Masaryk University, Faculty of Education, Brno). We compare here the "classical teaching (years 2017 and 2018) and the new way of teaching (STEM and flipped classroom) – years 2022 and 2023. Some characteristics of our experiment are given in Table 1.

*Table 1. Some characteristics of our experiment.*

semester	grade	Number of students	Content of the subject	Way of teaching
Spring 2017	2 <sup>nd</sup> semester of 1 <sup>st</sup> grade of the	7	chosen analytical and physical chemistry topics	Classical 1. theoretical lecture at school 2. some practical exercises at school
Spring 2018	Master's degree. Study program Teaching Chemistry for	21	Literature: chemistry textbooks	3. The majority of practical exercises at home
Spring 2022	Lower Secondary	15	Combination of the issues of chemistry, physics, medicine, mathematics and history.	Flipped 1 Theoretical study at home 2. The majority of practical exercises at school, including the most difficult ones 3. The easiest exercises made at home, written summary (protocol) prepared at home
Spring 2023	Schools	25	Literature: Forgotten Stories by M. Kechlibar (Kechlibar, 2018; Kechlibar, 2019; Kechlibar, 2020).	

The number of students of this subject is relatively small (see Table 1). In 2017 it was 7 students, in 2018 it was 21 students, in 2022 it was 15 students, in 2023 it was 25 students.

In 2017 and 2018 (classical way of teaching), the theory was first presented by the teacher during the lesson and afterwards it was practiced: partially at school, but for the most of tasks were to be done subsequently at home. The content of the subject Applied Chemistry was mainly focused on chosen analytical and physical chemistry topics.

In 2022 and 2023, after the innovation, the subject combines the issues of chemistry, physics, medicine, mathematics and history. The book to work with is now not a chemistry textbook, but a well-written popular science literature: *Forgotten Stories* by M. Kechlibar (Kechlibar, 2018; Kechlibar, 2019; Kechlibar, 2020). Before each one lesson of Applied Chemistry, students receive from their teacher a list of issues that they should review, as they will focus on them more deeply in the upcoming lesson. Since the subject is included in the Master's degree, most of the knowledge that the students need has already been covered by the Bachelor's degree. In the beginning of the lesson, the students receive a list of tasks to solve. In the text of *Forgotten Stories*, they can look for milestones in the development of physics, chemistry, medicine (for example, the history of vitamins, ecology, the history of study and use of nuclear decay or nuclear reactions etc.) and relate them to each other. They also carry out calculations related to the text, think about details and consequences of preparation of chemical substances mentioned in the text etc. The aim is to lead the students to critical and professional understanding the text.

First, they try to solve the tasks on their own without using literature, the internet, etc. (they can only use what they prepared at home). Afterwards, they can read (or listen to) a relevant chapter from the book series *Forgotten Stories*. Then, until the end of the lesson, they can discuss the text and their solutions of the tasks among themselves and also with their teacher, they can use any literature and Internet. At home, they write down the answers and submit them to the teacher. If the answers are not correct, the teacher consults them personally with individual students.

In our research (educational experiment), we measured the teaching achievements in five ways:

- 1) Personal statements of the students at the end of the semester (free unstructured written communication of students' own impressions).
- 2) Grades for the exam taken at the end of the semester.
- 3) Personal statements of both teachers of the subject (preparation for teaching, subjective feelings during teaching and examining).
- 4) Monitoring students' absences (attendance in the course of Applied Chemistry is not mandatory).
- 5) Results of a voluntary anonymous written course opinion poll at the end of the semester (regular survey common to the entire university, where students can give their opinion about their courses).

We compared the obtained information with analogous "historical" data (obtained in a similar way before the change in teaching).

## Results

The results are briefly summarized in Table 2.

*Table 2. Brief summary of our results. Exam grades: In the year 2017 the course was closed only by a credit. In the years 2018, 2022, 2023 the students received a grade. The number in the table represents the average grade. For details see the text.*

Group of students	Way of teaching	1. Students' statements	2. Exam grades	3. Teachers' statements	4. Students' absences	5. Opinion poll
Spring 2017	Classical	negative	Credit (86 %)		15-30 %	very difficult tasks left for home
Spring 2018	Classical	negative	1.9		5-10 %	good quality of the explanations
Spring 2022	Flipped	positive	1.3	A lot of work for teachers, but good idea	2 %	interesting information transmitted by the teacher
Spring 2023	Flipped	positive	1.2	Not so much work for teachers, but some students cheat	50 %	Expertise, approach to students - directness, clearly defined requirements, personal consultation, pleasant communication

### *Students' comments about the course in the end of the semester*

These comments usually told the students personally (orally) to the teachers after successful finishing their exam.

2017–2018: The only personal comments of the students about the course Applied Chemistry were the complaints that the practical exercises left for home are too difficult.

2022–2023: The students' personal comments at the end of the semester were only positive. However, it is necessary to realize that the findings may be distorted. Although the comments were anonymous, their content might have been influenced by the fact that they were provided directly to the teacher. We think that a student who would like to complain would probably prefer to mark the

problem in the official university survey in hope that it will be taken into account by the guarantor of the study program or by the head of the department. Examples of students' statements:

“It’s a great idea, I really liked this approach from the beginning.”

“I really liked this teaching method. Real stories interested me by integrating them with other school subjects.”

“Personally, I mainly listened to the stories and did not read them, but I think they would find their place in secondary school chemistry lessons. The first use that comes to mind is for the purpose of connecting theoretical knowledge with practice, for example in STEM lessons.”

### ***Evaluation of the students by grade at the end of the semester:***

We compared the exam evaluations given by the same teacher, although due to organizational situation these assessments are several years apart (classical teaching – years 2017, 2018, flipped teaching – 2022, 2023). So the teaching and examining of both forms of the subject was made by the same teacher. The results are obviously different: year 2018 (classical teaching): average exam grade was 1.9; year 2022 (flipped education): average exam grade was 1.1. The usual grades A-E were converted to numerical values according to the key: A = 1, B = 1.5, C = 2, D = 2.5, E = 3, F = 4 and then an arithmetic mean was calculated. Even in this case, of course, the results could have been distorted. The evaluation was given on the basis of an oral exam, where the grade is always weighted by the subjective influence of the examiner. In the year 2017 the course was ended by a credit. Only 6 of the 7 students received the credit (that means 86 %). In 2022, two students did not participate in the exam (internship abroad, personal reasons): these students did not receive any grade and they are not included in the calculation of average exam grade.

### ***Statements of the teachers of the course Applied Chemistry:***

Both teachers of the course Applied Chemistry agreed that the new approach was more time-consuming for them. They had to study well in advance the literature they planned to recommend to the students to work on, they had to select appropriate study topics, to create sets of tasks, to prepare deep explanations for students. After the lesson, the teachers had to go through the students' answers and provide them individual feedback and consultations. Nevertheless, in 2022 both teachers had a better overall impression of the new teaching approach in comparison with classical teaching. On the contrary, in 2023 there was not so much work for the teachers, but they were disappointed. Only part of the students worked. Approximately half of the students did not attend direct classes at all and

copied the solutions to the tasks verbatim from their classmates into the protocols. When asked why they behaved this way, they answered that “they were good friends and that the teachers allowed them to work together”. The copying of answers was so verbatim that even completely unexpected and illogical errors were transmitted: e.g. mistaking Brazil for Britain or claiming that carbon black is mainly used as paper filler, etc.

### ***Monitoring of students` absences:***

In 2017 and 2018 (“classical teaching”), one or two students were absent from each lecture, and in 2018 another one or two students regularly came up late for the lesson. In 2022 (flipped teaching), only one student was absent during the entire semester (3 absences due to Covid disease). The attendance of the rest of the students in 2022 was 100%. In 2023, however, approximately one half of the students were absent each lesson. This situation was personally discussed with the students both in 2022 and 2023. In 2022, the students` explanation of nearly absences in the subject was “These were exclusive lectures. If they were bad, no one would go there.” In 2023, the lectures were according to the schedule in Thursdays in the very evening (usually the last teaching hours of the week at our faculty).

### ***The results of students` voluntary opinion poll***

The results of the all-university voluntary students` anonymous opinion poll at the end of the semester were not so much positive. In this case we believe, as we stated above, that this official survey is used to a slightly greater extent by students who want to complain for any reason and they hope that this way their anonymous voice will reach the teacher`s superiors. However, we find this feedback to be very useful because it can provide information that would not be available to us in other case.

Among other things, students answered the following three questions in the survey:

1. Does the subject have educational value for me?
2. Was the teacher`s explanation always clear and understandable?
3. Was the teacher always well prepared for the lesson?

The following key was used to calculate the average value: completely agree = 1, agree = 2, somewhat agree = 3, somewhat disagree = 4, disagree = 5, completely disagree = 6. The answer “cannot answer” is not included in the average. The average results are summarized in Table 3.

Table 3. Average answers for chosen questions from the students' opinion poll.

	2017	2018	2022	2023
1. Does the subject have educational value for me?	2.0	2.0	2.3	2.7
average	2.0		2.5	
2. Was the teacher's explanation always clear and understandable?	2.0	1.0	2.0	2.3
average	1.5		2.1	
3. Was the teacher always well prepared for the lesson?	2.0	1.0	2.0	2.2
average	1.5		2.1	

It is clear from the data given in Table 3 that the answers to all three monitored questions shifted to a more negative evaluation of the subject itself and its teachers when using the flipped classroom method.

The reasons may be different and our hypotheses need to be verified.

Regarding the subjectively perceived lower educational value of the subject Applied Chemistry in 2022 and 2023 (question no. 1), it is necessary to realize that the question in the students' survey is stated quite vaguely. It is not said in the question what is meant by the "educational value". If it should be understood only as the acquisition of new knowledge, then the educational value of the course Applied Chemistry would be now actually lower than before. Previously, the mission of the course Applied chemistry was really to provide students with new information, while in its current form, the main purpose of the course is to combine previously acquired knowledge, use it to solve problems, search for connections within chemistry and between multiple disciplines, etc. In our new concept, the aim of Applied Chemistry is to lead students to solving problems, it should not bring them much new information.

Regarding the "less comprehensible explanation of teacher" and "less prepared lessons" (questions no. 2 and 3), the reasons might be similar to the previous question. Our students very likely expect that the main aim of education is receiving information. Therefore, when solving tasks, they probably expect that they will be given first of all a procedure or instructions how to solve this kind of tasks. But in the case of the upgraded version of the Applied Chemistry course, however, this did not happen. The purpose of teaching the subject is now not to give / receive information, but to work with information, to connect it, to use it to solve problems, to cooperate (use, for example, the different approval orientations of different students). However, our students are not used to this kind of work and especially in 2023 it was difficult to get them to do this. There can be a number of reasons for this, from the previous study habits of students to mutual interpersonal relationships in a specific study group or to the personal characteristics and interests of individual students.

The freely written statements in the survey also differed within the years that we compare. In 2017, the students complained about very difficult tasks left for home. In 2018 the students appreciated good quality of the explanations: “The teacher explains the curriculum in a very engaging way”.

In 2022 they mainly perceived interesting information transmitted by the teacher: “The teacher told us many interesting things that I can use in my practice to revive the teaching”.

In 2023, the only comment to the subject Applied Chemistry, that was written by words, was “Expertise, approach to students - directness, clearly defined requirements, personal consultation, pleasant communication”.

One could certainly debate how it is possible (in 2023) that students rate a teacher as not very well prepared for teaching, but at the same time they appreciate his expertise. But, anyway, we think that the students expect that that main aim of education is to provide the students with information. If they themselves look for the information, they think this was the duty of their teacher and that they are working instead of him / her.

Our findings from the students' survey more or less agree with the already published information that there are also students who do not like flipped teaching (Seery, 2015). Some of them need to get used to a new way of working. Others want the teacher to explain all the subject matter. Maybe, based on the answers received, some of the students perceive the teacher to be the main provider of education and do not consider the necessity of balance of the teacher's work and their own effort. Thus, if the teacher asks the students to prepare individually before the lecture, some of them perceive the teacher's work as less prepared (“We (students) had to work more because the teacher did not want to prepare the lecture”).

The information provided in our text is of a qualitative nature only. In all the years 2017, 2018, 2022 and 2023, the entire study group was always involved in the research, but each time it was a small number: in 2017 it was 7 students, in 2018 it was 21 students, in 2022 it was 15 students and in 2023 it was 25 students. On the other hand, we believe that our results more or less agree with the results obtained in other contexts by other pedagogues, see the overview made in work of O'Flaherty and Phillips (2015), for instance. The fact that some students perceived flipped teaching as less prepared also agrees with data published earlier by other authors (O'Flaherty & Phillips, 2015; Yeung & O'Malley, 2014). Also another research, focused at university students (two years lasting longitudinal research with nearly 260 participants) shows, that the model of flipped learning “improves students' motivation but it requires high levels of responsibility and commitment in both students and teachers” (Bravo et al., 2019).

## Conclusions and implications

We tested the flipped teaching approach in the conditions of upper undergraduate level of university study of chemistry teaching at a Czech university. Specifically, it was the course Applied Chemistry, taught in the master's degree at Faculty of Education, Masaryk University, Brno.

Our work confirmed that flipped teaching can be accepted differently by different students and that students may feel the necessity of home preparation before the lecture as a result of lack of work of the teacher. Some of them also cheated, when writing their reports (protocols), which should contain solutions to the tasks given to the students for work at home. On the other hand, the students reacted positively to the change regarding the content of the subject, where now knowledge from several disciplines (chemistry, physics, medicine, mathematics and history) is combined.

### *Ethics Statement*

The ethics committee confirmed to the corresponding author that this research did not require ethics approval because of the full anonymization of the publicly available data and because the data are not sensitive.

### *Conflicts of Interest*

The authors declare no conflict of interest.

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# Dyslexia and Chemistry Teaching

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## Abstract

Dyslexia is the best-known and the earliest known learning disorder from the group of specific learning disorders, because it most noticeably affects the school achievements of pupils. Dyslexia is usually known as a reading disorder. However, it is much more than only a problem with reading (Zelinková, 1994). Many publications have been written about dyslexia in general. A significant part of them deals with the practical effort to “teach dyslexics to read” (e.g. Novák, 2013, Navrátilová, 2015). However, there is significantly less literature dealing with the teaching of specific school subjects to pupils with dyslexia. The greatest part of this literature is represented by works focused on language teaching (e.g. Zelinková et al., 2020). Much less has been written about teaching science subjects to pupils with dyslexia. The goal of our work is to carry out a search aimed at finding just such literature, with special focus on teaching chemistry.

## Keywords

Education, Chemistry, Dyslexia, Specific Learning Disorders

## The context and purpose of the framework

Dyslexia is the best-known and the earliest known learning disorder from the group of specific learning disorders, because it most noticeably affects the school achievements of pupils. Dyslexia is widely known as a reading disorder. However, it is much more than only a problem with reading (Zelinková, 1994). Dyslexic pupils usually have weaker achievement in both knowledge and skills (Kamińska-Ostęp and Gulińska, (2008). According to The British Dyslexia Association (The British Dyslexia Association, n.d.a): “People with dyslexia tend to have poor working memory, speed of processing and rapid retrieval of information from long term memory. These weaknesses will also affect maths learning. 60% of learners with dyslexia have maths learning difficulties.”

One of the definitions of dyslexia can be found on the web pages of The British Dyslexia Association (The British Dyslexia Association, n.d.b):

Dyslexia is a learning difficulty that primarily affects the skills involved in accurate and fluent word reading and spelling. Characteristic features of dyslexia are difficulties in phonological awareness, verbal memory and verbal processing speed. Dyslexia occurs across the range of intellectual abilities. It is best thought of as a continuum, not a distinct category, and there are no clear cut-off points. Co-occurring difficulties may be seen in aspects of language, motor co-ordination, mental calculation, concentration and personal organisation, but these are not, by themselves, markers of dyslexia. A good indication of the severity and persistence of dyslexic difficulties can be gained by examining how the individual responds or has responded to well-founded intervention.

The number of dyslexics in the population is estimated to be approximately 10-15% (Kamińska-Ostę and Gulińska, 2008). From such a large value, it is clear that this part of the population needs to be given adequate attention. Due to their learning problems, relatively fewer dyslexics than non-dyslexics usually progress to higher education. It is estimated that only 1 – 2% of university students are dyslexic (Zingoni et al., 2021).

Many publications have been written about dyslexia in general. If we enter the keyword “dyslexia” (All Fields) into the Web of Science search engine (Clarivate, 2022), we get 15 914 records (date July 29, 2023). A significant part of them deals with a practical effort to “help dyslexics to read”. Also in Czech pedagogical literature, publications that aim to help dyslexics to read are relatively frequent and easily accessible (e.g. Novák, 2013, Navrátilová, 2015).

A significant number of papers on dyslexia deals with the genetic and medical aspects of dyslexia (for instance Neurosciences represent 3 460 records out of the 15 914 records mentioned above).

However, there is significantly less literature dealing with teaching specific school subjects, while having pupils with dyslexia in audience. A greater part of this literature is represented by works focused on language teaching (in Czech pedagogical literature for instance Zelinková et al., 2020, focused on teaching English language).

Much less has been written about teaching science subjects to pupils with dyslexia. The goal of our work is to carry out a search aimed at finding just such literature, with special attention to the teaching of chemistry.

## **Methods**

The main method was literature research. We searched the world professional literature in the WOS search system (Clarivate, 2022), then in the American Chemical Society publications search system (American Chemical Society,

2023b) and then also in the Czech literature (using common google search).

In the WOS search system (Clarivate, 2022), we entered various search terms related to dyslexia. The number of records found is shown in Table 1.

*Table 1. WOS, numbers of records related to dyslexia and chemistry found on July 25, 2023.*

Search terms	Number of records
ALL=chemistry and ALL="reading disability"	8
ALL=chemistry and ALL="reading difficulties"	2
ALL=chemistry and ALL="reading disorder"	1
ALL=chemistry and ALL="dyslexia"	36
In total	47

From the number of 47 texts (Table 1) found using the WOS search, duplicate records were discarded, and subsequently also one record referring to an unavailable text was discarded. Thus, 35 records remained for the study (Table 2).

*Table 2. WOS, the number of publications to study (related to both dyslexia and chemistry).*

	Number of records
After discarding duplicates	38
After discarding the unavailable text	37
After discarding texts not related to the topic of dyslexia	35

A more detailed study of the remaining 35 records revealed that only nine texts focus on teaching. The articles that we found mostly deal with the medical side of dyslexia, especially from the field of neuroscience and genetics. Only one of the texts is focused on teaching chemistry (Table 3).

*Table 3. Focus of the examined 35 texts from WOS (see bottom row from Table 2).*

	Number	Number
	medicine	education
Focused on	26	9
education general		6
education chemistry		1
education fields close to chemistry		2

Subsequently, we also performed a search using the ACS Publications system (American Chemical Society, 2023b). We entered analogous search terms as for the WOS search. The numbers of records that we found are given in Table 4. We did not enter the search term “chemistry” because chemical issues should be included implicitly in the publications of the American Chemical Society. However, we also verified this by simultaneously entering the search terms Anywhere: “dyslexia” AND Anywhere: “chemistry” (Access Type: All Content, Publication Date: All dates). This reduced the number of records from 65 to 62, i.e. there was nearly no change. That is why we continued to work with the full number of records, i. e. without using the search term “chemistry”.

*Table 4. ACS, numbers of records related to dyslexia and chemistry found on July 31, 2023 (Access Type: All Content, Publication Date: All dates).*

Search terms	Number of references
Anywhere: "reading disability"	2
Anywhere: "reading difficulties"	16
Anywhere: "reading disorder"	0
Anywhere: "dyslexia"	67
In total	83

In further work, we verified by reading that the records found using ACS are not duplicated the ones found by WOS. Afterwards, we processed the results found by ACS in a similar way to the results found by WOS. From the stated number of 83 texts found by ACS search, duplicate records and records referring to an unavailable text were discarded. Thus, 54 records remained for our study (Table 5).

*Table 5. ACS, the number of publications to study (related to both dyslexia and chemistry).*

	Number of references
After discarding duplicates	76
After discarding the unavailable text	68
After discarding texts not related to the topic of dyslexia	54

Of these remaining 54 records, only 31 texts are focused on teaching. Almost half of the articles found (specifically 23) deal with the medical side of dyslexia (texts dealing with the influence of intake of heavy metal ions on the induction of dyslexia or reports focused on study of various drugs that could have an effect on dyslexia). We also found articles aimed at ophthalmology. Relatively many articles (9) contained biographies of dyslexic chemists, or interviews with them.

We found only 12 texts in the ACS database that deal with teaching chemistry and dyslexia at the same time (Table 6).

*Table 6. Focus of the examined 54 texts found by ACS (see bottom row from Table 5).*

	Number	Number
	medicine	education
Focused on	24	30
education general		9
education chemistry		12
education fields close to chemistry		0
biographies of dyslexic chemists, or interviews with them		9

If we add up the search results found in both databases (the results from WOS and ACS were not duplicated), we get the following total numbers of publications on dyslexia and chemistry (Table 7):

*Table 7. Total number of publications to study (related to both dyslexia and chemistry), according to their focus, records from WOS plus records from ACS.*

	Number	
	medicine	education
Focused on	50	39
education general		15
education chemistry		13
education fields close to chemistry		2
biographies of dyslexic chemists, or interviews with them		9

## Results

In the publications focused on education, we tried to find advice how a pupil or student with dyslexia might be helped in studying chemistry. We did not deal with medical issues, as they fundamentally exceed the goal of our work. The information that we found we divided into several groups (Table 8).

Of course, not all the information found could be clearly classified into one of the categories given in Table 8, but that was not our goal either.

Table 8. Types of information found in texts related to both teaching chemistry and dyslexia.

A	Communication / cooperation between teacher and student
B	General principles of teaching organization
C	An effort to reduce problems closely related to reading
D	Help aimed at understanding / recalling the content of the text
E	Tips for teaching specific chemical issues
F	Other

### ***A: Communication / cooperation between teacher and student***

Riendl and Haworth (1995) write that one of the most difficult challenges in educating students with learning disorders is the need for teachers to have a positive relationship with their students. Teachers might tend to have a subjective feeling that teaching students with learning disorders is a waste of time and “nothing will come of it”. On the contrary, students with dyslexia usually have low self-esteem, resulting from the feeling that they are not and cannot be good. Teachers should therefore provide them with support and encouragement. This feeling of students that they are stupid and unable to learn can be wrong, but it can mark even the smart and gifted ones for a long time (Ragain, 2020). This is also confirmed by Hiscock and Leigh (2021), who describe in detail the personal experiences of a novice university lecturer with dyslexia. There is evidence about very successful chemists – dyslexics, for instance Marie-Paule Pileni, a physical chemist working in the field of nanotechnology, an Emeritus Professor at Sorbonne University (Pileni, 2022) or Archer John Porter Martin, a physical chemist and biochemist, winner of the Nobel Prize for Chromatography together with R. L. M. Synge (Stahl, 1977).

A useful general advice, which is also related to a good mutual relationship between teacher and pupil, is that the pupil should inform the teacher about his/her dyslexia right in the beginning of the course. The teacher should then ask the student what helps him/her in learning (Klane, 2009). Mutual openness is also recommended by Hiscock and Leigh (2021). Unfortunately, personal/work problems as a result of admitting dyslexia are also documented (Boxall et al., 2010).

### ***B: General principles of teaching organization***

Riendl and Haworth (1995) deal with special education, including chemistry and pupils with dyslexia. They remind that many techniques which help students with learning disorders can benefit ALL students. In general, the disabled students benefit from clear and consistent classroom discipline and management routines



and from clear communication of course expectations. They write about a variety of techniques that can benefit all students. For example: Key wording (mnemonic aids). Using schemes before and after exposition to new curriculum, before a test etc. Structured Overview that indicates the interrelationships between concepts, given to the students. They can not take notes and listen to explanations at the same time. Graphic Devices, Media, Field Trips. Computer simulations. Experiments and Demonstrations. Jejich rady k organizaci laboratorních cvičení rozebíráme v kapitole “Tips for teaching specific chemical issues”.

### ***Determining of possible help to dyslexic students via artificial intelligence***

The main benefit of the work of Zingoni et al (2021) is that they provide a very good and comprehensive list of ideas for what might help dyslexics. This list was subsequently assessed by approximately 800 dyslexics in Italy (in future, the researchers are also considering to ask respondents who are Spanish, English, French, Portuguese, Greek and Dutch). We strongly recommend to study in detail the useful and important results of this research directly in the article of Zingoni et al. (2021).

Their work is closely followed by the research of Yeguas-Bolivar et al. (2022). In their work, the proposals (and their assessment made by dyslexics) are confronted with artificial intelligence. The he answers of the artificial intelligence correspond to about 90 % with the answers of the dyslexics themselves. This finding seems to be very important and might be in future a “promising avenue” for people with dyslexia.

### ***Nonspeech audio can help the memorising***

Scaletti et al. (2022) write: “While it is known that adding speech audio to written text to increase redundancy can hinder the learning (Knoop-van Campen et al., 2020), when nonspeech audio and imagery channels are redundant (and not conflicting), memory for information increases with increasing redundancy (Lang, 2012).”

That is why Scaletti et al. (2022) suggest to supplement a computer model of some chemical process with a sound background, where the high energy of a certain molecule conformation would be represented by high tones and the low energy of another conformation would be accompanied by low tones. However, audio must only be used as an aid to remembering facts, otherwise it acts as a distracting element (Knoop-van Campen et al., 2020).

### ***Simplification of written records***

Cotton (1998) writes about a popular method of practicing new terms - using wordsearches. He points out that for dyslexics a simpler form of wordsearches is more appropriate.

### ***C: An effort to reduce problems closely related to reading***

Zingoni et al. (2021) state that in an effort to help dyslexics, research has been conducted on, for example, the suitability of the visual design of websites (Pang and Jen, 2018; Saidah Sarpudin and Zambri, 2014). Zingoni et al (2021) also point out that the problem of dyslexia is much deeper and more complex than only reading problems, so simply modifying the design of the text cannot be sufficient help for dyslexics.

Gledhill et al. (2006) write about a web site that is purposefully designed as dyslexic-friendly. To arrange this, it was envisaged that cascading style sheets (CSSs) would be used to create a distinct visual design to aid students with dyslexia.

Schneps et al (2010) propose something like a software reading window for university students. It enlarges the text and shades out the parts that the reader doesn't want to pay attention to.

Using the information in Kirchoff's (2007) article, we found the textbook *Chemistry in the Community: Digital Talking Book* (American Chemical Society, 2023a). The ACS Store (American Chemical Society, 2023a) says the following about the book:

Chemistry in the Community, Digital Talking Book is a powerful tool for students who have reading difficulties or for whom English is a second language. This product is also a valuable resource for students who are blind or visual impaired. Students may enlarge the text for reading, read along and/or have the text read to them in their choice of three different voices. Students can control the pace and volume as the text is read aloud. Charts, graphs and illustrations come alive as they are described in detail for the student as they read through the page.

Screen readers to help dyslexics are discussed by Egambaram et al. (2022): "Screen readers can be useful for anyone with a print disability, which might be due to a neurodivergence or specific learning disability such as dyslexia, or a physical disability that makes it challenging to hold or use a printed text".

A good experience with the use of voice recordings is already given by Himes (1995). He writes about a student with dyslexia who improved very significantly on tests (to the level of the best student in the class) after he began to receive an audio recording of the test items at the same time as the printed assignment of the test items.

### ***D: Help aimed at understanding / recalling the content of the text***

Reglinski (2007) found that a number of university students, while taking their exam, were unable to answer questions related to some general chemistry concepts (e.g. stereochemistry, chemical bonding, etc.), although the examiner knew from the previous work of the students that they do understand these concepts. The examiner therefore supplemented the word-written question with a picture related to the issue. In this case, the students answered fluently, accurately, with a number of unexpected details. Reglinski recommends to use this method of testing especially for students with dyslexia or other special educational needs. He explains as follows: It is now common practice to provide extra time in examinations to students with learning difficulties. The font can also be modified, a suitable paper with printed questions can be chosen. Extra time will allow pupils/students to read the text carefully, or to read the same text several times, but it may not help them understand the content. Moreover, not always the extended time is a full-fledged help because the student gets exhausted after a certain period of work. Reglinski therefore suggests, where possible, to help students with dyslexia giving them a picture-question instead of a plain text. He states that this form of test entry can be given to the whole class (not only dyslexics), so that the working conditions of different pupils will then be more similar.

### ***E: Tips for teaching specific chemical issues***

An excellent article, specifically focused on teaching chemistry and presenting the results of research with a relatively large number of dyslexics, is the work of Kamińska-Ostęp and Gulińska (2008). Their text refers, among other things, to an article by the Greek author Ragkousis (2000), which, however, is not published in WOS. Ragkousis was interested in the following question: “Do dyslexic pupils encounter particular problems when faced with language and chemical symbols?” He conducted an experiment in which students aged 16-18 had to solve complex tasks focused on chemical calculations. He found that when working with chemical formulas, dyslexics made errors approximately 5× more often than non-dyslexics. However, approximately twice as many dyslexics than non-dyslexics correctly understood the concepts. These findings indicate that dyslexics, even if they understand the concepts, might have very serious problems to work with chemical formulae. Therefore, the teacher should minimize the use of chemical formulae as much as possible, when teaching dyslexics. When testing, chemical formulae should be used only when they are absolutely necessary and they must be clearly written. It should be noted that many teachers use molecular formulas to speed up writing. However, such writing can be very difficult to understand for dyslexics.

Kamińska-Ostęp and Gulińska (2008) studied gymnasium schools pupils in Poland aged 13-15. Over 400 pupils took part in their three-years lasting research. About 20 % of pupils were dyslexic having the certificate from the psychological and pedagogical clinic about specific difficulties in learning. Among others, they studied the effectivity of learning the following items, using different attitudes:

Chemical computations, preparation for chemical experiments, using games to practice formulae of inorganic compounds and chemical reaction equations, formulae of organic compounds and chemical reactions equations.

The result show shows that dyslexic students achieve better results, when using: 1. the film instructions (video record containing demonstration of the experiment) rather than printed text instructions (to prepare themselves to perform chemical experiments), 2. computer games rather than board games to practice chemical nomenclature of inorganic compounds, 3. rod-ball models of organic molecules rather than computer animations to think about organic chemical reactions, 4. proportion method rather than mathematical equations, when performing chemical calculations.

All these methods helped both dyslexics and non-dyslexics, but they significantly reduced the differences in test results between these groups of students (Kamińska-Ostęp and Gulińska, 2008).

Blackburn et al (2019) also write about the positive benefit of using video recordings for preparation to laboratory exercises. Among other things, they found that students with learning disorders (including dyslexics) used a software simulation material (designed to prepare students for laboratory exercises) about 1.6 times more often than the other cohort.

The work of Eley et al. (2016) experimentally verified that visual instructions used in hospital operating conditions can be very useful in addition to verbal explanations. A trial was undertaken with 240 patients from whom midstream urine collection for urinalysis was clinically required. Both cohorts received verbal instructions by nurses. In addition to this, the experimental cohort received also an illustrated instruction on how to collect the urine sample. The contamination of urine by epithelial cells in experimental group was reduced significantly by this intervention. The illustrations were well received by more than 95 % patients.

Skaik (2010b) points out that dyslexia can be very dangerous in some professions. He reports problems from laboratory practice that are related to dyslexia and could have fatal consequences. He mentions the confusion of texts while designation of blood groups by one student of immunohematology. As ABO mishaps are a critical problem for both recipients and immunohematologists, all sources of error should be minimized (Skaik, 2010a). Skaik (2010b) also points to other specific problems. Confusion of LDH vs. HDL tests, substitution of digits and signs +, – during calculations, substitution of indices for symbols of physical

quantities and the consequent misuse of calculation formulas.

This also comes from the mouth of an Emeritus Professor at Sorbonne University, Marie-Paule Pileni, a dyslexic: “I wanted to be a medical doctor. When I had to go in this direction, I was afraid of killing people!!” (Pileni, M. P., 2022).

Hiscock and Leigh (2021) also talk about problems of dyslexics in connection with the teaching profession. Although students and colleagues positively evaluate the work of a beginning dyslexic teacher and they did not find any errors in her work, the teacher considers her work and the necessity of careful checks of preparations to be so exhausting that she recommends other people in a similar situation to consider teaching using a flipped classroom (O’Flaherty and Phillips, 2015).

Riendl and Haworth (1995) draw attention to possible problems with performing school laboratory experiments. According to them, students with a disability (including learning disability) should be paired with a willing nondisabled peer. Other safety accommodations should be made in the laboratory according to the type of disability. Laboratory experiences can be extremely difficult for the learning disabled students.

Vadanan and Prakash (2017) draw attention to the work where the author (Davis, 1992) lists 37 traits of dyslexia. One of the traits is also lack of depth perception and peripheral vision. That is why Vadanan and Prakash (2017) suggest showing various three-dimensional models (including models of molecules of organic substances) to dyslexics. They try to do it via illuminating points on a three-dimensional LED-cube. The shape of the model could be programmed by the teacher as needed. However, Vadanan and Prakash only show photographs of the  $3 \times 3 \times 1$  model in their article, which do not seem to be of much help.

The usefulness of supporting the depth perception is also confirmed by other works. We can mention the results of Kamińska-Ostęp and Gulińska (2008), according to which the teaching effect of using rod-ball models was significantly greater for dyslexics than that of computer simulations. Also Theisen (2022) talks about the suitability of using models in teaching chemistry (creating models by pupils, using Lego or plasticine).

### ***F: Other***

Allowing a calculator can help dyslexics with chemical calculations. While performing chemical calculations, the teacher must be aware that a student with dyslexia might change the sequence of numbers. A calculator can be of a help (Morse and Clapp, 1980).

Raje and Stitzel (2020) write about construction of didactic tests. They remind that students with learning disorders, e.g. dyslexia, must be able to freely skip

items during the test and choose those that suit them (e.g. according to the length of text or a form of the test items,...). It must therefore be possible to preview the entire test, scroll through the test, return to items, etc.

### ***Czech literature (also outside scientific publications)***

Searching through Google, by means of “dyslexia” AND “chemistry” as keywords, we found these links:

- commercial offers of kits for chemical experiments
- commercial offers of the Pasparta publishing house (link Publications on Learning Disabilities). However, after opening the link and entering the keyword “dyslexia”, we only got a book about teaching English (Zelinková et al., 2020) and a book focused on psychology (McNeill et al., 2023), i.e. no publication related to the problems of teaching chemistry.
- A link titled “Scientific Articles on Dyslexia AND Chemistry”. Under this link, we found a number of texts related to the teaching of chemistry for dyslexics. Coincidentally, the first of them was our own publication (Měcháčková, 2019). Another work of Měcháčková (2021) contains a relatively good literature overview focused on dyslexia. Měcháčková mentions here various aids for dyslexics (reading window, software reading window, readers, reading filters, editing the appearance of the text, including the possibility to download special sets of fonts, etc.). However, focused on teaching chemistry and dyslexia, Měcháčková also found only research by Kamińska-Ostęp and Gulińska (2008). In her own work, Měcháčková (2019, 2021) focused on creating a dyslexic-friendly website for teaching chemical nomenclature. She conducted interviews with 6 dyslexic pupils (lower secondary school) about learning chemistry. Based on such a small sample, we can only express hypotheses: Dyslexic pupils usually don't like chemistry very much. Their favorite activities in chemistry lessons include watching demonstrations and videos. Among the least popular and at the same time very difficult topics for them belong chemical nomenclature and chemical calculations. None of the children involved in the research reported using electronic aids helping dyslexics to read and they did not know any websites designed for dyslexics. To facilitate orientation in the text, many of them use color highlighting. To learn chemical nomenclature of inorganic compounds, they preferred cross-rule and analogy to calculation using oxidation numbers. When learning the nomenclature, the pupils would appreciate to be allowed to look at the list of Czech nomenclature word endings for positive oxidation numbers (I: -ný, II: -natý, III: -itý,...).

We also have read interesting work of Wyzikowska (2005). According to the results of this article, it seems that after pupils leave elementary school for other types of schools, dyslexics in different types of schools might have different types

of problems when solving the same test. However, this hypothesis would have to be investigated in more detail.

An overview of Polish materials on dyslexia (Osińska-Kurek, J., 2011) could also be useful, but its study exceeds the possibilities of our work published here.

## **Conclusions and implications**

Our text summarizes the current knowledge available on how dyslexics can be helped while studying chemistry. It turns out that there is little information available. We also remind that dyslexia is a complex problem that manifests itself differently in different individuals, so it is not possible to create a universal system of advice that would help everyone. However, our research has verified that a lot has been written about dyslexia in general, but the most of texts are focused on problems of pedagogy, psychology and medicine. However, when it comes to chemistry education, we managed to find relatively little information and not everything that we found is fully usable in practice. A great deal of work remains to be done in this direction.

Another problem is that we managed to study mainly texts written in English and mostly published through the WOS and ACS scientific databases. We practically did not get to the results of research published outside these databases and in languages other than English, Czech and partially Polish, although they may also contain a lot of valuable information. Here is an open field for further work, too.

The percentage representation of dyslexics in the population is estimated at about 10-15%, which is a relatively large amount. Dyslexia manifests itself not only in reading. Students with dyslexia process information in a different way than non-dyslexics. Therefore, usually used teaching methods may not be enough for dyslexics. Pupils with dyslexia, with the same or greater effort than non-dyslexics, usually achieve worse results in most academic school subjects than non-dyslexics, and they relatively smaller percentage of them progress to higher levels of education. It is estimated that only 1-2 % of dyslexics attend universities. On the other hand, dyslexics can be very intelligent and creative. They are often comfortable doing several activities at the same time, some of them can combine their knowledge more easily and in more imaginative ways than non-dyslexics. This is evidenced by interdisciplinary personalities such as Marie-Paule Pileni (physical chemist working in the field of nanotechnology, an Emeritus Professor at Sorbonne University) or Archer John Porter Martin, a physical chemist and biochemist, winner of the Nobel Prize for Chromatography together with R. L. M. Synge; it is worth noting that he was expelled from the University of Houston in 1979 for writing a too small number of publications).

If the education of dyslexics is not properly supported, the society may lose creative and intelligent workers who, with good encouragement, could be of great benefit to the society.

### ***Ethics Statement***

The ethics committee confirmed to the corresponding author that this research did not require ethics approval because of the full anonymization of the publicly available data and because the data are not sensitive.

### ***Conflicts of Interest***

The authors declare no conflict of interest.

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# Opportunities and obstacles to the implementation of integrated teaching from teachers' point of view

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## Abstract

In this paper we present results of our research about chemistry teachers' point of view on integrated teaching, its benefits, opportunities and obstacles that need to be overcome so integrated teaching can be better implemented into lessons. For data collection we used Q methodology in online environment. Respondents think that integrated teaching (hereinafter referred as IT) encourage students' interest in greater depth and breadth of their knowledge. They think that the teamwork of teachers is important for the implementation of IT at secondary schools but not all of them were prepared for teamwork at university. Most of them were not thoroughly acquainted with the integrated teaching concept during their pregraduate studies or during their training within the further education of teaching staff or courses. The obtained data were analysed using factor analysis.

## Keywords

Integrated teaching, integrated science, chemistry teachers, Q methodology

## Introduction

Integrated teaching can be defined in many ways for example as type of teaching that “realize inter-subject relationships and the connection of theoretical activities with practical ones in the following main forms:

1. integrated subjects or courses;
2. modules or topics included as part of several subjects;
3. projects combining knowledge from several subjects with practical experience and productive activities;
4. integrated days when the whole school implements one common theme” (Průcha et al., 2001).

Rakoušová sees integrated teaching as “interpenetration and integration of the content of subjects created from the real sciences into a new functional and tighter

educational content, while this integrated educational content pursues the goals of all these subjects” (Rakoušová, 2008). Podroužek understand it in the sense of “combining (synthesis) the curriculum of individual subjects or cognitively close educational areas into a single whole with an emphasis on the complexity and globality of cognition, where a number of intersubject relationships are applied” (Podroužek, 2002).

Vlček (1981) define integration of natural sciences as “approaches in which the concepts and principles of the natural sciences are presented in such a way as to express an essential unity of scientific thought and concepts and to suppress surviving or insignificant differences between the various fields of the natural sciences”.

In our research we understand integrated teaching as a type of teaching that connects the content, goals, expected outcomes, key competencies of all integrated subjects, while the integrated whole results in a new goal and at the same time enables the connection of the theoretical curriculum with the real world, practical activities of pupils, current problems and situations from practice. It can take the form of, for example, integrated days, modules, projects, integrated subjects, STEM (STEAM, STREAM) or CLIL.

Several studies are focused on integrated teaching from the point of view of teachers (Šimíčková, 2001, Škoda & Doulík, 2007, Jeská, 2012, Šíba, 2013, Bartoňová & Kričfaluši, 2021a, Bartoňová & Kričfaluši, 2021b, Rusek et al., 2022, Soukup, 2023, Rajtmajerová, 2023), its implementation in practice (Liliawati et al., 2017, Suciati et al., 2019, Nguyen & Pham, 2021, Kubátová, 2023), researches were comparing students who were taught in separate subjects and students taught in the form of integrated teaching (Ross & Hogaboam-Gray, 1997, Usmeldi & Amini, 2019), some studies focused on the creation of didactic materials for integrated teaching (Pekarová, 2016, Voglová, 2021, Vondra, 2023).

In our research we focused on chemistry teachers’ point of view on integrated teaching, how they perceive it, if they were prepared for this type of teaching during their pregradual education, what are in their opinion the obstacles that complicate or prevent the implementation of this method in lessons and what is not a problem.

## **Method**

For our research we used Q methodology in online environment using Google Slides (Bartoňová & Kričfaluši, 2022). „Q methodology encompasses a distinctive set of psychometric and operational principles that, conjoined with statistical applications of correlational and factor analytic techniques, provides researchers with a systematic and rigorously quantitative procedure for examining the subjective components of human behaviour“ (McKeown & Thomas, 2013).

We created 51 Q-types with statements about integrated teaching sorted into 4 areas (Pregradual and postgradual education, External conditions for the implementation of integrated teaching, Teacher’s personality, Pupils and parents). All Q-types are stated in Table 1.

*Table 1. Q-types with statements (IT stands for integrated teaching)*

Number of Q-type	Statement stated on Q-type
1	The teamwork of teachers is important for the implementation of IT at secondary schools.
2	Teachers are not able to implement IT because they are overloaded.
3	When choosing a training within the further education of teaching staff, the school management prioritizes the price of the course over its quality.
4	For the implementation of IT, it is important that the teacher has specific characteristics (e.g. flexibility, inquisitiveness, desire for lifelong learning).
5	The school management does not motivate teachers to do creative work.
6	During the analysis of the curriculum within the field didactics, the possibilities of IT are not sufficiently pointed out.
7	IT does not belong to the secondary school.
8	Adaptation of classrooms (e.g. arrangement of desks) is necessary for the implementation of IT.
9	In the framework of postgraduate education, the issue of IT is not given sufficient attention.
10	IT encourages students’ interest in greater depth and breadth of their knowledge.
11	Teachers cannot motivate students to construct their knowledge independently.
12	A problem for the introduction of IT in schools is the admission of students to universities according to the average of grades from individual subjects (they would have one grade for an integrated subject).
13	Teachers must be prepared for the IT in a specific subject - interdisciplinary didactics.
14	IT is unsuitable for weaker students who are comfortable with memorization.
15	IT develops students’ critical thinking.
16	With the introduction of IT, it is not possible to fulfil all the curriculum for grammar schools.
17	I got acquainted with the IT concept at a course/training within the further education of teaching staff.

Number of Q-type	Statement stated on Q-type
18	In order to implement IT, it is necessary to see its implementation in practice.
19	The implementation of IT at school depends primarily on the attitude of the majority of teachers to this issue.
20	To implement IT, the teacher must overcome the fear that the student will know more than he/she.
21	For the implementation of IT, it is necessary that future teachers are educated within educational areas (e.g. Man and Nature), not independent subjects.
22	The aim of the education of pupils at the grammar school is to prepare them for life.
23	For the implementation of the IT, it is important that the pedagogical focus is given priority over the field focus when studying at a university.
24	I became thoroughly acquainted with the IT concept during my pregraduate studies.
25	IT supports students' positive attitudes towards school and studies.
26	IT is primarily intended for gifted students.
27	Teachers do not fully use the possibilities of the curriculum for grammar schools.
28	The goal of secondary school education is to prepare students for university entrance exams.
29	The implementation of IT at the school depends primarily on the approach of the school management to this issue.
30	Teachers would tolerate the introduction of IT better if they were taught at university how not to burn out and how to cope with stress.
31	Parents don't understand IT because they've never met this approach by themselves.
32	Implementation of innovative (activating) methods in education is easy.
33	At university, I was prepared for teamwork - both knowledge-wise and skill-wise.
34	Teachers do not understand the concept of IT.
35	Information from bachelor and diploma theses is a good source of information for teachers for IT.
36	When creating a class schedule, I can set the requirements for a class schedule that is tailored to me.
37	I am convinced that non-integrated teaching is the right way to prepare a student for life.



Number of Q-type	Statement stated on Q-type
38	IT will contribute to the dumbing down of the population.
39	IT enables a transition in education from an emphasis on knowledge to an emphasis on competence.
40	Teachers confuse the term IT with the inclusion of pupils in schools.
41	The implementation of IT is possible only if it is introduced at all levels of schools at the same time.
42	For the implementation of IT, it is necessary that it be preceded by a suitable intermediate stage (circle, compulsory optional subject).
43	To implement IT, it is important that teachers master formative assessment.
44	Students are more comfortable with the traditional way of teaching individual subjects than with integrated subjects.
45	At university, I was educated in such a way that I could also implement IT into lessons.
46	There are enough materials available for IT (textbooks, worksheets, etc.).
47	Teaching through isolated topics is a suitable method for teaching chemistry in grammar schools.
48	For the implementation of IT, I lack basic knowledge of the content and school educational programme of other subjects suitable for integration topics.
49	IT cannot be implemented until a suitable textbook for IT of science subjects is created.
50	The problem with integrated subjects is that one mark is awarded from it. A student who is successful in chemistry but unsuccessful in biology may thus receive a worse grade on average.
51	IT can only be implemented within integrated subjects as e.g. Science.

Respondents sorted Q-types into the scheme showed in Figure 1. Each placement had its assigned value depending on the degree of agreement - see Figure 1. After processing the Q-sorts, individual statements were placed in a table with evaluations from all respondents, the average, standard deviation (as mentioned in Chráska, 2016) and median were calculated. Based on the values, the order of importance of the statements for the respondents was determined. The obtained data were analysed using factor analysis using the PCQMethod programme.

Data were collected from February 2022 to January 2023 in 4 rounds at total. We contacted 267 chemistry grammar school teachers in the Czech Republic with request to participate, 20 of them participate in our research. Despite the low number of respondents, the research brought a lot of information to current discussions related to integrated teaching.

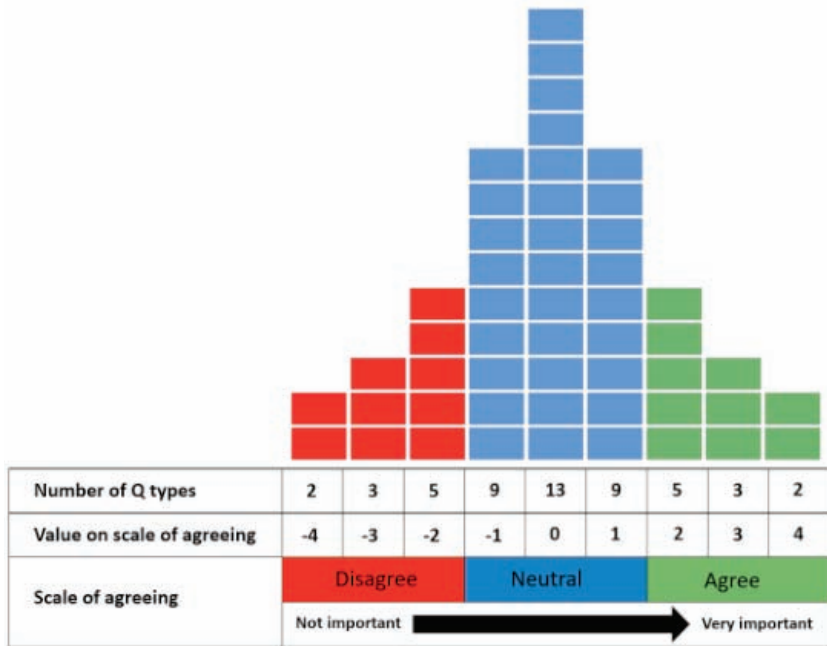


Figure 1. Scheme for Q-sorting with marked value on scale of agreeing

## Results

Based on the order of preference of the respondents (according to the average rating of the given statement), the most and least preferred statements (Q-types) were stated (see Table 2 and Table 3).

Data were processed by performing factor analysis with varimax rotation using PCQMethod program. The programme generated 8 factors (see Table 4), the critical value for factor loading was determined at 0.360 (this value was calculated using formula for critical value as mentioned in McKeown & Thomas, 2013).

Table 2. Most preferred statements (IT stands for integrated teaching)

Order	Q-type	Average	Standard deviation	Median
1.	IT encourages students' interest in greater depth and breadth of their knowledge.	1.9	1.446	2
2.	The teamwork of teachers is important for the implementation of IT at secondary schools.	1.75	1.337	2
3.	IT develops students' critical thinking.	1.45	1.499	2
4.	The implementation of IT at school depends primarily on the attitude of the majority of teachers to this issue.	1.45	1.687	1
5.	For the implementation of IT, it is important that the teacher has specific characteristics (e.g. flexibility, inquisitiveness, desire for lifelong learning).	1.25	1.813	2
6.	Teachers must be prepared for the IT in a specific subject - interdisciplinary didactics.	1.2	1.939	1
7.	In order to implement IT, it is necessary to see its implementation in practice.	1.15	1.314	1
8.	Teachers are not able to implement IT because they are overloaded.	1.1	1.997	1
9.	The goal of secondary school education is to prepare students for university entrance exams.	1.05	1.746	1
10.	IT enables a transition in education from an emphasis on knowledge to an emphasis on competence.	0.95	1.117	1
11.-12 .	In the framework of postgraduate education, the issue of IT is not given sufficient attention.	0.9	1.338	0.5
11.-12 .	A problem for the introduction of IT in schools is the admission of students to universities according to the average of grades from individual subjects (they would have one grade for an integrated subject).	0.9	1.513	1

Table 3. Least preferred statements (IT stands for integrated teaching)

Order	Q-type	Average	Standard deviation	Median
51.	IT will contribute to the dumbing down of the population.	-2.4	1.356	-3
50.	When choosing a training within the further education of teaching staff, the school management prioritizes the price of the course over its quality.	-1.95	1.499	-2
49.	I became thoroughly acquainted with the IT concept during my undergraduate studies.	-1.9	1.578	-2
48.	When creating a class schedule, I can set the requirements for a class schedule that is tailored to me.	-1.7	1.616	-2
47.	IT does not belong to the secondary school.	-1.7	1.676	-2
46.	I got acquainted with the IT concept at a course/training within the further education of teaching staff	-1.55	1.658	-2
45.	Implementation of innovative (activating) methods in education is easy.	-1.05	1.774	-1
44.	IT is primarily intended for gifted students.	-1.05	1.596	-1
43.	At university, I was prepared for teamwork - both knowledge-wise and skill-wise.	-1	1.304	-1
42.	At university, I was educated in such a way that I could also implement IT into lessons.	-0.95	1.83	-1.5
41.	The school management does not motivate teachers to do creative work.	-0.85	1.558	-0.5
40.-38 .	There are enough materials available for IT (textbooks, worksheets, etc.).	-0.7	1.584	-0.5
40.-38 .	I am convinced that non-integrated teaching is the right way to prepare a student for life.	-0.7	1.269	-1
40.-38 .	Teachers confuse the term IT with the inclusion of pupils in schools.	-0.7	1.382	0

Table 4. Factor Matrix with an X Indicating a Defining Sort

FACTOR LOADINGS								
Q-SORT	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6	Factor 7	Factor 8
1 r03	0.1418	0.0626	-0.1001	<b>0.8191X</b>	-0.0823	0.0553	0.0983	0.1118
2 r06	0.2273	0.2638	-0.5150	0.1739	0.2826	-0.0979	0.2471	0.4740
3 r20	0.1601	0.2693	0.2011	0.4846	0.4152	0.2577	0.0001	-0.0309
4 r27	0.0666	0.0248	-0.0426	-0.0193	<b>0.8930X</b>	0.0142	0.0513	0.1327
5 r29	<b>0.5228X</b>	0.0668	0.3548	0.3459	0.2198	0.1144	0.1616	-0.0086
6 r30	0.1341	0.2207	0.2054	0.0838	0.0097	<b>0.6738X</b>	0.0168	0.1978
7 r36	0.3807	0.4480	0.2022	0.3276	0.1554	-0.1953	0.3688	0.2720
8 r44	<b>0.6212X</b>	0.0913	-0.2113	0.2257	-0.3166	-0.0483	0.2853	0.2435
9 r45	0.1138	-0.0296	0.1241	0.1085	0.0147	0.0012	<b>0.8874X</b>	0.0943
10 r64	0.0896	<b>0.8551X</b>	0.0913	-0.0729	-0.0030	0.1820	0.0131	-0.0035
11 b21	<b>0.7627X</b>	-0.0137	0.0388	0.2125	0.0099	0.3354	0.0878	0.0561
12 b44	0.2846	0.0707	-0.0096	0.3456	0.0202	0.4656	0.5114	-0.0106
13 c16	0.1727	0.2192	<b>0.8248X</b>	-0.0066	0.0189	0.1448	0.1302	0.1697
14 c20	0.2060	0.0137	0.1366	0.0791	0.1066	0.2861	0.0915	<b>0.7960X</b>
15 c34	0.1585	0.4515	0.3352	0.4196	0.3214	-0.1329	0.2328	-0.0657
16 d06	0.3411	0.2268	-0.1812	-0.2750	0.2208	0.4656	0.5376	0.1411
17 d09	<b>0.7107X</b>	0.1330	0.0676	0.0736	0.2114	0.2644	0.0436	0.1407
18 d10	0.5545	0.5322	0.1077	0.0166	0.0563	-0.0054	0.0494	-0.2719
19 d20	<b>0.7002X</b>	0.2224	0.1444	-0.0734	0.0602	-0.1893	0.2162	0.3700
20 d84	0.0616	<b>0.7190X</b>	-0.0087	0.3079	0.0487	0.1591	-0.0137	0.2055

From next analysis were excluded factors that included only 1 respondent and respondents that were included into more than 1 factor were excluded as well. Furthermore, the data analysis was processed with the number of two factors, the characteristics of which are given in Table 5.

Table 5. Factor characteristics

	Factor 1	Factor 2
Eigenvalue	6.2370	1.7652
S.E. of Factor Z-Scores	0.218	0.333
No. of Defining Variables	5	2
Average Reliability Coef.	0.800	0.800
Composite Reliability	0.952	0.889

### Factor 1

Respondents grouped in factor 1 think that one of the most important conditions for implementing integrated teaching into lessons is the approach of most teachers at the school to the issue of integrated teaching (Q-SV 4). According to these respondents, future teachers must be prepared for integrated teaching at universities in a specific subject (interdisciplinary didactics) and it would be

beneficial if they learned at universities how not to burn out and cope with stress (Q-SV 3). The respondents were not educated at university in such a way that they are able to implement integrated teaching in their lessons (Q-SV -3) and during their pregraduate studies they were not thoroughly acquainted with the concept of integrated teaching (Q-SV -4). In their opinion it is also important for the implementation of integrated teaching into educational process that the teacher has specific qualities (Q-SV 3).

They believe that the obstacle to the implementation of integrated teaching in education is the difficulty of implementing innovative (activating) methods in education (Q-SV -4). According to their opinion, integrated teaching will not contribute to the dumbing down of the population (Q-SV -3).

Factor 1 included 2 men and 3 women with a length of teaching experience from 0.5 to 37 years. Teachers had degrees in teaching chemistry and biology (3), chemistry and mathematics (2). The highest education achieved was a master's degree (3), Ph.D. (1), Mgr. et. Mgr. (1).

## ***Factor 2***

Respondents grouped in factor 2 perceive integrated teaching positively. They think that integrated teaching develops students' critical thinking (Q-SV 4), this type of education belongs to secondary school education (Q-SV 4) and will not contribute to the dumbing down of the population (Q-SV -4). They are convinced that integrated teaching is the right way to prepare students for life (Q-SV -3).

They believe that the obstacle to the implementation of integrated teaching in education is the impossibility to fulfil the whole curriculum when implementing integrated teaching and the fact that when the teacher implements integrated teaching, then the teacher has to overcome the fear that students will know more than the teacher (Q-SV 3).

Factor 2 included 1 man and 1 woman with a length of teaching experience from 1.5 to 3 years. Teachers had degrees in teaching chemistry and physics and chemical engineering. The highest education achieved was a master's degree.

### **Consensus Statements**

All respondents agreed on the following statements stated as consensus statements. For the statement to be included into these consensus statements, the statement had to be valued by all respondents at range from +4 to 0 in the case of an affirmative opinion or at range from -4 to 0 in the case of a disapproving opinion.

Respondents agree that the teamwork of teachers is important for the implementation of IT at secondary schools.

Respondents disagree with the statement that states when choosing a training within the further education of teaching staff, the school management prioritizes the price of the course over its quality.

They think that integrated teaching encourages students' interest in greater depth and breadth of their knowledge and they do not think that integrated teaching will contribute to the dumbing down of the population.

## **Conclusion**

Benefits, opportunities of implementing integrated teaching as well as obstacles that need to be overcome so integrated teaching can be better implemented into lessons were determined from the chemistry teachers teaching at grammar schools' point of view. Integrated teaching among grammar school chemistry teachers is perceived positively. The research result clearly supports the fact that the curriculum at universities in the Czech Republic should focus more on the theory and practice of integrated teaching as well as teamwork.

## ***Ethics Statement***

The ethics committee confirmed to the corresponding author that this research did not require ethics approval because of the full anonymization of the publicly available data and because the data are not sensitive.

## ***Conflicts of Interest***

The authors declare no conflict of interest.

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# What is the appropriate methodology for Generation Z (and Generation Alpha) education?

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## Abstract

The aim of the paper is to present the outcomes of our recent research. The research was focused on the analysis of preferred methods of teaching and learning physics by Generation Z (and Generation Alpha) learners. It is known that a great emphasis is now given to research-oriented learning, real-life applications, problem-solving, and project-based learning. Project-based learning is considered as a future-focused methodology that fosters skills needed for the labor market of the 21st century. The findings of our research can be summarized as follow: generation Z and Alpha learners as digital natives are „hungry“ for the opportunity to conduct real experiments. Students are more attracted to doing real experimental activities during physics lessons than using multimedia. This statement is formulated and based on the outputs and evaluation of project days, which have been prepared for secondary school learners. The used research methodology was semi-structured interviews with teachers and a guided discussion with students. The project day was dedicated to the topic of metrology, one of the first teaching topics that can be found in physics textbooks for the 6th grade of elementary school. The project day was realized at 15 secondary schools in the Czech Republic, and about 236 learners took part in this activity. The topics of the project day were: the measurement of length and the measurement of weight. The activities were prepared in three variants, for ordinary students but also gifted and bright students with specific needs. The theoretical basis of the said research so as the structure of the project day with main activities will be described in this paper.

## Key words

Generation Z, Generation Alpha, physics, project-based learning

## Introduction

Research has explored the concept of generations for decades as a way to understand social change. New approaches have taken ideas from the sociological literature and applied them to understanding attitudes and behaviors of individuals. The idea of categorizing people by their generation became popular,

and generational terminology has now taken hold in the common vernacular. In the modern era, generations are often described by labels and defined as a group born between specific years—for example, the “millennial” generation, born roughly in the 1980s and 1990s (Tippins, 2023).

The commonly used generation timeline is shown in figure 1.

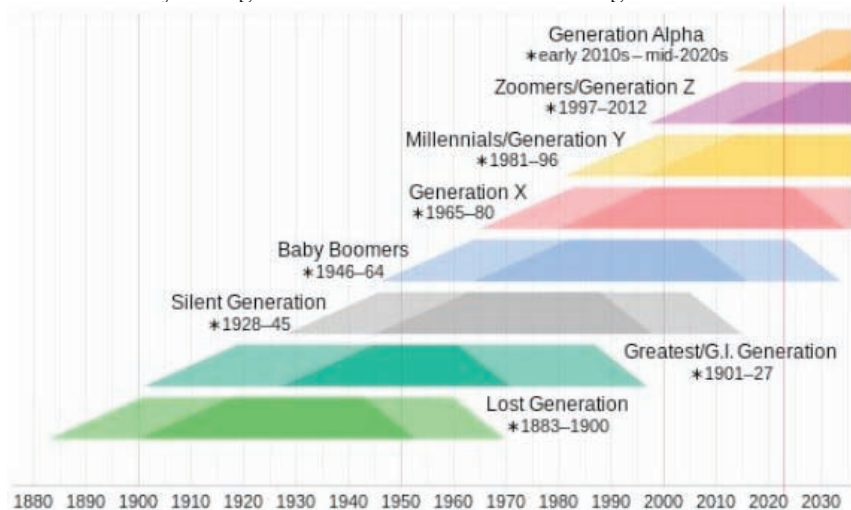


Figure 1. Generation timeline [https://commons.wikimedia.org/wiki/File:Generation\\_timeline.svg](https://commons.wikimedia.org/wiki/File:Generation_timeline.svg)

About 31% of the world’s population (2.5 billion people) are from Generation Z. Their birth years are the late 1990s to 2010. A great number of papers and various manuscripts about Generation Z were published (Iftode, 2019, Shorey et al., 2021).

The most important characteristics of Gen Z can be summarized as follow. Gen Zers grew up in a digital world, they are online all the time. They have a short attention span, it is only eight seconds. They typically socialize online (Parker, 2020).

During the past five years, we had the opportunity to cooperate with many elementary schools, and the following has been verified. We were interested in the problem what impact the characteristics of Generation Z have on the learning process and how the approach to the younger generation needs to be changed (from the point of view of schools and teachers).

Several case studies were carried out and classroom visits were analyzed (project Didaktika – Člověk a příroda A, CZ.02.3.68/0.0/0.0/16\_011/0000665). It has been found that Generation Z students prefer teaching methods that can be characterized as learner-centered methods. Learners seem to be more practical,

they prefer learning by doing. Very important and effective can be hands-on learning. It was pointed out that these activities (methods) lead to greater interactivity, and teaching science is more motivating or “fun”. On the other hand, hybrid learning plays an important role in learning and contact between classmates and the teacher. The use of an interdisciplinary approach is essential. This meets best the concepts of STEM (STEAM) and IBSE education.

According to Claire Jollain, seven rules to teach Gen Z were formulated:

1. Generation Z likes clear directions. They are afraid of doing wrong or wasting their time doing something that is not asked.)
2. Make sense. (Things done in class - how will they be useful for their future.)
3. Listen and adapt. (The teacher starts from the level of knowledge of their students.)
4. Tell stories.
5. Break the monotony of a long speech with a multitude of activities.
6. Teach less or less is more. (Teach less but better, go over a concept two or three times, in different ways.)
7. Innovate and take risks. ( Zers like new ways of learning.) (Jollain, 2023)

We currently know a lot about Gen Z, but Generation Alpha students are entering our schools. A key question is if the students of this generation are different, what teaching methods are appropriate to choose?

Generation Alpha includes those born from 2010 onwards and who have therefore grown up in a fully digital world. The world of Alpha generation children overflows with technological conveniences, everything, and everyone are connected. Their lives are affected by technologies whose development can hardly be predicted. The characteristics of the Alpha generation have and will influence learning.

Reduced attention span and concentration. As they are used to using several screens at once and quickly scanning information, their attention span and concentration are impaired.

Less time for socializing. Spending much of the day online, both inside and outside the home, reduces the time for learning, playing, and socializing in more traditional ways. Much of socialisation is transferred to social networks.

Less development of creativity and imagination. Without questioning the skills that the Alpha generation will acquire thanks to new technologies, it should be stressed that as the use of physical toys is reduced, the development of imagination and creativity will suffer.

Reduced ability to achieve happiness. As psychologist Jean M. Twenge notes in her book *iGen*, there is a “link between the rise of smartphones and social media and the increase in depression, anxiety, and loneliness in today’s youth”.

In short, the Alphas are presented as a generation profoundly marked by new technologies and social networks, with a more uncertain future in the face of rapid political and economic change, and with the pressure to lead the fight against climate change and the transition to a more sustainable planet (Fig. 2).

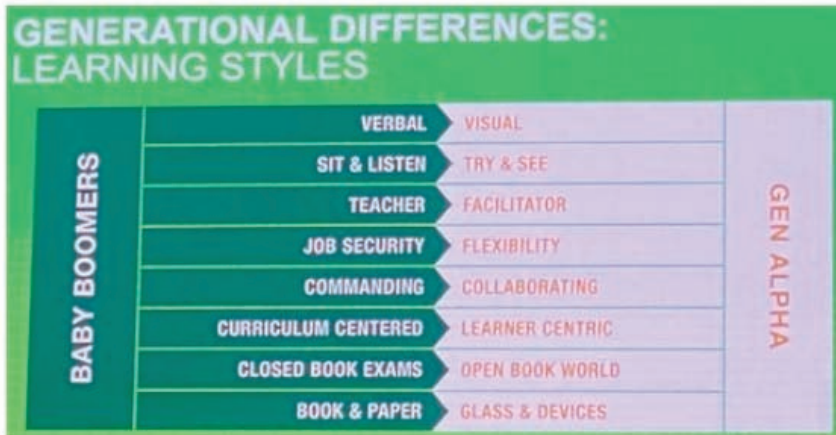


Figure 2. Generational differences

(<https://www.belfastcsd.org/site/default.aspx?PageType=3&ModuleInstanceID=2486&ViewID=DEDCCD34-7C24-4AF2-812A-33C0075398BC&RenderLoc=0&FlxDataID=12171&PageID=2334&Tag=&Comments=true>)

### **How to teach gen Z and gen Alpha**

Learner-centered methods or activation methods were subjected to analysis, and one method that appears to be suitable for use in school practice to the greatest extent possible is project-based teaching and learning.

Project-based learning (PBL) or project-based instruction is an instructional approach designed to give students the opportunity to develop knowledge and skills through engaging projects set around challenges and problems they may face in the real world, it is learning by doing. Students need experience in STEM subjects (science-technique-engineering-mathematics). The real world of the 21st century is a project world.

Various definitions of PBL can be found in the literature. Průcha (2003) defines the project method as follows. Project method - students are guided to independently work on certain projects and gain experience through practical

activities and experimentation projects can take the form of integrated topics, practical problems from real life, or practical activities leading to the creation of a product, a visual or verbal product (Průcha, 2003).

The PjBL model has the great potential to provide a more interesting and meaningful learning experience for students. This model is one of the developments of constructivist learning theory, where humans as learners must build their own knowledge in the context of their experiences. (Ningsih, 2020)

According to Průcha (2003), Hosler (2013), and Love (2021) the PBL model consists of these seven characteristics:

Focuses on a big and open-ended question, challenge, or problem for the student to research and respond to and/or solve

Brings what students should academically know, understand, and be able to do into the equation

Is inquiry-based, stimulates intrinsic curiosity, and generates questions as it helps students seek answers

Uses 21st-century skills such as critical thinking, communication, collaboration, and creativity, among others (Battelle for Kids)

Builds student choice into the process

Provides opportunities for feedback and revision of the plan and the project, just like in real life

Requires students to present their problems, research process, methods, and results, just as scientific research or real-world projects must stand before peer review and constructive criticism (Hosler, 2013, Love, 2021).

Shortly, PBL is an organized activity of the teacher and pupils, the learning activities of the pupils and the counseling activity of the teacher are dominant. From the teachers' point of view, the basic stages of project preparation are preparatory work, the study of literature, realization, message, presentation, discussion, conclusion, and evaluation.

The focus of learning lies in the principles and concepts of a scientific discipline, involving students in investigating problem-solving and other meaningful tasks, giving students the opportunity to work autonomously in constructing knowledge and for making products. The project-based learning model requires students to actively explore real-world challenges and problems (Ningsih, 2020).

The student is led to apply his ideas and ideas to innovations. The project requires less supervision. The contribution of the project to the development of pupils' manual skills is not negligible. When writing the project, the student must receive clear, comprehensible, and unambiguous instructions. In terms of content,

the project must be developed linguistically and formally correctly (diagrams, tables, and pictures). It must contain a proportionate amount of references to the literature. The project must include a conclusion.

PBL learning can be realized at different levels as shown in the table.

*Table 1. Levels of project-based learning*

<b>Element</b>	<b>Ideal</b>	<b>1<sup>st</sup> reduction</b>	<b>2<sup>nd</sup> reduction</b>	<b>n-th reduction</b>
	Project-based teaching	Project-oriented teaching	Subject-oriented project	??
<b>Topic</b>	Students determine the topic and content	Students and the teacher jointly determine the topic	Students choose from a list of topics	The teacher determines the topic
<b>Material</b>	The students provide the material	The students and the teacher provide the material	The students choose from the presented material	The material is ready
<b>Goals</b>	Students formulate goals	Students and the teacher formulate goals	Students choose from a catalog of goals	The teacher defines goals
<b>Methods</b>	Free choice of procedure	Selection from the list	Recommendation of the procedure by the teacher	The teacher prescribes the path
<b>Group</b>	Free creation	Homogeneously created groups	The teacher creates a group	Class
<b>Subjects</b>	Unrelated to subjects	Two subjects or 2 teachers	One subject	1 subject, 1 teacher, given a narrow topic
<b>Evaluation</b>	Self-evaluation of progress and result	Students and teachers evaluate together	Teacher's evaluation is discussed	Teacher's marking
<b>Result</b>	Model, exhibition, protocol, behavior change, new interests			Page in notebook
<b>Student</b>	Actively plans	Co-plans, active	Active and passive work activities	Recipient
<b>Teacher</b>	Moderator, counselor on request, supervision	Coordinator	Structures, binding recommendations	Teacher leads throughout the entire scope

### *The problem of project evaluation*

The student requires feedback during learning – he should know if he is progressing correctly, if the educational goal is in several stages, he needs to know if he has met the requirements for the given level and can progress further.



The problem remains, what should the teacher evaluate first – the quality of the project outputs or the work? On the other hand, during the time when the project is being solved, the teacher gets an overview of the abilities of each student. For longer-term projects, it is necessary to regularly check the laboratory diary, to check the accuracy and thoroughness of the work. However, the project should be the student's independent work, he should be given freedom in processing it, and the teacher assumes the role of advisor and consultant.

### ***Examples of project days – n-th reduction of PBL***

Project day 1 – Metrology (length)

Task 1: Search the Internet for current definitions of basic SI units, quantity symbols

Let us see how our ancestors measured - can we imitate them?

The smallest unit was a grain of barley. Today it would represent a length of about 4.9 mm. If we put four grains of barley next to each other, we get a unit finger, about 20 mm in today's units (19.7 mm to be exact). Four fingers placed next to each other represent a palm, i.e. 78.6 mm long. Ten fingers placed next to each other make a foot. The length is therefore 197.1 mm. Does not make it your head spin? Three cubits placed next to each other make a cubit. This is how the Czech cubit was measured, the Austrian or German cubit was determined differently.

Do you know what an almond is? It is a structure built of hay, grain, or straw. He stood in the field in the form of a shot. Each of the shots contained fifteen sheaves. A sheaf is a bale of hay tied up immediately after cutting. And so the almond was used as a numerical measure for fifteen.

Let us recall the units of volume. The bucket had a volume of 47-78 liters, the barrel contained 248 liters. You may know the trowel from fairy tales: 23-25 liters.

Think about it: Why did people in the past use length to measure parts of the human body? What was the disadvantage of such a measurement?

Find out where we still find elbow standards today - they are usually walled up in the town hall. (Mělník Town Hall, New Town Hall in Prague)

Research activities

Match the gauges in the picture with the correct name

digital pedometer

digital distance meter

tape measure

ultrasonic sensor

tailor's tape measure

folding tape measure



Figure 3. Pictures of gougues

Try to estimate the length of 1 meter. Find the most accurate estimate that is possible.

Procedure: everyone draws a line on the blackboard with chalk and writes their name next to it, then the lines are measured with a tape measure and the results are evaluated.

Evaluation - who in the class had the best guess?

Task 2: Measure the bench in your elbows and inches. In what other units could you measure the length of a bench?

(write the results on the board)

1 Czech cubit = 59.3 cm,

1 inch = 2.54 cm,

1 Viennese cubit = 77.8 cm,

1 foot = 30.5 cm (12 inches),

1 foot = 19.7 cm (1/3 Czech cubit),

1 fathom = 179.3 cm (3 Czech cubits),

Activity: Production of gauges for various units.

Production of a ruler with a measuring unit, e.g. 1 inch, 1 Czech cubit, 1 foot.

Activity: Measure your body.

Measure the height of your figure; elbow length; distance of open thumb and forefinger; head circumference; neck circumference; foot width and length.

Tools: chalk, calculator, different types of meters, scissors, transparent scotch tape, paper, pencil, colored crayons (markers), pencil, and string.

Discussion – criminalistics - bertillonage

PROJECT: Find your average stride length.

Tip: The more steps you take with a natural walk, the more accurate your calculation will be.

Estimate the length of the hall and then measure it. How accurate was your guess?

a) Pupils first estimate the length of the corridor while standing at one end of it. They write the estimates in the table. b) Pupils measure the length of the corridor, while they may use anything that does not have a scale in units of length (you may not use a ruler, folding tape measure, etc.). They can use the gauges prepared in previous tasks. c) Pupils measure the length of the corridor with a laser scale.

Project day 2 – metrology (weight)

Let us see how our ancestors weighed! Czech scales:

stone = 20 pounds = 10.28 kg

centyr (cent) = 6 stones = 61.68 kg

pound = 514.37 grams

lot = 16.05 grams

Austrian scales:

cent = 100 pounds = 56 kg.

pound (Ppound) = 32 lots = 0.56 kg (560.0119 g).

lot = 4 quarts = 17.5 g.

Viennese quintal = 60 grains = 4.375 g.

Vienna hryvnia = 280.644 g.

Task 1: Match the pictures with the correct type of weight

- personal weight
- digital laboratory scale
- kitchen scale



Figure 4. Picture of weights

## Task 2: Weight estimate

Compare the weights of objects from world around us: raindrop, 50 CZK coin, 1 liter of water, car, elephant, a plane taking off. Compare the weight of the coins!

How many coins do you need to balance ten korunas (fifty korunas)? Estimate by comparing in the palms of your hands, then weigh on the digital scales. Is it true that if a ten-crown pays more than a crown, it is also much heavier?

Task 3: Select items from your briefcase to weigh on both the digital scale and the hanging scale. Which weighing is more accurate? Determine the weight of your school backpack!

What units of weight were used in the past? What different units are used in other countries?

(in our country: 1 carat = 0.21 g, 1 quintal = 4.38 g, 1 lot = 17.50 g, 1 hryvnia = 280.67 g, 1 stone = 10.25 kg, England: pound = 560.06 g)

Activity: Make an isoscales scale from a hanger and compare the weight of different objects.

Procedure: a) Tie two strings of equal length to the ends of the hanger. Hang the hanger on your finger and adjust so that the hanger is balanced. b) Attach 2 identical bowls, from the bottom of a PET bottle, to the ends of the strings. c) Put different objects (e.g. potato, soap, onion, tartar, lemon, pen, 20 sugar cubes, case, etc.) into the bowls made and compare their weights. Always try to guess which is heavier first and then check with isosceles scales. d) Write down your results on paper, use the symbols  $>$ ,  $<$ ,  $=$ .

Activity: Make a scale using the following aids: a large plastic bottle, a 50g weight, masking tape, scissors, a bucket of water, plasticine, a CD marker.

Procedure: a) Cut off the upper part of a large PET bottle, about 1/2. b) Load the PET bottle (e.g. with plasticine) and immerse it in a bucket of water. The PET bottle should not tip over in the water. We make a line on the PET bottle at the height where the water level is. We will write the value 0 g to this line. c) Put a weight of 50 g in the bottle and make a line on the bottle at the height of the water level and write the value 50 g, this procedure should be repeated several times. d) When the entire bottle is marked, take out all the weights, except for the first weight (e.g. plasticine). Now we put any object, for example 1 lemon, into the PET bottle, which is still immersed in the bucket of water, and determine its weight according to the scale.

Example of o project – ideal PBL

The topic of the project – Fire

The topic and content of the project were chosen by a student within the

subject Physics-technology-nature taught to pre-service physics teachers at the Department of experimental physics.

The project presents an everyday used phenomenon from the perspective of various teaching subjects and presents questions that can be analyzed in detail within the framework of the given topic. Individual parts of the project can be solved by different groups of pupils. The project also includes an interesting experimental task - the Prometheus problem.

Basic topics that can be addressed within the project are listed below.

What exactly is fire?

(Combustion is a redox exothermic reaction, i.e. occurring with the generation of light and heat.)

Historical ideas about burning

Until the 18th century, people believed that flammable substances contained phlogiston gas, which causes them to burn and is released when they burn.

Conditions for burning

Flame

A flame is a visible area of burning gases or vapors. From its color and luminosity, one can infer the type of substance burned and the perfection of the burning.

Flame temperature: cigarettes – 500 °C; matches – 800 °C; wood – 1100 °C; brown coal – 1100 °C; black coal – 1200 °C; diesel, oil – 1100 °C; gasoline – 1200 °C; natural gas – 2000 °C. These characteristics can be studied using a thermal imaging camera.

Types of flame

Burning phase

Flame color

Some chemical elements and their compounds characteristically color the non-luminous flame of a laboratory furnace: sodium – deep yellow; potassium – purple; calcium – brick red; copper – grass green; lithium – purplish red; strontium – crimson red; barium – yellow-green; antimony – blue.

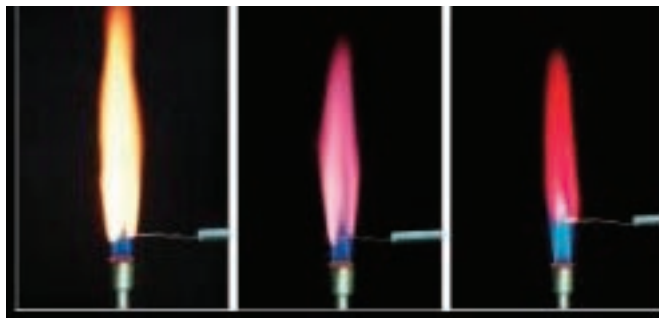


Figure 5. Flame coloring with sodium, potassium and lithium

(<https://vyuka.p3k.eu/ch8-alkalicke-kovy-souhrn/>)

### Use of fire

For example the social functions of fire - various ceremonies; birthday candles; memory of the dead; camp and conversation fires; destruction of people and things (torture, arson, executions, burning at the stake; cooking in a cauldron); war use of fire; fear of fire, the Olympic flame.

Man and fire - meaning for life, the ability to make fire, fire and religion, philosophy, fire, and art.



Figure 6. Fire and art - Josef Čapek: Fire. ([https://sbirky.ngprague.cz/dielo/CZE:NG.O\\_10747](https://sbirky.ngprague.cz/dielo/CZE:NG.O_10747))

The basic experimental activity included in this project is the study of different methods of making fire.

Prometheus' problem. Describe the physical mechanism, based on friction, that allowed our ancestors to make fire. Estimate the time required to spread the fire this way.

The most common method of starting a fire is rubbing wood (soft linden or birch wood). Prepare a hole in a smooth plate, take a stick with a point at the end, insert the stick into the hole, and spin it. Friction creates sawdust which have a lower ignition temperature than wood.

The task can be solved using basic physical relations for heat calculation, calculation of friction force, and calculation of work. In the tables, you need to find the ignition temperature of wood and the coefficient of friction. It is possible to solve the problem of friction without sawdust, with sawdust, dry wood, wet wood, etc.

$$Q = mcT$$

$$W = \frac{Q}{\eta}$$

$$p = \frac{fF}{R^2}$$

$$P = \frac{2}{3} fF\omega R$$

$$\tau = \frac{3mcT}{2fFR}$$

where  $m$  is the weight of the wood we light,  $Q$  is the supplied heat,  $c$  is the specific heat capacity of the wood,  $T$  is the ignition temperature,  $W$  is the work performed,  $\eta$  represents the efficiency,  $f$  is the coefficient of shear friction,  $F$  is the force with which we push the tip,  $R$  is the radius of the contact surface,  $\omega$  is the angular speed of rotation,  $P$  is the power, and  $\tau$  is the time required.



Figure 7. Making fire in prehistoric times. ([https://www.archeologienadosah.cz/sites/default/files/clanky/obr\\_2\\_7.jpg](https://www.archeologienadosah.cz/sites/default/files/clanky/obr_2_7.jpg))



The estimated fire time based on the above relationships and wood characteristics that were looked up in the tables is for dry wood about 400 seconds. In the case of damp wood, the time will be extended to more than 3600 s.

## **Conclusion**

Work on projects can replace some of the problems of implementing interesting teaching supplemented by experiments with cross-subject links and solve connections to problems of everyday life. Today's school is often faced with the problems of technical security of experiments, descriptions of experiments in textbooks mostly include standard experiments, and only slowly are the subjects of today's technology included in the content. The projects will enable linking theory with practice. Solving projects students improve their knowledge and understanding of how things work. PBL is one of the key methods to motivate Gen Z and Gen Alpha learners. They can solve open-ended problems, they practice meaningful work. Technology and technique can be used during the project work. The ideas of inquiry- based education (IBSE) and STEM can be fulfilled.

## ***Ethics Statement***

The ethics committee confirmed to the corresponding author that this research did not require ethics approval because of the full anonymization of the publicly available data and because the data are not sensitive.

## ***Conflicts of Interest***

The authors declare no conflict of interest.

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# **Be or not to be a reflective teacher?**

## **Reflection as a dominant quality of the teacher's work – a pilot study**

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### **Abstract**

In modern societies, teachers must meet high expectations, with self-reflexion and feedback acceptance crucial. While creating educational programs, teachers must see the world “through the eyes of a student.” Future chemistry teachers participate in school practise, conducting lessons at various levels, and reflecting after each lesson is valuable. The study aimed to gather opinions on preparation and conducting lessons, using a diagnostic survey in three stages. The questionnaire included 7 closed questions on a Likert scale. Results from 87 responses revealed difficulties faced by future chemistry teachers, such as class diversity and time management issues.

### **Keywords**

Future teachers, chemistry lesson, preservice teachers training, reflexion, reflective practise

### **Introduction**

Teachers live and work in a very complex world; a world in which constant change is taking place. The power of globalisation is reflected in every area of social life; it affects, for example, everyday school life and educational processes.

The teacher is essential in the teaching-learning process, being at the same time one of the most important determinants of the quality of the educational process (Valtonen et al., 2021). The realisation of educational outcomes depends on the teacher; hence the importance of improving teacher education in higher education institutions. A program based on the principles of school-university partnership is becoming a priority for new teacher education strategies (Margolis et al., 2014).

Katarzyna Grabarek (2021) clearly emphasises the importance of contemporary education paradigms, stating that “the paradigm thus determines

the nature of education and leadership and influences the formulated strategies and initiatives...". (p.20); paradigm shifts, especially in relation to teacher professionalism, entail changes in, e.g., the context of social expectations placed on teachers (Cheng & Townsend, 2000).

Teaching experiences are gained by future teachers during their internships in schools. The preparation of their proper program and their planning ensures that future teachers are competently prepared for their profession; school placements give them a practical opportunity to understand the teaching profession and the prospects and working conditions of the profession (Darling-Hammond, 2006).

No education system can prepare a future teacher to overcome all the teaching and learning problems they will encounter in the future. The tool that such a student teacher trainee needs, and that he or she can acquire and refine in the educational process, is reflection.

## **Reflection in pedagogical training and education**

The word reflexion immediately evokes certain associations: reflexivity, reflective attitude, and, with regard to the teaching profession being an asset, reflective practise. But do we actually understand these terms in the same way? Do they acquire a special meaning in the pedagogical context?

Considerations of reflection in didactics can be found in the literature as early as the 1960s - we can find descriptions of different types of reflection, the concept of reflexivity or reflection in action, reflective practice.

Table 1 presents definitions of selected entries based on the Polish language dictionary and the pedagogical dictionary (Kupisiewicz & Kupisiewicz, 2009).

According to John Dewey, reflexion is a special way of thinking, which consists in pondering deeply or analysing one's own thoughts. Reflection is a complex activity in which the state of confusion, anxiety, uncertainty or doubt leads to active study or searching for other facts, which can confirm or refute the assumptions that have arisen (Schon, 1983; Letseka & Zireva, 2013).

Moreover, according to John Dewey and Jürgen Habermas, reflection is a thought process, which consists in contemplating one's own experiences, structuring them, drawing conclusions and applying them in practice. Reflexion takes place during active observation and is the basis for active experimentation (Denton, 2011).

David Kolb emphasises that reflexion is a mental activity required for learning on the basis of experience. This is the stage in the experiential learning cycle (concrete experience (problematic situation), reflecting, abstract conceptualisation, and acting (problem solving) in which one makes self-

reflexion on experience and draws conclusions (Moon, 2013). On the other hand, Schön describes reflexion as the mechanism that builds professional and personal development and is applied by a ‘reflective practitioner’. The reflective practitioner uses two kinds of reflection: reflection-in-action and reflection-on-action (Brockbank & McGill, 2007).

*Table 1. Definitions of chosen terms*

Term	Polish language dictionary ( <a href="https://sjp.pwn.pl/">https://sjp.pwn.pl/</a> )	Pedagogical dictionary
reflexion	<p>“thinking about something, pondering something, intellectualization, afterthought”</p> <p>“capacity for self-knowledge, self-control, self-criticism”.</p> <p>Action: Dwelling on something, which goes to the heart of the issue</p> <p>Result: The thought, which is the result of thinking deeply about something.</p>	<p>In pedagogy, reflexion often refers to the process in which teachers or students think about their educational experiences, their practise of teaching or science, their progress and results. The purpose of this is to understand, analyze, evaluate and improve their practice, strategy, skills, attitudes and knowledge.</p>
reflectivity	<p>In the pedagogical context, in Polish, the term ‘reflectivity’ often refers to the capacity to deeply and critically think about one’s own learning or teaching. Reflectivity is the ability to assess and analyse one’s own activities, experiences, and thoughts to make some changes or corrections.</p>	<p>In the pedagogical context, reflectivity is usually related to the ability of teachers (or future teachers) to analyse, understand and improve their teaching practice through constant pondering over it.</p>

Term	Polish language dictionary ( <a href="https://sjp.pwn.pl/">https://sjp.pwn.pl/</a> )	Pedagogical dictionary
reflective attitude	Reflective attitude is the capability for deep, critical thinking about one's own behaviour, actions, beliefs and ideas. This means being aware of one's own thoughts, feelings, reactions and understanding how they influence our decisions and actions. Reflective attitude is crucial in a wide range of areas, including education, where teachers and students are invited to reflect on their own teaching and learning.	In the pedagogical context, reflective attitude generally refers to a teacher attitude, which consists of constant rethinking, analysing and evaluating one's own teaching practise. This is the process in which teachers reflect on their own teaching and learn from these reflections in order to improve their practices.
reflective teacher	A reflective teacher is the term used in education to describe a teacher who continuously analyses and evaluates his teaching methods and strategies. Such a teacher regularly ponders on their own practise in order to understand what works, what does not work, and what can be improved.	A reflective teacher is the one who regularly analyses, assesses, and adjusts his teaching methods based on personal experiences and observations. A reflective teacher is usually open to criticism and ready for changes that will help them improve their teaching effectiveness. This attitude is recognised as the key element of professionalism in teaching and is being increasingly promoted in teacher education.

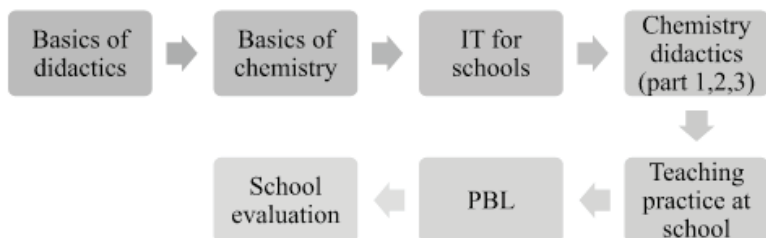
According to John Dewey, reflectivity is the ability for reflective thinking, which is comprised of intentional understanding of one's own thinking strategies, feelings, and actions. This is the process that develops throughout life, beginning in childhood and expanding in adulthood (Osterman & Kottkamp, 2004). By contrast, Jürgen Habermas presents reflectivity as the basis for constructing theories, focusing on how people process various information, generate new knowledge and create ideas and concepts (Biesta, 2015).

In the context of Donald Schön's concept, reflectivity means using theoretical knowledge in a critical way, being able to verify it according to current situations, particularly difficult or unpredictable (Moon, 2013).

According to Kolb, reflectivity occurs during active observation and is the basis for active experimentation. Schön describes reflectivity as the ability of a reflective practitioner to carefully consider one's own practical experience to achieve mastery in their profession (Kolb & Kolb, 2005).

### ***The pre-service teachers training – Faculty of Chemistry, Jagiellonian University***

The Faculty of Chemistry of Jagiellonian University in Kraków offers the opportunity to obtain the qualification to teach chemistry at school by starting students' participation in pre-service training. In 2019 new standards for teacher education standards have emerged (<https://isap.sejm.gov.pl/isap.nsf/DocDetails.xsp?id=WDU20190001450>). This was the reason for modifying the curriculum of courses for pre-service chemistry teacher training. The pre-service chemistry teacher training programme consists of various courses (see Figure 1).



*Figure 1. Scheme of courses for pre-service chemistry teachers*

The practice of teaching in school is a crucial part of the pre-service teacher training (Kirbulut & Bektas, 2011). The practice of teaching in schools must precede good theoretical preparation. Students learn methods, strategies, rules, and didactic tools. The following topics in the student meeting are planning lessons, completing tasks, preparing didactic tools, and writing the outline of the lesson.

Before the four-week internship at school (teaching practise at school), university students have the option of conducting three lessons at school. This is done through a course called Chemistry didactics (part 2). One lesson is conducted at the primary school level (during winter semester), and the next two ones at a secondary school, basic and extended level (during summer semester).

### ***Purpose of the study***

The purpose of the research was to collect student opinions and reflections on three chemistry lessons that they conducted at the primary and secondary school level; as well as after completing a 4-week internship at the school. Furthermore,

the research was designed to encourage trainees to reflect on their preparation for lessons and their ability to provide learning opportunities and positive classroom outcomes, also in the aspect of expected change. The authors assume that students, reflecting on own lesson is – in the first phase - the result of peer review of the student (peer assessment) and discussion after each conducting lesson at school.

According to the authors, participation in this survey provides an opportunity for students to reflect on their lessons, thereby shaping a reflective attitude.

## **Research Methodology**

### ***Methods***

The method used in the study was a diagnostic survey using a questionnaire developed by the authors. The survey in each academic year was carried out in the form of an online version in three steps: step no.1 – at the end of winter semester, step no.2 – at the end of summer semester and step np.3 after 4-weeks internship in school.

The questionnaire consists of 14 questions on the chemistry content and didactic preparation of the lesson and self-reflection after the lesson. The questionnaire included five open-ended questions and nine closed questions; The five closed questions were prepared on a Likert scale of five levels (1= very difficult; 5 – very easy). The open questions have been prepared in a way that “forces” students’ reflexion-on-action (Schon, 1983).

#### **Participants**

Participants in this study are university students who enroll in course Chemistry didactics (part 2):

in the academic year 2021/2022 (27 students / group A/),

in academic year 2022/2023 (20 students / group B) .

During the winter semester of each academic year 2021/2022 and 2022/23, university students conducted the first lesson themselves at primary school (lesson no.1) in present of school and university teachers. During March 2022 to June 2022 and March 2023 to June 2023 students were escorted by the university supervisor, visited the secondary school, met the school supervisor for the first time, and conducted their own lessons (lesson no.2 and lesson no.3).

### ***Context***

University students go to the upper secondary school to practise chemistry teaching under the supervision of a school supervisor and a university supervisor. Each student conducts two lessons: the first at the basic level and the second at the



level with an extended chemistry program. During the “preparation of the lesson” part, the student prepares a detailed lesson plan. This plan is sent to a school supervisor to prepare the final version based on the comments received. While the student conducts the lesson, the rest of the group fills in the class observation sheet. This tool was created by the authors for this student course. Observation is a basic source of human knowledge.

Each lesson is followed by a discussion phase with usage of a class observation sheet. Some details of this sheet are presented in Table 2.

It is obvious that conducting a lesson is not enough to develop and make some changes. There must be reflection. Reflective practise is a process that facilitates teaching, learning, and understanding, and plays a central role in the professional development of teachers (Mathew et al., 2017; Priya et al., 2017).

## **Results and discussion**

Wanting to stimulate students to reflect after a lesson at school, the authors asked questions about the assessment of easiness (on a scale of 1-5; 1 – very difficult; 5 – very easy):

- a) formulating an interesting, unusual lesson topic
- b) preparing an interesting form of engagement, getting students interested in the topic
- c) preparing an interesting recapitulation
- d) preparing an appropriate reference of the content to everyday life
- e) preparation and presentation of scientifically correct issues

All students completed these questions. Results - divided into three periods: 1. after the first lesson conducted in elementary school, 2. after two consecutive lessons conducted in upper secondary school, and 3. after four weeks of practice in school - are shown in the figures 2-6.

Table 2. Details of an observation sheet

LESSON OBSERVATION SHEET Name and surname of the person completing the sheet:

Date: Name and surname of the person conducting the lesson:

Topic of the lesson:

1. The teacher gave the students the topic of the lesson: <input type="checkbox"/> Yes <input type="checkbox"/> No	
2. The teacher used teaching aids: <input type="checkbox"/> Yes <input type="checkbox"/> No What and was their use justified?	
3. During the lessons, the teacher used methods and forms of work: <input type="checkbox"/> lecture <input type="checkbox"/> individual work <input type="checkbox"/> discussion with students <input type="checkbox"/> students solve a problem on their own <input type="checkbox"/> discussing the method of the obtained solution.	
4. The teacher created the possibility of individual work of the students: <input type="checkbox"/> Yes <input type="checkbox"/> No	
5a. What was the activity of the students during the lesson? Enter in %	5b. What was the teacher's activity during the lesson? Enter in %
6. During the lessons, the teacher referred to the out-of-school experiences of the students. <input type="checkbox"/> Yes <input type="checkbox"/> No Interesting example:	
7. Did the teacher correct the incorrect statements of the student? <input type="checkbox"/> Yes <input type="checkbox"/> No	
8. The teacher summarised the lesson. <input type="checkbox"/> Yes <input type="checkbox"/> No	9. The teacher gave homework to combine the latest content learned in the lesson. <input type="checkbox"/> Yes <input type="checkbox"/> No
10. Was the idea for the lessons good? <input type="checkbox"/> Yes <input type="checkbox"/> No Comment:	11. Did the teacher remember the principles of teaching? Which? And which has he forgotten?
12. Have the main goals of the lesson been achieved based on the topic of the lesson and your own interpretation? <input type="checkbox"/> Yes, completely <input type="checkbox"/> Yes, partly <input type="checkbox"/> No, (and why?)	
13. Noticed substantive and didactic errors; suggestions / proposals for changes, remedia comments, etc.	

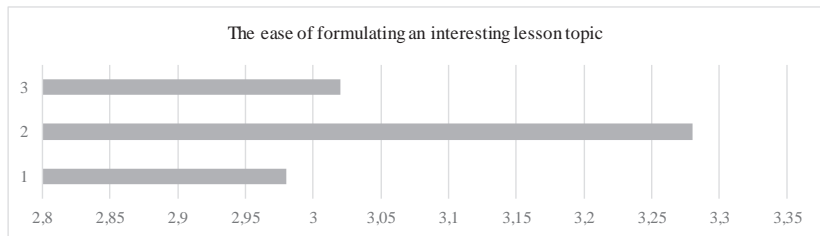


Figure 2. Results for question about formulating an interesting, unusual lesson topic

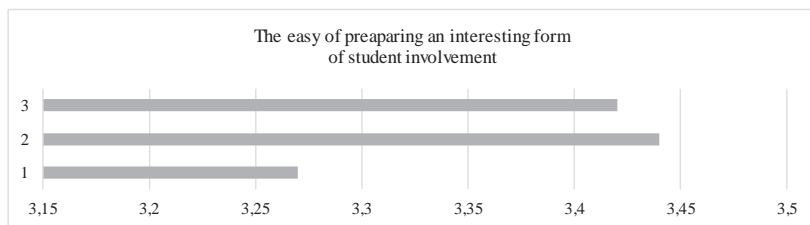


Figure 3. Results for question about preparing an interesting form of engagement, getting students interested in the topic

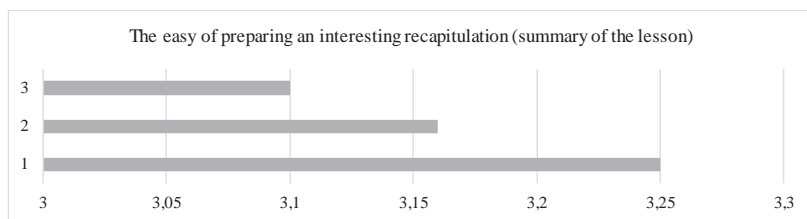


Figure 4. Results for question about preparing an interesting recapitulation (summary of the lesson)

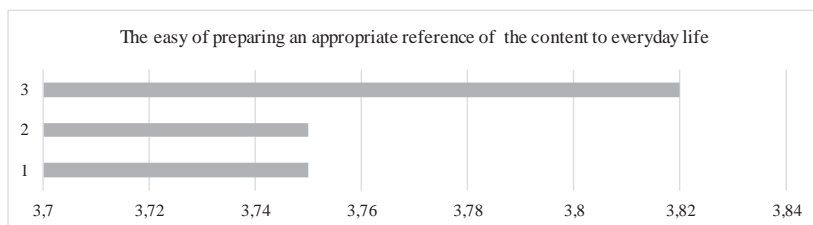


Figure 5. Results for the question of preparing an appropriate reference of the content to everyday life

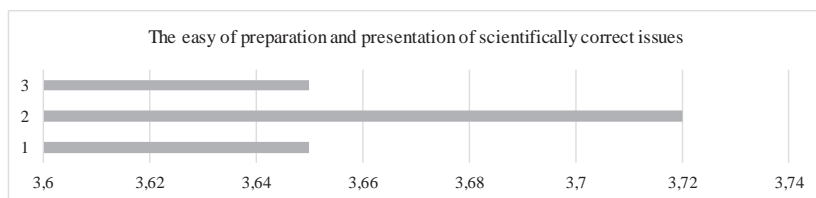


Figure 6. Results for question on preparation and presentation of scientifically correct issues

Very mixed results were obtained. It cannot be said that with each successive lesson conducted at school, the ease of preparing an interesting recapitulation, an interesting form of involvement, reference to everyday life, etc. increases (e.g. Aglazor, 2017). In theory, it should be easier, but on the other hand, perhaps university students are more critical of themselves (Farnicka & Koch, 2020).

There was no correlation between the gender of the respondent, whether it was before or after a four-week school placement and the ease of preparing/formulating a-e. Spearman correlation was counted, since the analyzed characteristics do not have a normal distribution. The coefficient values are very low, mostly positive. The highest coefficient value (0,33255) may be related to the weak correlation of gender with the ease of preparing an appropriate reference of the content to daily life.

According to the authors, the four open-ended questions in the survey are the most powerful in stimulating reflexion.

Q.A - What surprised you the most while conducting the lesson?

Q.B - What caused you the most difficulty while conducting the lesson?

Q.C - What do you need to work on to strengthen your competence?

Q.D - In what area do you need support?

Analysing the answers to these questions in terms of frequency, both for the period before and after the four-week internship, students strongly indicated that the competency they need to work on is the ability to manage time and, thus, the appropriate time balance of lessons. Respondents wrote that what surprised them the most was that time passes so quickly; and this was indicated most often by men. Another area in need of support that represents a difficulty - especially for the male respondents - is the lack of ideas for interesting, engaging lessons. The most difficult thing, on the other hand, according to women, turned out to be keeping the student's attention, focussing on what is happening in the lesson. What they need to work on, mostly the women surveyed, is first and foremost the ability to deal with educationally difficult situations and an empathetic approach to the student. There were also questions: How do we maintain discipline? How to silence disturbing students?

Figure 7 presents topics and issues that need to be continuously developed, regardless of the student's experience. Their knowledge allows us, reflective teachers, to appropriately create teaching situations in subsequent courses but also serves as a basis for discussions with teachers, supervisors from the school.

It is worth returning to the question: How to silence disturbing students? and consider it by asking further questions: Why are students in the lesson disruptive? Students disrupt because they are bored. Why are students bored in the lesson? Are they bored because they were not engaged or interested in the topic? Knowledge of interesting lesson ideas and interesting ways to engage students is essential.

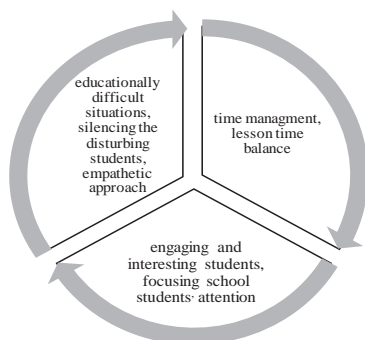


Figure 7. Students' indications of problem areas and competencies

Is the student who has completed the questionnaire in full more reflective than the one who has only partially completed it? Is answering all open-ended questions by the student, which require them to think and engage, a determinant of their greater reflectiveness in relation to those who did not answer all or part of the open-ended questions? Not all respondents answered these open-ended questions, as shown in the figure 8. The percentages given represent non-responses and the a, b designations refer to two periods: a before the 4-week internship and b after the 4-week internship. Moreover, black represents women, and grey represents men. The question arises whether the lack of response indicates a lack of engagement, reflexivity, or indicates that “nothing” of the respondents surprised, was not difficult, and does not need to be completed. This is a valuable lesson learnt from this pilot study.

The predominant group of respondents who did not answer is male. Only 33% of the respondents completed a Q.D question in period a and 45% in period b. Is it to be understood that the majority of respondents do not need support in any area?

At the end of the survey, students were asked to grade their general satisfaction with their school lesson (on a scale of 1-5; 1 - not satisfied; 5 - very satisfied). Overall satisfaction with the lesson increases slightly after the practice – internship (4,06) compared to the evaluation of the lesson made before the practice (3,99). In both cases, men's lesson satisfaction rating is slightly higher (4,12; 4,17) than that of women (3,87; 3,94).

Perhaps during the four-week internship at the school, the students applied the comments, suggestions emerging from the discussions in the Chemistry Didactics course in the winter and summer semesters.

During the internship, students realised that they could handle different situations, gained confidence; the results show that women are more critical of themselves.

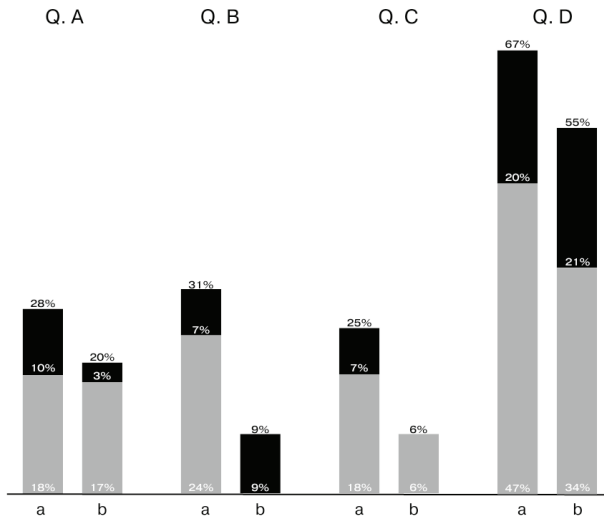


Figure 8. Deficiencies in answers to Q.A - Q.D questions as a determinant of lower student reflectiveness?

## Conclusions

The theme of reflection in teaching practice appears in numerous studies (e.g., Erdemir & Yeşilçınar, 2021). Teacher feedback and self-reflection have been found to be particularly useful in improving teachers' practice skills, so it is important for teachers to engage in self-reflective practices on a regular basis; self-reflection according to Sacco and Amende (2021) can serve as a means to raise awareness, improve learning and promote development.

According to Arrington (2023), pre-service teachers who engaged in the process of self-reflection experienced a significant increase in self-efficacy; their engagement, forms of classroom management, and teaching styles changed; teachers noticed increased concentration and better engagement of their students in class (Syam et al., 2023).

Pearce, de la Fuente, Hartweg, and Weinburgh (2019) emphasise that regular self-reflexion, especially when supported by other students, teachers, can play a key role in the long-term professional development of teachers. This approach can contribute to the continuous improvement of teachers' instructional practices, resulting in better learning outcomes for their students and the development of multiple competencies. For a more effective implementation of the idea of reflection, changes in the way teachers are trained seem to be necessary. But what can already be done is not to stop practising oneself-reflexion.

However, as Elżbieta Zawadzka-Bartnik (2014) writes, “for the implementation of the idea of reflexion, teachers need to be prepared, to ensure, in addition to professional knowledge, the formation of appropriate qualities, skills and the right attitudes regarding self-education, innovation, creativity, and especially a reflective attitude and readiness to apply reflexion to solve teaching and educational problems.”

### ***Ethics Statement***

The ethics committee confirmed to the corresponding author that this research did not require ethics approval because of the full anonymization of the publicly available data and because the data are not sensitive.

### ***Conflicts of Interest***

The authors declare no conflict of interest.

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# Innovative strategies for the assessment of geology in secondary education

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## Abstract

Evaluation in Slovakia is currently a frequent topic of discussions, which are focused on the unfairness of marking and its negative impact on the progress of students in education. Students' assessment is mainly focused on summative assessment. In contrast, formative assessment is a process aimed at frequent and interactive assessment of students' progress and their understanding of the subject matter. This is a statement of what level the student is currently at and what he has to do in order to get to a higher level. As part of the research, we implemented 6 formative assessment tools in the teaching of geology in the 9th grade at two elementary schools. 98 students participated in the research. We used: prediction card, exit ticket, INSERT strategy and self-evaluation card. The teacher's communication with the student, a positive approach to each individual, the creation of a favorable working atmosphere that supports cooperation between students and the awareness of the teacher's position as a coordinator are important in the learning process.

## Keywords

formative assessment, formative assessment tools, biology, implementation

## Introduction

Natural sciences have become an integral part of society, and today a person cannot do without many inventions and discoveries, despite the fact that interest in the study of natural sciences has significantly decreased in recent decades, especially in relation to physics and chemistry (Sjøberg, Schreiner, 2005; Steidtmann, Kleickmann, Steffensky, 2022). The decline in interest in studying biology was more moderate (Steidtmann, Kleickmann, Steffensky, 2022). Randler et al. (2011) found, based on the results of a questionnaire survey in Germany of 3rd and 4th grade elementary school students, that interest in studying science decreased by approximately 10% between 1983 and 2011. The decrease was most obvious in the demand for botanical subjects (12%), while the demand for

the study of zoology decreased the least (3%). Similar results were recorded by Wegner & Schmiedebach (2020) in 2nd grade elementary school students and in secondary school age students. Interest was significantly lower in the 9th grade compared to the 7th grade. On the contrary, students in the last two years of high school pay more attention to biology. This is understandable, because the optional study of biology is preferably chosen by students who are interested in this subject. Different attitudes towards individual topics can also be observed on an international scale or in relation to gender (Randler et al., 2011).

According to the OECD, the aim of science education is science literacy (OECD, 2003). A scientifically literate person is one who tries to understand how the world works, what role the natural sciences play in it, and knows how to use his scientific knowledge not only for his own benefit, but also for the entire society. In order for a student to become scientifically literate, he must first experience how real science works, and this is only possible by examining nature itself (Kireš et al., 2016).

For a long time, Slovakia has achieved an unfavorable position in PISA testing. In 2018, Slovak pupils ranked well below the global OECD average in both the science test and the reading comprehension test. Slovak pupils achieve approximately average results in mathematics. As for scientific literacy, excellent results were obtained by 4% of Slovak pupils, while the OECD average is 7% of pupils with excellent results. In all three areas, Slovaks 2003/2006 have a downward trend, with the trend in scientific literacy being the most unfavorable (OECD 2018). PISA describes science literacy as “the ability to use scientific knowledge, identify questions and draw evidence based on sound conclusions to understand and make decisions about nature and the changes that have occurred in it as a result of human activity“.

In the current era of global problems and an increasing number of natural disasters (torrential rains, floods, landslides, fires, etc.), it is impossible to do without basic natural science knowledge and the ability to apply them in practice. The opportunity to recognize phenomena directly in their natural state must become a priority in education. environment, which is especially necessary in the teaching of geology. Nowadays, the main goal must be to understand nature as the source of sustainable life on Earth and life as the highest value.

### ***Teaching geology in Slovakia***

Geology provides complex information that is the basis for understanding natural processes and ecosystems, as well as a necessary prerequisite for re-evaluation and rational use of raw materials, evaluation of thermal, mineral and ordinary underground water sources. It is no less important for the optimal use and protection of waste repositories, including radioactive waste, assessment of

geological risks, assessment of the territory from the point of view of engineering-geological factors, including the issue of urbanization and the establishment of buildings, assessment of the state of environmental pollution with toxic substances, as well as assessment of the effects of human activity on the environment and conditions of land use.

The main problem of teaching geology is the regulation of its representation in secondary school textbooks. In 2006, a new textbook *Prírodopis 8* was published, in which the curriculum related to geology was limited by up to 40%. After various reforms, Natural History was renamed to Biology, which does not correspond to the curriculum contained in the textbook for the 9th grade. It is therefore based on the name bios, which means life, while the textbook is mainly focused on inanimate nature (Turanová & Ružek, 2015). With a reduction in the hourly subsidy the content and knowledge about inanimate nature also changed, which began to be taught together with ecology, as it was already in grammar schools with an 8-year study. Many geological topics were moved to the subject of geography, or physics, knowledge about minerals and crystals to the subject of chemistry. According to the findings of Jesenák (2014), the result of this is the fact that today's students say that iron is made from iron oxide, but that glass is made from silicon dioxide or silicon (90% of high school graduates do not know what ordinary glass is made of). It is paradoxical that, despite the importance of information based on geology, geological awareness among the general public is very low, and geology does not have the right representation in the state educational program.

### ***School assessment***

In Slovakia, evaluation in schools is mainly based on the summative assessment of the student's learning results achieved during the entire classification period. The OECD report points to the fact that entry, exit or weekly written assessments are most often used in Slovakia. With such frequent testing, students experience little progress in learning. They do not consider receiving a grade from a paper as adequate feedback (Shewbridge et al., 2014). According to Laufková (2016), grades have a number of disadvantages – they provide insufficient feedback, they primarily motivate excellent students, while weaker students are compared with “better” students based on their grades, instead of being provided with feedback and learning support. Grades can also be a source of stress and fear of failure.

Formative assessment is coming to the fore in Slovakia as well, through three projects solved at the PF UPJŠ in Košice. Two monographs and a number of articles in the form of case studies, contributions from conferences were created as part of the solved projects, not only for the professional public, but also for teachers, which can help them in introducing formative assessment into teaching. The researchers implement webinars for teachers, which are focused

on information about formative assessment, tools, strategies and techniques, but also their implementation in teaching. The output of one of the solved projects is a digital library (<https://digilib.fri.uniza.sk/>) with formative assessment tools that registered teachers verify in real school practice and monitor their efficiency and effectiveness.

### ***Formative assessment***

There is no generally accepted definition for formative assessment. Sometimes it is referred to as an alternative assessment, other times as an assessment for learning (Chappuis & Chappuis, 2009). It is also referred to as ongoing assessment, feedback assessment, assessment for formative purposes or mini-assessment (Newton, 2007; Straková & Slavík, 2013). The Assessment Reform Group (2002) understands formative assessment as “the process of obtaining and interpreting results for the needs of students and their teachers in order to determine where the student is in the learning process, what goal he or she is aiming for, and how best to reach that goal.” to grow up.” OECD (2005) understands formative assessment as “frequent, interactive assessment of the pupil’s progress, understanding of his learning needs and adaptation of teaching to these needs”.

Most authors perceive the essence of formative assessment in providing feedback to students, teachers and parents (Gipps, 1994; Black & Wiliam, 1998; McLaren, 2012). The reason is that the feedback not only informs about the student’s performance, but also provides information about the teacher’s attitude, describes his relationship to the subject matter. Among other things, feedback is also considered a method of pedagogical communication. It represents a message intended for the student, which should inform him about how his learning process is going, that is, the difference between his current level and the reference (determined) level (Lipnevich & Smith, 2008). On the other hand, it should be emphasized that not all feedback is the same, not all is of good quality and not all supports learning (Hattie & Timperley, 2007). Studies (Black & Wiliam (1998) point to the fact that formative assessment helps to reduce differences between students and is especially effective for students with special educational needs, where their performance increases because they benefit from immediate feedback. Subsequently, learning becomes more effective. Pupils are involved in the process of learning and assessment by assessing themselves (self-assessment) but also each other (peer assessment) (Anamalai & Yatim, 2019; Boud, 2013; Laufková, 2016; Mulder, 2013). They perceive the teacher not only as an authority but also as a helper in learning. This improves the climate in the classroom and students are more intrinsically motivated (Clark, 2011; Chappuis & Stiggins, 2002; Laufková, 2016; OECD, 2018). The formative assessment system helps teachers organize their time better, determine how and what they want to teach students, clarify the goals of the teaching process, as well as the organization and preparation of

various educational activities for students. Formative assessment contributes to constructive criticism, which leads to the fact that teachers know where exactly where they should focus their efforts (Anamalai & Yatim, 2019). Hendrick & Macpherson (2021) state that a major problem with classroom assessment is that teachers often confuse marking with feedback. Formative assessment inherently emphasizes the need for assessment as something to which teachers and students respond in a process of reflection. According to Laufková (2016), the successful implementation of formative assessment in teaching includes the support of formative assessment by the entire school, so that the school management also supports formative assessment strategies. Emphasis should be placed on cooperation between teachers, sharing experiences and creating sufficient space for reflection. No less important is a pleasant school and classroom climate, teacher education and teachers' inner conviction about the effectiveness of formative assessment, and cooperation between teachers, pupils and parents. If the changes associated with the implementation of formative assessment in teaching are to be permanent, they must be incorporated into teachers' routines. But that takes time. Many experts dealing with the professional development of teachers have already encountered the fact that teachers supported the idea of changes, which they later implemented in practice. However, after some time, they reverted back to their previous practices (William & Leahy, 2020), mainly due to the amount of time it is necessary to devote to the preparation of tasks and the lack of internal conviction that formative assessment is effective and brings results not immediately or after a certain period of time. a longer period of time.

## **Research aim, research questions and methodology**

We carried out the research at two secondary schools in the Košice and Prešov regions. Our goal was to determine the impact of the implementation of formative assessment tools on the development of students' conceptual understanding in the teaching of geology.

The research aims were defined as follows:

1. Design and implement a pedagogical experiment using tools formative assessment.
2. Analyze the received feedback.
3. Propose recommendations for effective implementation of formative assessment tools in teaching.

The research questions resulted from the objectives:

1. Which implemented tools support the development of understanding of concepts and relationships in the teaching of geology?
2. How teachers can use the results of the implementation of the proposed

tools formative assessment for developing conceptual understanding educational content in secondary school.

## Methodology

Before the actual implementation of the experiment, we created formative tools for the teaching of Biology in the 9th year of grammar school. We have developed 3-5 different tools for each topic. We verified the formative assessment tools within the output continuum of pedagogical practice in the academic year 2022/2023. We are tools implemented at Secondary school Staničná 13 in Košice, in the months of September - October and at Secondary school Šmeralova 25 in Prešov, in the months of February - April.

In Table 1, we present a list of topics and specific tools that we implemented in the teaching of Biology in the 9th grade. For each topic, at least one tool was used during the lesson, which was described just before the students worked on it so that they understood what the teacher expected from them.

*Table 1. List of the selected FACTs*

<b>Fact</b>	<b>Topic</b>	<b>Time</b>	<b>Number of students</b>
Prediction card	Minerals and rocks	beginning and end	48
Exit ticket	Construction of the Earth	end	38
Self-assessment card	Protozoan and Mesozoic	end	50
INSERT	Protozoan and Mesozoic	during	48

## Results

In the next part, selected FACTS will be characterized, examples and results will be provided using topics from geology.

### *Prediction card*

The main goal of the Prediction card is to activate previous knowledge and at the same time motivate students to new information. This tool consists of pre-made statements created by the teacher. In the left part of the prediction card there are columns labeled true/false statement before taking over the subject, in the central part of the card there is a topic and prepared statements about which students have to decide whether they are true or false. In the right part, there are again columns labeled true/false statement, which the students fill in after reading teaches.

Table 2. Prediction card - “Minerals and rocks” (9th grade)

Student's name:		Form:	Date:	
1. At the beginning of the lesson, decide whether each of these statements is true (T) or false (F). 2. Circle your choice in the left part of the table. 3. Repeat the process at the end of the lesson: circle your choice in the right part of the table. 4. Compare your decisions at the beginning with those at the end of the lesson and justify them.				
At the beginning of the lesson		“Minerals and rocks”	At the end of the lesson	
True statement	False statement		True statement	False statement
T	F	<i>A mineral is a diverse natural product.</i>	T	F
T	F	<i>Petrology is the science that deals with formation and construction of rocks.</i>	T	F
T	F	<i>The most common minerals on earth crusts are feldspar and quartz.</i>	T	F
T	F	<i>Rocks are mostly found in liquid form (petroleum), <del>no we</del> also know rocks in the solid state (granite).</i>	T	F
T	F	<i>Metamorphic rocks are formed inside of the earth's crust by the action of reduced pressure and temperature.</i>	T	F
T	F	<i>Sedimentary rocks are formed by settling rock-forming components.</i>	T	F

48 students of three classes filled out the prediction card. We did not notice significant differences between the classes in the statements at the beginning of the lesson. We noticed wrong information in the fifth statement “Metamorphic rocks are formed inside the earth’s crust under the influence of reduced pressure and temperature”, when only one student teaches before taking over marked the statement as correct. The best results occurred with the third statement “The most abundant minerals in the earth’s crust are feldspar and quartz”. Students reacted positively to the prediction card, actively participating into the teaching process and tried to answer the teacher’s questions. After filling out the prediction card, the students shared their answers at the end of the lesson, and the correctness of individual statements was checked together with the teacher. In the case of false statements, the students argued why the given statement is not correct.

### Exit ticket

Strategy the Exit ticket is used at the end of teaching the topic, or teaching hours. According to (Fisher & Frey, 2004), this strategy allows students to summarize key elements of the curriculum and to realize its essential details acquired during teaching. Students answer the teacher’s questions, which can be aimed at the



goal, progress or effectiveness of current teaching. According to (Wormeli, 2004) research has shown that students who summarize their knowledge have a deeper understanding of them and remember them longer.

*Table 3. Exit ticket - Construction of the Earth (9th grade)*

Student's name:	Form:	Date:
1. List the layers of the continental and oceanic crust.		
2. What parts does the earth's body consist of ?		
3. Which information from today's class was the most interesting for you?		

Students prepared an Exit ticket in which they answered three questions. In the first part, they were supposed to list the layers of the continental and oceanic crust, in the second part they had to list three parts of the earth's body and in the third part they had to list the information from the lesson that was most interesting to them. The tool was used at the end lesson in two classes. Exit ticket a total of 38 students completed it. We explained to the students how they got the ticket to fill in, since they had no experience with it yet, they were also informed about the evaluation method and what the ticket is for when leaving. It was necessary to clearly describe the tool and encourage the students to take action. Subsequently, the learning tool without major problems worked out. However, some of them were not quite sure of their answers, so they hesitated when handing in the instrument, probably out of concern for classification.

*Table 4. Evaluation of the students answers in the most interesting information*

<i>1. Which information from today's class was the most interesting for you?</i>	<i>Number of answers</i>
Information about the lithosphere.	9
Information about the asthenosphere.	3
The lithosphere extends to a depth of 100-150 km.	4
The Earth's core has great density and magnetic properties.	3
The earth's core consists mainly of iron and nickel.	3
The core is divided into outer and inner.	1
What are lithospheric plates.	1
Components of non-living nature.	1
The layers of the continental and oceanic crust.	1
They didn't state anything.	12

All the students filled out the ticket when they left, which gave us feedback. It is necessary for this tool to be used more often in classes so that it was naturally integrated into the teaching process. Students were given space to review the basic structure of the Earth, and also to reflect on the information that is given to them seemed interesting. Based on this information, we obtained information about the level students' understanding and also about the areas that interested them, which we subsequently used in other lessons so that we actively involve students in the classroom process and developed topics that are most engaging for students.

### *Self-assessment card*

The Self-assessment card allows the students to analyse their own learning. The main goal of this FACT is for the students to develop the competence to "learn how to learn" and promote their interest in life-long learning.

This card was filled in by 50 students in the 9th grade of a secondary school after taking over the curriculum Protozoan and Mesozoic. Before filling in, the students were warned that they should read individual statements in turn and write a mark in one of the columns after each one.

*Table 5. Evaluation of a self-assessment card*

Student's name	Form	Date:		
Level of understanding of the subject matter	<b>On my own</b>	<b>With the teacher's assistance</b>	<b>I don't understand it yet</b>	
	number	number	number	
<b>I can name</b> 1 example of the leading fossil of the Protozoan.	33	15	2	
<b>I can describe</b> how white limestone was formed.	12	23	15	
<b>I can explain</b> why the Mesozoic is called the era of reptiles.	36	9	5	
<b>I can name</b> 3 periods of the Mesozoic Era.	22	17	11	
<b>I can state</b> 3 different signs between the Protozoan and the Mesozoic.	7	32	11	

Looking at the difficulty of individual statements, we came to the conclusion that the 1st statement most students were able to answer independently. For the second statement, 23 students said „With the teacher's assistance“. The third statement was most often marked „On my own“, the fourth the statement had relatively balanced values, but the highest occurred in „On my own“ and the fifth statement was most often marked with the „With the teacher's assistance“. The most the 5th statement "I can state 3 different signs between the Protozoan and the Mesozoic", on the basis of which we can conclude that he is with the students need to repeat the given information.

The results of the self-assessment card are listed they provide feedback not only for the students themselves, but also for the teacher, which areas the subject matter needs to be focused on, which needs to be additionally explained or repeated. The implementation of the self-assessment card was not time-consuming, but it should be used much more often. The positive consequences of the implementation of this approach would be probably most visible only after the instrument is included in the regular classroom process so that students can objectively evaluate their preparation and provide feedback teacher regarding problematic parts of the curriculum.

### ***INSERT***

INSERT is the acronym of Interactive Notation System for Effective Reading and Thinking. This FACT It represents a strategy that enables students to reading the text to better understand its content, and thus to understand it better integrate into the structure of their knowledge (Vaughan & Estes, 1986). While reading the text, using special symbols (I know it, new information, I don't understand it and I have a question), students write marks with a pencil at the edge of the text, thereby actively reacting to what they have just read the text and at the same time express their level of understanding or his own. A total of 48 students completed the text. The text was taken from the biology textbook and contains a total of 35 sentences that the students had mark the task with the appropriate characters. After labeling the texts, we focused on the signs that the students used to label the sentences. For each worksheet, we counted the individual characters within the class. The students wanted to learn more about trilobites and insects from the first mountains, about the form of primitive fish, the way of development of the first amphibians, about the size tree ferns, cephalopods, or the extinction of animals at the end of the Mesozoic Era, Archeopteryx, the historical periods of the Mesozoic, way the respiration of two-breathed fish, the appearance of cephalopods and amphibians in the primeval mountains, Predominance of Mesozoic Reptiles and Mesozoic Fossils.

An interesting finding Chart 1 was also the number of sentences marked with the sign √. In the 9th C class there was this one the character most used, which means that the students had relatively enough information about the topic. In the 9th A and 9th D classes, the most used sign was plus + in 50% of cases from the total number of marked sentences, from which we assume that given the professional text brought new information to the students that they had not encountered before. By sign ? students could mark the information they would like to know more about, with students marking roughly the same statements. After evaluating this tool, it would be subsequently appropriate to discuss the individual information in more detail with the students in the next lesson, or already in the form of searching for information, discussion or group work.



Figure 1. Comparison of results between classes 9.A, 9.C, and 9.D when implementing the INSERT strategy

## Conclusions

We implement selected formative assessment tools they discovered that for the correct use of individual tools it is necessary to know the possibilities of their use, both strong and weak pages so that teachers can use them correctly and thus achieve the most favorable results. The introduction of formative assessment into teaching is still in progress in Slovakia in its beginnings and in order to be successful, teacher education is needed, modify their usual understanding of the concept of assessment and create a support system, which would assist in implementing the strategies of this assessment.

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## ***Ethics Statement***

The ethics committee confirmed to the corresponding author that this research did not require ethics approval because of the full anonymization of the publicly available data and because the data are not sensitive.

## ***Conflicts of Interest***

The authors declare no conflict of interest.

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# Do we need knowledge of chemistry in everyday life?

Małgorzata Nodzyńska-Moroń

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## Abstract

Although not everyone will be a chemist, chemistry affects many aspects of our lives. For example, food chemistry allows you to understand what nutrients are present in different foods, how food additives work, and what processes occur during cooking and baking. Chemistry knowledge helps you make informed food choices and understand the impact of food on your health. Chemistry is involved in the production of cosmetics, cleaning products and personal care products. Understanding the chemical ingredients present in these products helps you make informed choices and avoid substances that are harmful to our health or the environment.

Understanding the basic principles of chemistry allows you to better understand the impact of our activities on the environment. Chemical knowledge is essential in considering problems related to air and water pollution, climate change and ways to reduce the negative impact on the natural environment. Chemistry is an integral part of medicine and pharmacy. Chemical knowledge is used to develop drugs, diagnose diseases, analyze laboratory samples, and many other aspects of healthcare. Chemistry knowledge can help you understand how different chemicals work, such as detergents, cleaners, dyes, and painkillers. This may contribute to the safe and effective use of these substances in daily household activities.

The article presents the results of research on adults regarding their role of observing and using chemistry in their daily lives.

## Keywords

teaching chemistry, key competences



## Introduction

Chemistry is a compulsory subject in primary and secondary schools in most countries. This is due to the fact that although not all students will be chemists in the future, knowledge of chemistry is necessary in many areas and affects many aspects of our lives. For example, food chemistry allows us to understand what nutrients are present in different foods (Kozlowski, 1988), how food additives work, and what processes occur during cooking and baking (Peng, 2022). Chemical knowledge helps to make informed food choices (Kresic, & Mrduljas, 2016; Zakir, et al. 2021) and understand the impact of food on health. Chemistry is involved in producing cosmetics, cleaning products and personal care products. Understanding the physical and chemical properties of the chemicals present in these products helps you make informed choices and avoid substances that are harmful to our health or the environment. Understanding the basic principles of chemistry allows you to better understand the impact of our activities on the environment. Chemical knowledge is essential in considering problems related to air and water pollution, climate change and ways to reduce the negative impact on the natural environment (Wang, 2017). Chemistry is an integral part of medicine and pharmacy. Chemical knowledge is used to develop drugs, diagnose diseases, analyze laboratory samples, and many other aspects of healthcare. Chemistry knowledge can help us understand how chemicals work, such as detergents, cleaning agents, dyes, and painkillers. This may contribute to these substances' safe and effective use in daily household activities. Therefore, in addition to the presence of chemistry in formal education (Dassarma, 1994; Guiberteau, et al 2012; Quevedo, & Zucolotto, 2020; Strocchi, Torroni, & Trifiro, 2010), various activities are often used to popularize chemistry in non-formal and informal education (Delgado, et al 2018; Espada-Bellido, & Fernandez-Barbero, 2014; Guiberteau, et al 2012; Stinson, 1995; Wang, 2017). This is obvious to any chemist. However, the question arises whether they are equally obvious to the average citizen. Does formal, non-formal and informal education properly shape the image of chemistry - as necessary in everyday life?

Since the belief in the usefulness of knowledge (the principle of illustrativeness and the relationship between theory and practice) translates into students' interest in a given topic - it was decided to examine the beliefs of "non-chemists" regarding the usefulness of chemistry in everyday life. It was assumed that about 4 years of studying chemistry at school should show students the usefulness of this subject in everyday life. Similar studies on the usefulness of school knowledge, e.g. on evolution among students, were conducted by Borgerding, & Kaya (2022) and on physics and science by Rodriguez et al. (2016). Wojuola and Alant (2017) found positive correlations between the perceived usefulness of knowledge about renewable energy sources and the intention to use it. However, there are no similar studies on chemistry.

## Materials and Methods

The research was conducted in the Czech Republic. The study involved 58 people aged 19 to 50. About 60% were women, and 38% were men (2% refused to state their gender). About 2% completed only primary school, 21% completed lower secondary school, 50% completed secondary school, and 27% completed higher education. The respondents were asked 5 questions:

1. Why do we study chemistry? (open question);
2. Is learning chemistry difficult? (5-point Likert scale);
3. How important/necessary is learning chemistry? (5-point Likert scale);
4. When was the last time you used your chemistry knowledge outside of school? (open question);
5. What was the knowledge? - give an example. (open question).

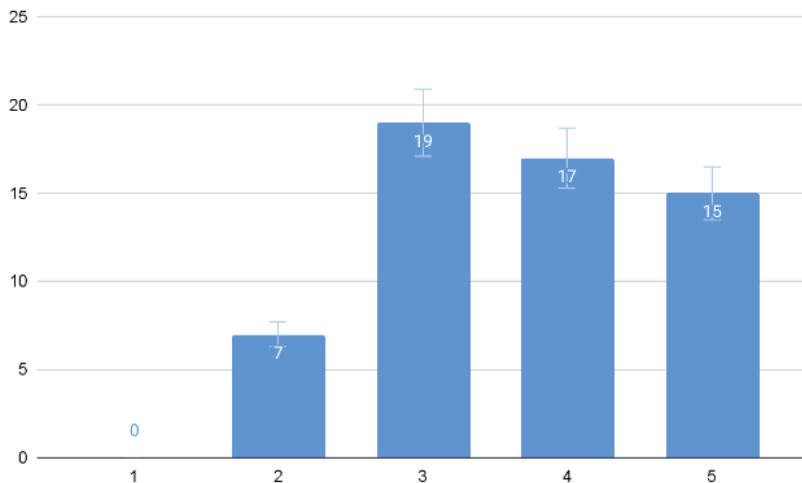
## Results

The answers to the first open question were very diverse. Most people wrote that we need chemistry to understand the world around us. The broadest answer was given by one of the respondents: “Because we are able to describe not only the chemical processes taking place naturally around us, in nature and within us but also to use them to understand the function of other processes. For example, why some materials are more resistant than others to the effects of the environment in which they are operated. It is also important to understand the chemical processes and materials around us to better use them in practice. Without this knowledge, we will not be able to invent or discover new compounds and materials. Another aspect of the importance of chemistry in everyday life is understanding the cycle of materials. Nature has taught us that everything has a beginning and an end. But an end for one means a beginning for another. It’s the same with materials. By changing one material into another we understand a chemical process. However, some processes used extensively by humans do not produce other easily recyclable materials. For example, plastics. That’s why we should know chemistry so that we can recycle materials better or look for alternatives. An equally important aspect is the safe handling of dangerous substances. We should also know the materials that are dangerous to humans in order to avoid them. For example, when handling asbestos, lead, mercury and other dangerous substances for humans and the environment. Finally, it is important to know where to properly dispose of these hazardous materials after use, so as not to cause problems for nature.” The other answers were not so broad.

Only 8 people wrote “I don’t know why we study chemistry”, 2 people wrote that we study chemistry because it is “a compulsory subject in school”. And one

wrote: “Chemistry doesn’t matter to the common man in my opinion. Only those who need it at work use it. In total, about 19% of the respondents believe that they do not need chemistry and do not use the knowledge and skills acquired during chemistry lessons in everyday life.

Answering question 2, the vast majority of respondents stated that chemistry is a difficult subject and learning it is difficult for them, which constitutes 55% of answers (4 & 5). Only about 12% found it not difficult (answer 2).



*Figure 1. Respondents’ answers to the second question: Is learning chemistry difficult? (Likert scale 1 - no; 5 - yes).*

Answering question 3: How important/necessary is learning chemistry? the respondents gave more diverse answers. However, as many as 43% of the respondents believe that teaching chemistry is not necessary (answers 1 & 2), 38% are of the opposite opinion (answers 4 & 5) and 19% have no opinion on this subject.

Answering the fourth (open) question, the respondents gave many different answers, which were grouped into 7 categories: Every day; At work; Today; Yesterday; Sometimes; I don’t remember; Never. Only a small group (24%) admit that they use chemistry often (answers: Every day; At work; Today; Yesterday). 47% of the answers were classified to the group Sometimes and 29% to the group: I don’t know, I don’t remember.

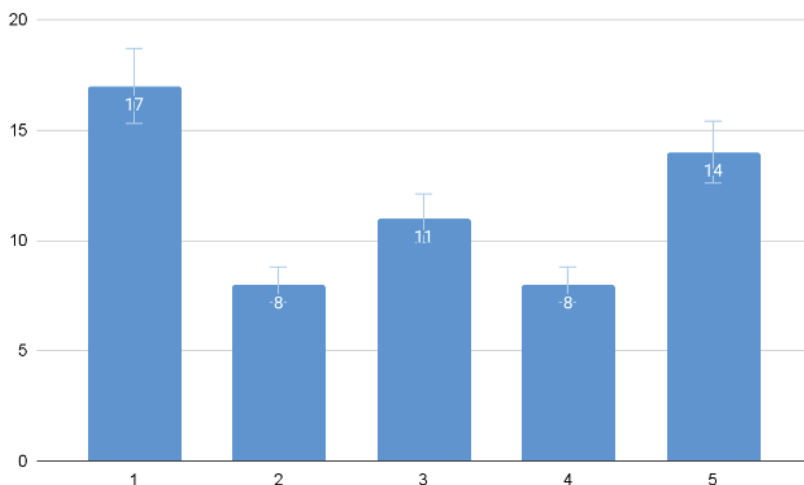


Figure 2. Respondents' answers to the third question: How important/necessary is learning chemistry? (Likert scale 1 - no; 5 - yes).

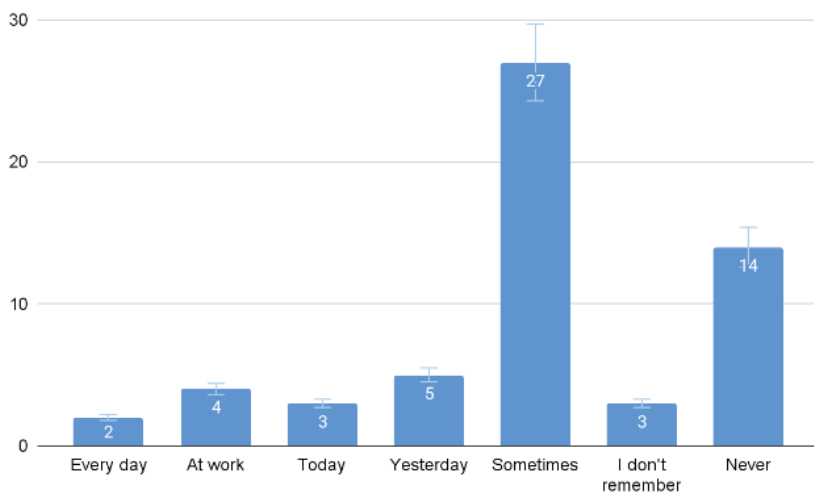


Figure 3. Respondents' answers to the fourth question, answers grouped into 7 categories.

The answers “sometimes” included answers in which the respondents mentioned specific, often repeated activities. The most frequently repeated activities related to cleaning (i.e. the use of the so-called household chemicals)

- 4 answers and the use of chemical knowledge in crossword puzzles, games and quizzes (4 answers).

Responding to the fifth (open) question, the respondents gave many different answers, which were grouped into 4 categories: "Purely" chemical information, Practical information from everyday life, I don't know, Nothing.

What was that knowledge? - give an example.

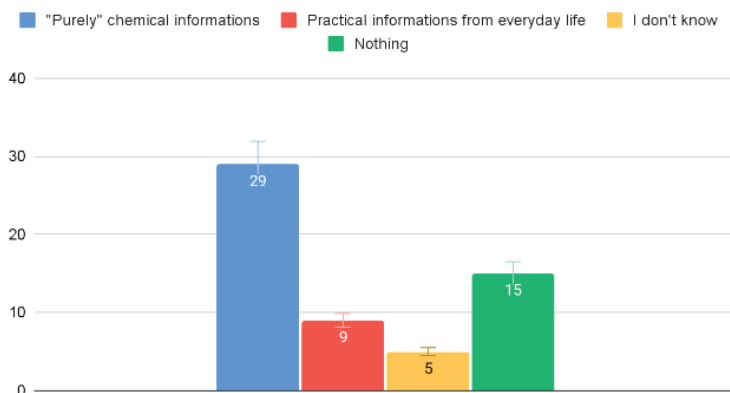


Figure 4. Respondents' answers to the fifth question, answers grouped into 4 categories.

Only 15.5% of the respondents reported practical everyday applications of chemistry.

Correlations between the answers to the questions and gender, age and level of education were examined. Only a weak correlation (-0.2) was found between gender and the ability to mention the use of knowledge and chemical skills in everyday life (women mentioned them more often than men). The correlation between individual questions was also examined (Table 1.)

Analyzing the obtained results, we can conclude that people who claim that chemistry is necessary to understand the world are statistically more likely to believe that it is easier. They also more often believe that learning chemistry is needed, they use it more often in everyday life and they can name specific examples of applications. Students who think that learning chemistry is not difficult are more likely to think that learning chemistry is necessary. There is a strong positive correlation between the answer to the question of how much chemistry learning is needed and the frequency of using chemical knowledge. And slightly weaker with the answer to the question: What was this knowledge? There was also a strong correlation between the frequency of using chemical knowledge and the correctness of the answer to the 5th question.

Table 1. Correlations between answers to individual questions.

	1	2	3	4	5
1		<b>-0,30</b>	<b>0,41</b>	<b>0,40</b>	<b>0,34</b>
2	<b>-0,30</b>		<b>-0,19</b>	-0,14	-0,16
3	<b>0,41</b>	<b>-0,19</b>		<b>0,64</b>	<b>0,31</b>
4	<b>0,40</b>	-0,14	<b>0,64</b>		<b>0,57</b>
5	<b>0,34</b>	-0,16	<b>0,31</b>	<b>0,57</b>	

## Discussion

Chemistry is generally considered a difficult subject (812 results from Web of Science Core Collection for difficulties & chemistry & learning). Similar results were obtained in these studies. In response to question 1, 55% of the respondents considered it difficult.

One of the methods to encourage students to learn chemistry that is difficult for them is to use a variety of motivational strategies. In methodological guides for teaching chemistry, it is most often suggested to explain to students how often and how chemistry is present in their everyday lives and its importance for various fields, such as medicine, environmental protection or industry. The teacher is urged to show the practical application of chemistry in the real world. Which should help students understand why chemistry is worth being interested in. Although most teachers follow these recommendations, as many as 43% of people believe that chemical knowledge is not needed in everyday life. And as many as 29% do not know or do not remember when they used chemistry in their lives.

Looking at both the percentage of answers to individual questions and the correlations found, it can be concluded that the awareness of “why we learn chemistry” makes it easier for students to understand the subject, and the belief that it is necessary to learn chemistry increases the awareness of the use of chemistry in everyday life.

It seems, therefore, that it is very important to draw students’ attention to any use of chemical knowledge in everyday life.

## ***Ethics Statement***

The ethics committee confirmed to the corresponding author that this research did not require ethics approval because of the full anonymization of the publicly available data and because the data are not sensitive.

## ***Conflicts of Interest***

The authors declare no conflict of interest.

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# Why do we teach chemistry? - considerations of future teachers

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## Abstract

A good teacher must answer the following questions: Why am I teaching my subject? What is the purpose of it? This is especially true for young teachers who are starting their work. It was decided to examine whether students of the teaching faculty can answer the question: Why do we teach chemistry? 15 students - future chemistry teachers - took part in the research. Their task was to give 3 arguments for teaching chemistry at school. The students' answers mainly concerned the general statement that learning chemistry allows us to understand the world around us, but some of the respondents also noticed the aspect of developing the competence of logical thinking or experimentation. However, in general, it seems that students are not fully convinced of the role of chemistry education.

## Keywords

teaching chemistry, key competences

## Introduction

An effective education process depends on many factors. One of them is a 'good' teacher (Hattie, 2015). Therefore, many researchers try to define the characteristics of a good teacher (Azer, 2005). Korthagen, (2004) investigated the identity and professional mission of teachers, and Sgrecciai & Cirelli (2015) investigated the characteristics of teachers of memorable students. A good teacher should also be able to answer the students' question: "Why do we study chemistry?" (Nodzyńska, 2014). This will allow him to correctly create lesson objectives or determine the criteria for student success.

The answer to the question: Why do we teach chemistry? seems obvious - we teach chemistry because it is a field of science that has a wide range of applications and importance in various areas of life. There are several main reasons why we teach chemistry:

### 1. Understanding the material world:

Chemistry helps us understand the structure, properties and behavior of the substances that surround us. Thanks to the science of chemistry, we can understand why substances react with each other in certain ways, how chemical reactions occur, and what processes control various phenomena in our environment.

### 2. Foundations for other fields of science:

Chemistry is the foundation for many other fields of science, such as biology, medicine, physics, geology, and engineering. Chemistry knowledge is essential to be able to understand and deepen knowledge in these fields.

### 3. Practical applications:

Chemistry has many practical applications in our daily lives. For example, chemistry is an integral part of the pharmaceutical industry, food production, building materials, energy, information technology and many other areas. Learning chemistry enables us to better understand these processes and how they affect our lives.

### 4. Cognitive skills development:

Learning chemistry develops many important cognitive skills such as critical thinking, logical reasoning, data analysis, and problem-solving. The thought processes used in the study of chemistry also apply to other fields of science and everyday life.

### 5. Environmental Awareness:

Chemistry is important for understanding the chemical composition of the environment, pollution issues, climate change and ways to reduce it. Learning chemistry can help us better understand the impact of our actions on the environment and look for sustainable solutions.

6. It can also be considered that chemistry can also be a fascinating subject in itself, leading to further research and discovery. Discoveries in the field of chemistry have had a huge impact on the development of technology, medicine and our understanding of the world.

## **Research Methodology**

It was decided to examine whether students of the teaching faculty can answer the question: Why do we teach chemistry? 15 students - future chemistry teachers - took part in the research. Their task was to give 3 arguments for teaching chemistry at school.

## Research Results

Students gave a variety of answers, which were grouped into the six categories listed above. Two answers did not fit into any of the groups.

### The basis for other fields of science

The basics of chemistry help you understand other scientific disciplines.

This is important for understanding the natural sciences as a whole

We need to know the basics of all basic fields.

It's important to have a general overview.

It is intertwined with other subjects, so it is part of a comprehensive teaching.

Because it is one of the natural sciences that helps us understand the laws of nature and facilitates the existence of human life on earth.

Expanding knowledge

Science

Tests

### Environmental awareness

Because it is closely related to natural phenomena and explains them.

Because she is all around us.

Chemistry explains various natural processes

This is an area belonging to the Human and Nature educational field, thanks to which we can understand the processes occurring in nature and the laws that govern them.

Chemistry is an important natural science, everyone should know the basics of chemistry, because chemistry is around us, everyone is in contact with it every day

To be able to describe how the surrounding world works.

To be able to describe how the human body works.

It appears around us.

### Practical applications

It contains important information that can also be useful in our practical

life.

So that students have at least a basic knowledge of the hazards and toxicity of the substances they come into contact with.

To be able to recognize substances that are dangerous to us

To understand medicine a little bit

Preparation for future work - is part of the production processes in various professions

Not jumping on fake news.

To learn, for example, more about photosynthesis.

Development of cognitive skills

So that children develop their skills and logical thinking.

Chemistry promotes the development of open thinking, critical thinking and logical reasoning.

The ability to understand things around you.

Using chemistry, we develop the skills of consistent objective observation and experimentation.

Based on the observed phenomena, we analyze the results and draw conclusions from them.

To understand phenomena, different laws and be able to connect them with other subjects.

A fascinating subject leading to further research and discovery

Because we enjoy it.

Entertainment

Show children that science is a beautiful field.

Because it is a science that I like and find interesting.

other

Chemistry is only for the select few who truly understand it.

Since no one else wants to teach it, it's too complicated to understand.

Considering that each of the students had the opportunity to name three reasons, it was expected that the answers would be fairly evenly divided into individual categories. However, it turned out that students most often indicated four of them:

The basis for other fields of science,  
Practical applications,  
Development of cognitive skills,  
and Environmental awareness.

Only 4 (out of 15) students gave an answer that could be classified as: Chemistry is a fascinating subject leading to further research and discovery. And none of the answers matches the answer:

Understanding the material world - Chemistry helps us understand the structure, properties and behavior of the substances that surround us. Thanks to the science of chemistry, we can understand why substances react with each other in certain ways, how chemical reactions occur, and what processes control various phenomena in our environment.

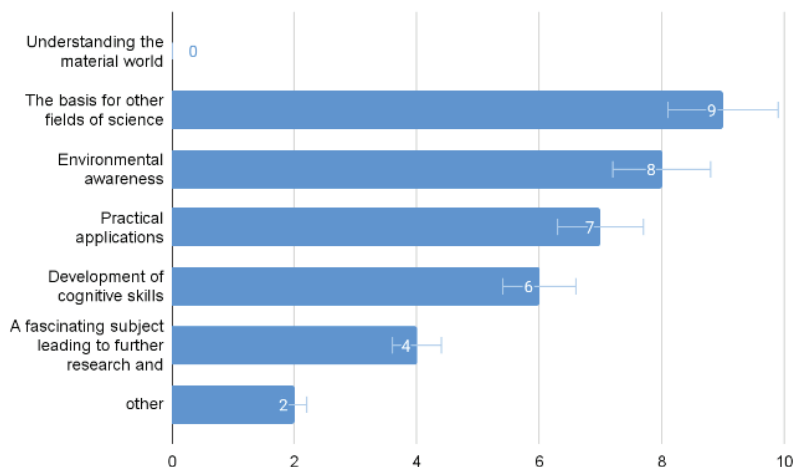


Figure 1. Grouped student responses.

## Discussion

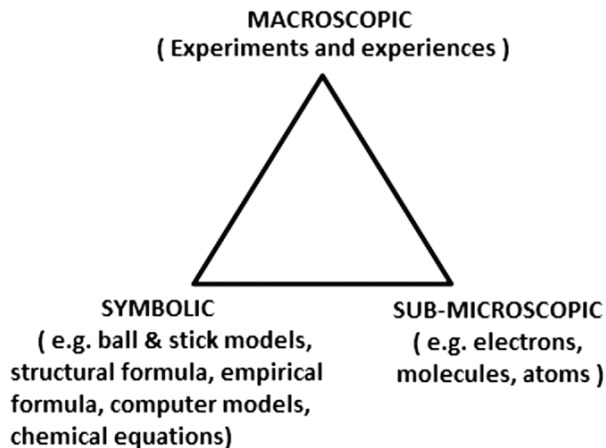
The answers of students - future teachers indicate two serious problems.

First - these teachers are not passionate about chemistry, chemistry does not entertain them, and it is known that the best way to infect students with passion for a given subject is to involve the teacher.

The second - who knows if not more important. The reasons for teaching chemistry mentioned by prospective teachers (Basics for other fields of science, Practical applications, Development of cognitive skills, Environmental

Awareness) also apply to other science subjects (e.g. biology and physics). So why should we teach chemistry? It can be concluded that future teachers do not understand the specifics of teaching chemistry.

Another problem is that these students do not realize that teaching chemistry is based on three pillars (Fig. 2).



*Figure 2. The three representational levels in chemistry*

Learning chemistry additionally requires the student to be able to navigate in 3 areas (Johnstone, 2000):

The first one is the level of the observable world - that is, the macro-world, the world in which we live, which we perceive with our senses and in which we observe the symptoms of chemical reactions taking place.

The second area is the level of the micro-world - the level of chemical individuals - atoms, ions and molecules, i.e. the world in which the occurring changes actually take place and in which the micro world can be explained.

The third level is the area of chemical symbolism - a specialized language of chemical code - the level of summary and structural formulas, the level of models of chemical compounds. Symbolic notation is necessary when describing the course of chemical reactions.

This movement through the three areas is specific to chemistry and is absent from the rest of the natural sciences. And that's why chemistry should be taught in school.

The analysis of the results reveals one more problem. One of the pillars of teaching chemistry, as shown above, is students' understanding of the structure of matter, i.e. the microworld. Without it, teaching chemistry makes no sense and is

impossible. And since none of the future teachers mentioned this issue - it can be assumed that their effectiveness as chemistry teachers will not be high.

## **Conclusions and Implications**

It seems that in the education of future teachers, attention should be paid to all six aspects of chemical education. But special emphasis should be placed on the specificity of chemistry - that is, the fact that it is based on understanding the macro- and micro-world and their symbolic notation. It is also necessary to make students - future chemistry teachers more aware of the role of the micro-world in chemical education.

## ***Ethics Statement***

The ethics committee confirmed to the corresponding author that this research did not require ethics approval because of the full anonymization of the publicly available data and because the data are not sensitive.

## ***Conflicts of Interest***

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# TLC in the experimental preparation of future chemistry teachers

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## Abstract

At the Department of Chemistry of the FPE ZČU in Pilsen, TLC is included in regular teaching (laboratory exercises in organic chemistry) and forms an important part of some qualification papers. Currently it is used as an analytical and preparative method. For analytical chromatography, both commercially available material and plates cast in the laboratory are used, while for preparative chromatography the chromatographic layers are prepared in the laboratory. As work with small quantities of substances is becoming more and more important, preparative TLC is also gaining in importance and has the advantage that it can be developed in several stages as follows:

- 1) Adsorption layer preparation
- 2) Application of split material
- 3) Developing the chromatogram
- 4) Detection and isolation of components

## Keywords

TLC, preparative TLC, TLC of colored materials, TLC of colorless components.

## Home

Since its discovery at the beginning of the 20th century, chromatography has found applications in many fields, both in the form of the simplest methods with minimal equipment requirements (paper and thin-layer chromatography) and methods using expensive equipment (e.g. gas or high-performance liquid chromatography), where modern analytical instruments - mass spectrometry (MS) - are used as detectors.

In all cases, the basic principles are applied, which the reader learns about by studying basic publications in the field of laboratory technology (Kvíčala, 1998) or publications directly focused on chromatographic methods (Mikeš at al.,

1998; Gasparič & Churáček, 1981; Sherma & Fried, 2003). The issue of thin-layer chromatography in chemistry education has been addressed previously (Richtl & Kraitr, 2004) and is currently the subject of a number of other publications, e.g. (Lambert, 2022; Švec, 2023). In the preparation of future teachers, it is incorporated directly into the teaching of the subject Laboratory Exercises in Organic Chemistry and is used in a number of qualifying papers.

## **Chromatography principles and important concepts**

Chromatography is a separation method, applicable for analytical and preparative purposes, which achieves the separation of a mixture based on the differential migration of its components in a two-phase system - stationary (stationary) and mobile (mobile).

The stationary phase may consist of a solid or a liquid trapped in a solid porous material (carrier). The mobile phase consists of a liquid (liquid chromatography) or a gas (gas chromatography). Depending on the arrangement of the stationary phase, chromatography is divided into column chromatography and planar chromatography, represented by paper chromatography and thin-layer chromatography.

Paper chromatography uses special (chromatographic) paper as a stationary phase, which can be replaced by filter paper for less demanding work, including in teaching. As far as the mechanism of paper chromatography is concerned, it is, with some exceptions, a split between two phases (stationary and mobile), with the paper being the carrier of the stationary (anchored) phase. If the paper is not treated prior to chromatography, the stationary phase is the water in the paper, the content of which is in equilibrium with the moisture content of the air. The partitioning of the components of the chromatographed mixture is governed by Nernst's partition law and the whole process can be thought of as a repeated simple partitioning of the substance between two mutually immiscible liquids, analogous to the establishment of equilibrium by repeated shaking in a separating funnel.

Thin-layer chromatography differs from paper chromatography primarily in that a fine-grained sorbent is used as the stationary phase, either loosely or fixed with a suitable binder in a thin layer on a substrate (adsorption chromatography), or the stationary phase is anchored to the support (partition chromatography). In some cases, other finely modified materials with specific properties may be used. Then, even in a planar arrangement, the separation of substances can take place by other mechanisms similar to column chromatography. Most often, however, thin-layer chromatography is implemented as adsorption chromatography. Compared to paper chromatography, it has some advantages, which in the analytical version include, in particular, smaller equipment and higher speed of analysis.

In the preparative version, thin-layer chromatography allows the separation of much larger quantities of mixtures (depending on their composition) than paper chromatography, given that the thickness of the adsorbent layer can be up to 3 mm. However, at such a layer thickness, undesirable effects begin to appear which impair the separation ability.

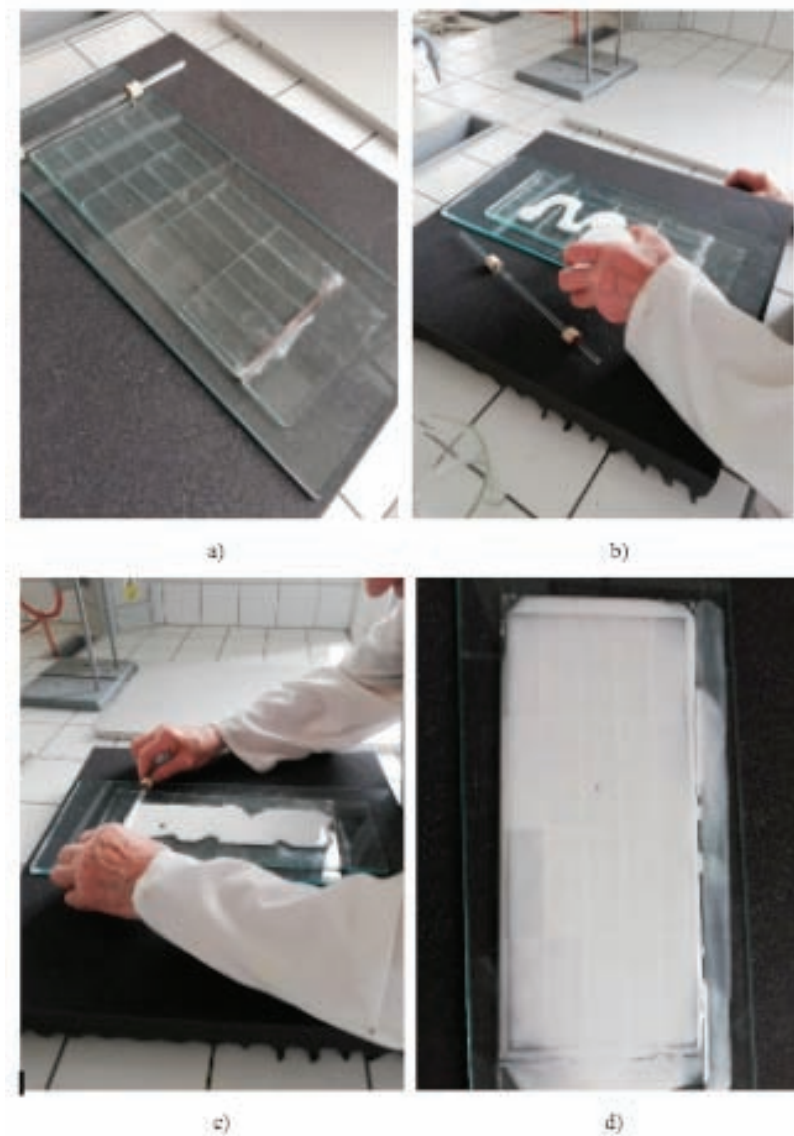
## **The importance and implementation of TLC**

TLC is mainly used to monitor the progress of reactions and is one of the indicators of product purity and also provides the necessary information for the correct choice of mobile phase in the separation of the reaction mixture by column or preparative thin layer chromatography. The thin layer of the stationary phase is either formed by a free-flowing sorbent or prepared as a fixed layer using a suitable binder (starch, gypsum), which, however, not only affects the separation capacity of the prepared layer but also the detection capabilities of the chromatogram (Gasparič & Churáček). Currently, fixed thin films, which are well handled and give reproducible results, are more commonly used. There is a sufficient range of good quality finished fixed layers on the market in a variety of sizes. Most commonly, aluminium or plastic foil is used as a substrate. The actual chromatography is usually performed in an ascending manner. Fixed thin layers can be loaded almost perpendicularly into the chromatography chamber, whereas loose thin layers require more careful handling and are loaded obliquely into the chromatography chamber. Loose thin films (sorbent without binder) simulate the course of column chromatography quite faithfully and can be useful in planning column chromatography separations. The separating power of bulked layers is usually inferior compared to fixed layers. The preparation of bulk thin layers consists of spreading the bulk sorbent evenly on a suitable support using a stick fitted with two rings defining the thickness of the desired layer. In the case of the preparation of cast layers, a similar procedure is followed, except that the same rod is used to pour and evenly distribute the previously prepared and poured suspension onto the glass slides aligned on the glass plate (e.g. a suspension of 20 g of silica gel for TLC is applied to 20 microscopic slides measuring 75 x 26 mm in sufficient water to form a thin slurry which spreads on the surface but does not flow).

During the first preparation of cast layers, it is advisable to add the necessary water gradually to the weighed silica gel from the measuring cylinder so that the volume of water consumed can be determined and a suspension of the same quality can be prepared for the next time.

Historically, the mixture of silica gel and binder was prepared according to proven formulations. Currently, commercially supplied mixtures are used as listed by individual companies supplying laboratory equipment and chemicals. These mixtures, under a specific label, guarantee the reproducibility of the

chromatography performed. The procedure for making the cast layers can be seen in Figure 1.



*Figure 1. Preparation of the cast silica gel layer (a) Set of 20 75 x 26 mm slides ready for pouring the silica gel suspension for TLC in water, (b) start pouring the suspension, (c) start spreading the suspension, d) completed preparation of cast layers.*

Chromatography is proceeded only after perfect drying of the poured layer, or the necessary modification of the prepared layer. The solution to be examined is applied with a thin capillary to a pre-marked starting line (start) so as to form as small a target as possible. After the solvent has evaporated, the plate is placed in a tightly closed (Kvičala, 1998; Gasparič, 1981; Lambert, 2022) chromatographic chamber with the solvent so that the applied sample is not immersed in the liquid, but the solvent reaches the level of the start only by rising. When the solvent front reaches within a few millimetres of the edge of the plate, the thin film plate is removed from the chromatographic chamber and the chromatogram is evaluated, which is the simplest for coloured substances. In the case of colourless substances, the traces obtained must be made visible by detection after evaporation of the solvent. A number of methods are used for detection, some of which are almost universally applicable if suitable thin layers are used. For example, when using layers of silica gel or alumina loose or in a fixed layer with gypsum as a binder, it is convenient to use baked layers on an electric cooker. Places with organic (non-volatile) substance turn brown. The process is accelerated and accentuated if the firing is preceded by spraying the layer with 10% sulphuric acid. This method cannot be applied to layers where an organic binder (starch) is used, as the whole area darkens during firing.

Another method of detection is irradiation with UV light using adsorbents containing a fluorescent indicator. Spots containing UV-absorbing substances appear as dark spots on a light background. If the compounds to be analysed do not absorb in the UV region, the developed plate can be sprayed with a morin solution and after drying the substances can be identified under a UV lamp as spots of a different colour on a fluorescent background. In some cases, it is convenient to detect the detection by spraying with a suitable reagent. Sprayers of various designs are used for spraying. The common feature of these devices is the formation of finely dispersed droplets of reagent and the resistance to the reagent being sprayed.

The distance the stain travels when analyzed on a thin film depends on the polarity of the substance and the polarity of the solvent. More polar substances are more trapped by the polar groups of silica gel or other stationary phase. On the other hand, a substance of a given polarity travels a greater distance when a solvent of higher polarity is used, but also undergoes greater scavenging. The distance of the stain and its shape can also be significantly affected by the solubility of the substance in the mobile phase. Thus, the distance a substance travels on a given plate in a given solvent is inversely proportional to its polarity and is given by RF (retardation factor).

The retention factor is a dimensionless quantity, taking values from 0 for compounds that remain at the start to 1 for compounds that advance with the solvent front (see Figure 2).

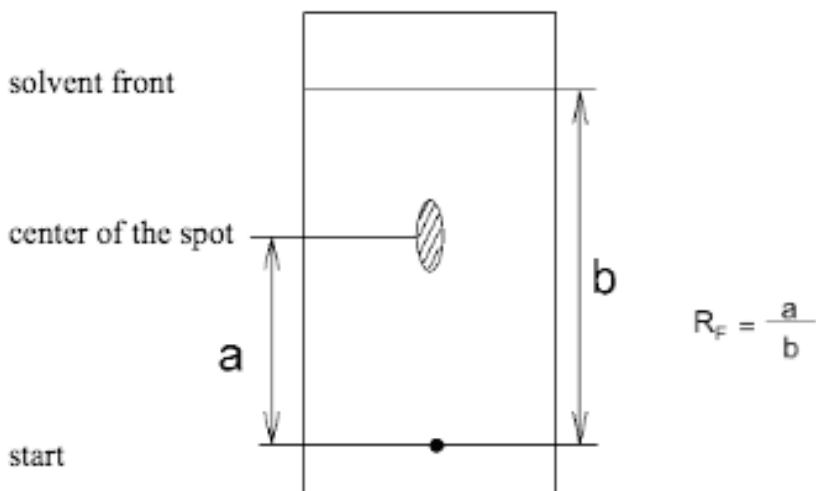


Figure 2. Evaluation of the chromatogram  $R_F$

The first step in the separation of a mixture of substances by TLC is the selection of the stationary phase (adsorbent), taking into account the properties of the substances to be chromatographed and the adsorbents available. We choose an adsorbent that does not bind the individual components of the separated mixture too tightly. If we cannot rely on literature data, we are forced to orient ourselves by preliminary experiments: we first try separation with a more active adsorbent; if the substances are adsorbed too strongly on it and cannot be washed out even with more polar solvents, we choose an adsorbent with a lower degree of activity, etc. If even this does not lead to the goal, we switch to another adsorbent.

The main difference between alumina and silica gel is that aluminium has a greater coordination capacity than silicon. Therefore alumina is a more suitable adsorbent for medium polar substances. Deactivated alumina can be used for highly polar substances. Substances capable of forming intermolecular hydrogen bridges (alcohols, acids, etc.) are retained more firmly on alumina than on silica gel because of the donor-acceptor interaction of the active hydrogen with the metal atom to form a chelate-type hydrogen bond.

If we sort the functional groups according to decreasing adsorptivity on the polar adsorbent, we obtain the following series:  $R-SO_3H$ ,  $R-COOH$ ,  $R-CONH_2$ ,  $R-OH$ ,  $R-NH_2$ ,  $R-COOCH_3$ ,  $R-NH-R_{12}$ ,  $R-NO_2$ ,  $R-OCH_3$ ,  $R-Cl$  and  $R-H$ . The polarizability of the molecule and the magnitude of the dipole moment also have some influence on the adsorptivity, which can be applied in the partitioning of isomers (Gasparič & Churáček).

The most suitable solvent system for a given mixture of substances is usually determined experimentally from experience and is recorded as part of the working protocol. The choice of solvents is based on the so-called eluotropic series. In this series the solvents are arranged in order of decreasing relative permittivity: water, methanol, ethanol, propan-1-ol, acetone, ethyl acetate, diethyl ether, chloroform, benzene, toluene, carbon dioxide, cyclohexane, hexane.

Solvents standing highest in the eluotropic series are also suitable eluents for washing out components of mixtures with high polarity. In contrast, the lowest members of the eluotropic series or mixtures thereof are solvents suitable for finer separation of mixtures. Several principles apply to the choice of the most suitable solvent. The first requirement is that the solvent used must be soluble in the mixture of substances being divided. Another requirement is that the split substances are neither too tightly nor too loosely bound to the chosen adsorbent. In the first case the mixture remains at the start, in the second case the mixture of substances without splitting advances at the head of the solvents. Both limiting possibilities show that the most favourable case is that of splitting the mixture under conditions where its components are adsorbed moderately tightly and differences in their RF can be applied.

The differences between the members of the eluotropic series sometimes need to be reduced. For this purpose, a mixture of two adjacent solvents in series is used. The addition of the more polar solvent to the less polar solvent must be increased only very slowly. As a rule, it is added first at about 1-2%, then 5-10% and finally up to 50%; for the mixture of solvents approaches the properties of the more polar solvent quite rapidly. The properties of the solvent system verified by TLC are extremely valuable for preparative TLC and column chromatography, where the column is washed successively with solvents from the least polar to the most polar.

When using unpurified solvents based on hydrocarbon halide derivatives, it is necessary to take into account the presence of 1-2% ethanol, which significantly increases the overall polarity of the solvent.

In some cases, the products separate only in low polar solvents where the difference RF is very small, but the separation deteriorates when more polar solvents are used. In this case, it is advantageous to use multiple elution, i.e., after elution and evaporation of the solvent, the plate is reinserted into the developing chamber and the chromatography is repeated. This procedure is often used for preparative TLC.

### *Preparative TLC*

The preparative version of thin-layer chromatography differs from the analytical version mainly in the dimensions of the chromatographic plates, which

are usually 20 x 20 cm, but can be larger (e.g. 25 x 50 cm), with a layer thickness of up to 3 mm. The layer can be either bulk or cast with or without binder. Both loose and cast layers are applied using suitable applicators. If commercially supplied equipment is not available, the layer can be made in a simple way. In the case of loose layers, a new glass rod is used to spread the chromatographic material, with a thin plastic or rubber tube at the edges, the thickness of which defines the thickness of the chromatographic layer. The rod thus prepared can also be used to stratify the pre-prepared material for the cast layer. Good results in the preparation of the cast layer can also be achieved by pouring the necessary amount of adsorbent mixed with water (the ratio of the components must be tested beforehand) onto the plate. 20 - 25 g of silica gel for TLC is used per 20 x 20 cm plate. After rough spreading with, for example, a glass stopper, a continuous smooth layer is achieved by tapping the bottom of the plate slightly with the fingers while tilting it in all directions.

Another difference from the analytical design is that a concentrated solution of the substance to be chromatographed is applied to the start to form a 2 to 3 mm wide continuous strip. This is done either by placing a droplet next to a droplet, or by practicing applying in a continuous strip directly from a glass balloon or syringe. Maintaining the width and linearity of the strip is necessary to maintain proper chromatography. The amount of the sputter must be determined experimentally and is dependent on the composition of the split mixture, which is determined in advance by analytical TLC performed on the material used for preparative TLC applied to a microscope slide (Figure 1). We proceed to develop the chromatogram only after thorough evaporation of the solvents from the trace at the start. A suitably sized aquarium, covered so that evaporation of the solvents cannot occur as they progress across the plate, is best used as a chromatographic vessel. The covering can be done, for example, with aluminum foil or other solvent vapour-resistant material, overlaid with weak foam. Place a glass plate on top of the foam, which should be weighted down. The success of the whole chromatography depends on the tightness of the apparatus, since it is necessary that the solvent front should advance evenly across the width of the plate.

The solvent system used for chromatography should be tested on a small plate prepared on a microscope slide made of the same adsorbent. If the split mixture is more varied, it is preferable to choose less polar solvents for chromatography. The isolated substance thus forms a continuous chromatographic zone (band) on the preparative thin film near the start, surrounded by bands of other components of the split mixture. If the same solvents are allowed to rise again along the entire length of the plate after complete evaporation of the solvents, the distribution of the bands of the split mixture is somewhat better. In some cases, the necessary distribution of the mixture is achieved only after the plate has been dried several times and new solvents have risen. The principle of this procedure is that by



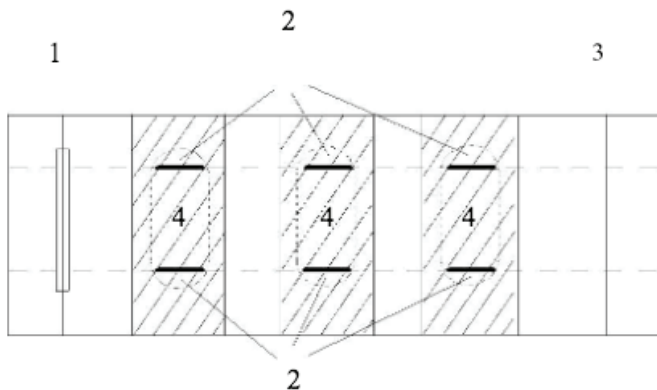
repeatedly plunging the preparative plate into the solvent, individual bands of compounds with slightly different  $R_f$  become the starting point for new chromatography. For colourless substances, it is necessary to test the conditions of repeated elution on a small analytical plate. When using a mixture of solvents, it is always advisable to use a new mixture of the same composition. Simply adding more would result in an undefined change in the composition of the mixture in favour of a less volatile solvent.

In case the isolated substance is coloured, we can proceed to remove the corresponding adsorbent strip after evaporation of the solvents and extract with a suitable solvent to obtain the isolated component. In most cases, however, the isolated substances are colourless and we have no choice but to opt for a suitable detection method. If we have a suitable UV source available, we can use luminescence or quenching using a suitable UV indicator which is part of the thin film or, more commonly, spraying the layer with a solution of the UV indicator before irradiation.

If we do not have a suitable UV-lamp available, we can use one of the methods below:

a) Measure the preparative thin layer in a series of equal pieces from the start to the front and use a spatula to take successive samples of the adsorbent on the drip plate. Then add 1 to 2 drops of a suitable solvent to each sample on the dropping plate and then attach a glass capillary, which is commonly used to apply solutions to the thin layer. If the adsorbent contains any component of the split mixture, it passes into the solution which is drawn up through the capillary. The presence of the individual components in the capillaries is then identified by conventional thin-layer chromatography. If we proceed carefully, with an optimal choice of 'probes' on the preparative thin layer, we can get a good overview of the composition of the individual bands of this layer and proceed to extraction, e.g. in a chromatography tube. If the adsorbent with binder is in pieces after removal, grind it to powder in, for example, a folded sheet of coated paper before filling it into the tube. After the powder has been poured into the tube, if necessary, tap the tube vertically on a wooden support with the stopcock open so that the column is as homogeneous as possible before the solvent is poured in and the organic matter is washed out perfectly.

(b) Place the preparative thin film on a suitable support (e.g. laboratory jack) and touch the electrically heated resistance wire at two points in the start-to-face direction (Figure 3). At the points where the components of the split mixture are contained, browning occurs due to charring of the organic matter. The electrically heated wire can be replaced by a 3 mm diameter stainless steel rod heated in the flame of a gas burner.



*Figure 3. Preparative thin layer after detection with hot resistance wire:*

*1 - start, 2 - places where carbonization (browning) occurred, 3 - front, 4 - adsorbent stripes, which, after removing the charred parts, we scrape off to the elution*

Mark these sites and apply a sample from the intact portion of the marked bands to an analytical thin layer using the method described in procedure (a) to identify the organic matter present. Before removing the relevant portions of the adsorbent from the plate into the extraction tube, the charred hot wire track must be removed, e.g. by scraping with a spatula, to prevent degradation products from contaminating the isolated substance. Remove the labelled adsorbent strips (see Figure 3) from the plate and, after grinding (if necessary), pour the adsorbent into the prepared and labelled chromatographic extraction tube.

c) In some cases, we use spraying with a suitable reagent that reacts with the isolated compound to form a coloured compound for detection. In this case, prior to spraying, the plate is covered with a suitable template so that the reaction occurs only in narrow bands along the length of the plate and the entire area is not degraded. Further processing is the same as after hot-wire detection (see procedure (b)).

d) It turns out that the method of comparing the analytical plate with the preparative plate can be well used with careful work. The prerequisite is that the mixture has been previously analysed by TLC on an analytical plate loaded onto a slide with the same sorbent as the preparative plate. Obtaining the  $R_f$  of the desired component of the mixture using the same solvent system is then accomplished by calculating the position (center) of the band formed on the preparative plate from the position of the solvent face of the preparative plate and the observed  $R_f$  of the isolated component. This method is also advantageous in combination with the use of electrically heated wire (method b).

Since larger quantities of solvents are handled (e.g., when using a 20x20 cm plate, about 100 ml of solvents are poured into the bottom of a slightly sloping aquarium, of which about 50 ml remain after elution), care must be taken in their management. In practice, this means transferring the remaining solvents to a closed container for further use. This flask or bottle should, of course, be labelled so that the experimenter does not lose track of the composition of its contents. In the case of the use of a mixture of elution liquids, their different volatilities may lead to an increase in the proportion of the less volatile component, which will ultimately result in a change in the elution properties of the mixture. For precise work, it is advisable to verify the solvent properties using a standard (of known  $R_f$  for a given solvent mixture) and, if necessary, to adjust for the addition of the more volatile component.

### **Incorporating TLC into the preparation of future chemistry teachers**

In the changed conditions of implementation of chemical experiments at primary and secondary school, chromatography finds considerable application. It is necessary that students, future chemistry teachers, fully understand the principles of chromatography and know how to work with them. TLC is an easy and fast method that serves this purpose well. At the Department of Chemistry, FPE ZČU in Pilsen, this goal is achieved by including two basic tasks in the basic laboratory exercise in organic chemistry. Both methods were developed based on the isolation procedures included in the laboratory instructions (Richtř, 2004). By modifying the elution mixture for chromatography in the preparation of capsaicin by omitting the most polar component formic acid, it was achieved that the dyes advancing in the solvent headspace were distributed according to  $R_f$  over practically the entire chromatogram area. The whole chromatography is then a visible demonstration of all the theoretical considerations and conclusions. The second work concerns a TLC extract of birch bark which contains a number of triterpenes accompanying the most abundant betulin, the most important of which are the more mobile lupeol on TLC and the more tightly bound betulinic and oleanolic acids. Details of this chromatography as well as that of plant dyes have been published previously (Trnka, 1989). These papers may inspire modifications of procedures described in textbooks and journal articles and the design of new procedures.

### **Acknowledgement**

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### ***Ethics Statement***

The ethics committee confirmed to the corresponding author that this research

did not require ethics approval because of the full anonymization of the publicly available data and because the data are not sensitive.

### ***Conflicts of Interest***

The authors declare no conflict of interest.

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# Teaching carbohydrates at the secondary school using the TASC method

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## Abstracts

This paper is devoted to the validation of the benefits of the TASC method in a high school. The name of the method is derived from the initial letters “Think Actively in a Social Context”. The TASC method is a globally used method to develop students’ key competencies across the curriculum. The method is based on pupils’ critical thinking and active engagement in learning. Pupils become active co-creators of the teaching process and are not merely passive receivers of information.

The method was tested in the fourth year of the lower level of an eight-year grammar school (corresponding to the 9th year of primary school) in the teaching of the thematic unit “Carbohydrates”. The research method chosen was a structured questionnaire, which the students completed after the final colloquium. The results of the research show that the TASC method is another activation method that should be included in chemistry teaching, as it increases the activity of pupils in the lesson and develops their creativity.

## Keywords

TASC, research experiment, questionnaire, carbohydrates

## Introduction

The aim of pupils’ education in primary school is not to acquire isolated knowledge, but to acquire key competences, which are the sum of knowledge, skills, abilities, attitudes and values important for the personal development and fulfilment of every member of society. The purpose and aim of education is to equip all pupils with a set of competences at a level that is attainable for them and thus prepare them for further education and employment in society. The acquisition of key competences is a long-term and complex process in which sub-competences are gradually developed. Key competences do not stand in isolation, but are intertwined and complementary in various ways, are multifunctional, have a cross-curricular form and can therefore only be acquired

as a result of the overall learning process. All educational content and the activities and activities that take place in school must be directed towards and contribute to their formation and development (MŠMT, 2021). The interweaving and multifunctionality of key competences is developed by teaching methods that emphasise the active involvement of pupils in learning. An instructional method as defined by Prucha et al. is an educational process in which one learns something through an organized process. It is a system of teaching activities of the teacher and learning activities of the learner, which is directed towards the achievement of set learning goals (Průcha a kol., 2013).

### ***What is the TASC method***

The TASC method is loosely translated as the “Active Thinking and Reasoning in Social Context” method, which presents students with a structure for independent or group creative work. Students can choose a specific topic for their work, conduct research, or organize research projects within a given topic to the depth and breadth they choose (Wallace a kol., 2012). In this way, the TASC method supports the achievement of the educational goal and the development of key competences as they are defined in the curriculum framework (MŠMT, 2021).

The TASC method is very close to the method of inquiry-based science education (IBSE). Both methods support the development of students’ critical thinking and their active approach, and incorporate the procedures and methods of scientific work (Stuchlíková, 2010). Grading the level of support for individual students is also common for both methods. Each pupil is different and therefore needs a different level and form of support. Some pupils use TASC intuitively and independently, while others need varying forms and degrees of teacher support as they work through the sub-phases of TASC. For some pupils, teacher support is needed throughout the processing of the topic. The advantage of the TASC method is that it allows the teacher greater flexibility when working with pupils who have different levels of knowledge and development, or different interests and hobbies. The TASC method uses communication and information technology (ICT) to interact between the teacher and students, students with each other and the teacher, and students with parents (Wallace a kol., 2012).

The TASC method is built on two basic pillars. The first pillar of the TASC method is the use of topics that are close to the students and that they know well from everyday life. The students easily relate the topic to their existing knowledge and experience while putting it in a different - new - context. By educating pupils in a real-life context, pupils can identify with the topic more easily and orient themselves more quickly, thus developing their enthusiasm and thus their interest in the topic to a greater extent. At the same time, pupils build a relationship with self education and lay the foundations for lifelong learning

(Wallace a kol., 2012).

The second pillar of the TASC method is based on the fact that human beings are social beings and need to satisfy their social needs, which include the need for social contact, the need for recognition and acceptance, the need for cooperation, and the need to teach others (Holeček, Miňhová, Prunner, 2003). During verbal and nonverbal communication, among other things, our thoughts, ideas, and concepts are crystallized and developed. The TASC method takes advantage of students' need to teach others. Students are able to explain a problem in a different or different way than how the teacher explains it, and therefore the explanation is more understandable to their classmates (Wallace a kol., 2012). Students use information technology to varying degrees in processing and presenting the findings of their work. The TASC method also helps pupils to navigate the digital environment and leads them to use digital technologies safely, confidently, critically and creatively, which is one of the educational objectives newly defined in the RVP (MŠMT, 2021).

The TASC method is divided into eight consecutive phases. In each phase, students focus on a different specific activity and engage a different part of the brain. Figure 1 shows the different phases of the TASC method. Below the title of each phase is the main question that students should ask themselves as they work through the assignment.



Figure 1. TASC wheel (Wallace, 2019)

### *Description of the phases (Wallace, 2019)*

#### 1. Gather/organise.

Students are introduced to the topic of the paper, sorting their knowledge and skills. In this phase, the teacher determines what pupils know about the topic and to what extent they are familiar with it.

#### 2. Identify the problem.

Pupils find out whether they have understood the assignment correctly and ask follow-up questions to the teacher or to each other. Pupils set criteria for successfully achieving the aim of their work.

#### 3. Generate.

This phase is creative and has an open end. All ideas on how to accomplish the task are valid and equally valuable.

#### 4. Decide.

In this phase, unlike the previous fancy one, it is purely rational. In this phase, students consider considerations (time, material, health and safety, etc.) that affect the accomplishment of the set goal.

#### 5. Implementat.

Pupils implement their idea, product or prepare a presentation. The key point of this phase is teamwork. Pupils may work according to a pre-prepared structured plan, using mind maps, working diagrams or charts. The aim is to think actively, not to gain a final 'product'.

#### 6. Evaluate.

When evaluating work, the emphasis is on motivating students to take responsibility for their learning, to be realistic about their achievements and to be able to alter their progress or suggest steps to improve their performance. Self-assessment and peer realistic evaluation are key elements of the TASC method.

#### 7. Communicate.

One of the most motivating influences on students is to have a real audience to whom they can present their work results - the results of their learning. The audience can be within the classroom, school, family, or completely outside the school setting. By using TASC we can increase pupils' motivation and engagement in learning. Pupils can use ICT technology, posters or involve the audience in the project to present the results of their work.

#### 8. Learn from experience.

The last phase of the TASC method. It focuses on metacognition or "thinking



about thinking”. Learners reflect and talk together about what they have learned and how they have learned it, evaluate whether a given process of acquiring knowledge and skills suits them and suggest a different way of learning. This phase increases the effectiveness of experiential learning.

## **Validation of the TASC method**

The method was validated in the fourth year of the lower grade of an eight-year grammar school (corresponding to the 9th year of primary school) in the teaching of the thematic unit “Carbohydrates”. The expected outcomes and the content of the curriculum are characterised in the Framework Educational Programme for Primary Schools (FPEP), which was amended in 2021 (Ministry of Education, 2021). Chemistry falls under the area of Man and Nature, which includes a range of problems related to the exploration of nature, understanding natural facts and their laws. It helps pupils to better understand and use current technology and helps them to better navigate everyday life. It promotes the development of open and critical thinking and logical reasoning. The aim of the learning area is to develop pupils’ key competences by leading them to investigate natural facts and their connections using a variety of empirical methods of knowledge such as observation, measurement, experimentation and various methods of rational reasoning. And also a way of thinking that requires the verification of assumptions made about natural facts and laws.

### ***Objective and research questions of the research investigation***

The aim of the research investigation was to find out how students perceive the incorporation of the TASC method into schooling in relation to their intrinsic motivation. The following research question was established.

“How do pupils perceive the incorporation of the TASC method into schooling in relation to their intrinsic motivation?”

To determine the intrinsic motivation of the students, a didactic research was designed that included 4 categories:

1. interest (Is teaching using the TASC method enjoyable for pupils?),
2. effort (Are pupils willing to put effort into the chosen activity in order to succeed in it?),
3. awareness of ability (Do students feel that they understand the TASC method?),
4. perceived usefulness (Is the implementation of the TASC method beneficial for the pupils?).

2.2. Research sample

The teaching of the thematic unit “Carbohydrates” was verified in the teaching of the Grammar Joachim Barrand in Beroun in the quartet of the eight-

year grammar school (corresponding to the 9th grade of primary school). The research involved 28 students (N=28) in the chemistry course in the school year 2022/2023. The class was taught by the author of the article.

### ***Research tools***

The implementation of the TASC method in the classroom was evaluated both in terms of observation of pupils' work in the processing of a selected task by pupils within the thematic unit of Carbohydrates and through a standardized questionnaire: the Intrinsic Motivation Inventory (IMI) (McAuley, Duncan, & Tammen, 1989); (Ryan, 1982).

The post questionnaire used was created by selecting 25 statements (items) from the IMI instrument in such a way that each statement belonged to one of four selected subscales:

1. interest/pleasure,
2. effort/importance,
3. awareness of one's abilities and
4. value/usefulness.

In all cases, these were subscales of intrinsic motivation. The questionnaire was administered to the students after the presentation of each outcome and the final summary. This was an anonymous survey.

### ***Evaluation of the survey***

For the negative statements from the post questionnaires, it was first necessary to perform reverse recoding. Cronbach's alpha was then calculated for each scale for the entire sample of respondents. The results are presented in Table 1 for clarity. The results indicate very good internal consistency of the data (all calculated alphas are greater than 0.89) and therefore high reliability.

*Table 1. Cronbach's alpha for the scales interest/pleasure; effort/importance; awareness of one's abilities and value/utility.*

Scale	Cronbach's alpha
interest/pleasure	0.91
effort/importance	0.89
value/usefulness	0.9
awareness of one's abilities	0.95

Subsequently, the arithmetic mean of the scores of all items that characterized these variables was calculated. The interest/enjoyment variable signified the student's perceived interest in the subject matter being discussed using the TASC method (the activity was enjoyed by the student). Higher measured scores indicated a perception of higher interest. The variable effort/importance represented the pupil's willingness to put effort, effort (they were trying to succeed) or energy into processing the outcomes. Higher measured scores signified a willingness to put more effort into the process of learning. The variable awareness of one's abilities represented the pupil's perception that he or she understood the task and performed well in the activity (pupil's perception that he or she understood the implemented task). Higher measured scores meant that pupils felt that they understood the task and felt good about their performance. The value/utility variable represented the pupil's perception of the value (usefulness) of the activity undertaken. Higher measured scores meant that the pupils perceived the value and usefulness of the activity implemented.

The individual arithmetic means of the scores of all items are presented in Table 2.

*Table 2. Mean values from the interest/pleasure; effort/importance; value/usefulness and awareness of one's abilities scales.*

Scale Cronbach's	alpha
interest/pleasure	5.29
effort/importance,	5.93
value/usefulness	5.48
awareness of one's abilities	5.65

For all variables, the average value of the scale was calculated and ranged from 1 to 7. The mean values ranged from 5.29 to 5.93. Thus, it can be concluded that the teaching of the thematic unit Carbohydrates using the TASC method aroused the interest of the students, the students tried their best to succeed and felt that they did well during the processing of the work and realized the importance of the activity they were doing.

At the end of the post-test, a supplementary question "Do you have a message?" was included in which pupils were free to, but not required to, answer. Below are the three answers that the pupils gave.

"I liked it and I think that especially in this topic I was working on I got a much more comprehensive insight than through normal interpretation."

“I think it’s beneficial in terms of problem solving skills and working together rather than learning the material.”

“I always learn a lot in this type of activity because I have to do a lot of reading and research on the topic. In addition, to be able to talk about the topic in front of the class, I need to understand the topic and know what I am talking about. The information I get stays in my memory longer.”

## **Conclusion**

The research investigated how students perceive the integration of the TASC method into school education in relation to their intrinsic motivation. To determine the intrinsic motivation of the pupils, a didactic research was designed to find out the interest (Is learning using the TASC method fun for pupils?), the effort pupils have to put in (Are pupils willing to put effort into the chosen activity to succeed in it?), whether they feel useful (Is the implementation of learning using the TASC method beneficial for pupils) and whether they are aware of the abilities (Do pupils feel that they understand the material discussed using the TASC method?).

The use of the TASC method in the teaching of the thematic unit “Carbohydrates” was tested in the school year 2022/2023 at the Grammar school J. Barranda in Beroun in the fourth year of the eight-year grammar school.

The students worked in groups of four, into which they were divided at their discretion. When choosing the topic and the method of elaboration, pupils had the opportunity to consult the teacher, to search in the literature or on the Internet and for practical elaborations to perform the tasks repeatedly. During the implementation it was found that the topic interested the pupils and the choice of method was very appropriate for the topic. The pupils worked independently and approached the problem very creatively. In the processing of the thematic unit by the whole class, all the curriculum prescribed in the curriculum was included (Gymnázium J.B.Beroun, 2020).

After completion, the students completed a post-questionnaire that was aimed at monitoring the intrinsic motivation of the students. The reliability of the research instrument used was calculated through Cronbach’s alpha coefficient. According to the calculated values of the reliability measure, it can be concluded that the data has a very good internal consistency and therefore high reliability. The results of the questionnaire survey showed that the teaching of the thematic unit Carbohydrates by the TASC method has a high educational potential. The assessments achieved above average positive scores in relation to all four scales under study. Thus, the results showed that the work aroused pupils’ interest, pupils were keen to succeed, felt that they did well and felt the importance of the work activity included.

## ***Acknowledgment***

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## ***Ethics Statement***

The ethics committee confirmed to the corresponding author that this research did not require ethics approval because of the full anonymization of the publicly available data and because the data are not sensitive.

## ***Conflicts of Interest***

The authors declare no conflict of interest.

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# Readiness of the Czech school environment for the implementation of the Computational thinking principle

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## Abstract

Computer thinking is becoming an increasingly popular topic in schools around the world and is gradually making its way into Czech education as well. Education systems recognize that understanding the fundamentals of computer science and being able to apply computational thinking is key to success in today's digital society. On the other hand, schools are dealing with the lack of qualified teachers in this direction. The aim of the article is to focus on the readiness of Czech universities to implement the principles of Computational thinking at all levels of teacher education. The article shows how Czech universities react to the change and whether all levels of teacher education correspond to this change.

## Keywords

Computational thinking, school, CF, RVP, FEP

## Introduction

Computational thinking has become an increasingly popular topic in schools worldwide and is gradually being introduced into Czech education. Educational systems are realizing that understanding the foundations of computer science and the ability to apply computational thinking is key to success in today's digital society. Computational thinking also includes problem-solving and creative thinking, skills that are in demand in all areas of life. Pupils and students learn to break problems into smaller parts, find solutions and create effective algorithms. In this way, they can approach problems systematically and find innovative solutions. Computational thinking also creates space for creativity and experimentation, which helps pupils and students develop their ability to think in the direction of developing cross-curricular relationships.

The introduction of computational thinking into the Framework Educational Program (next we will use Curriculum Framework – CF, in Czech: Rámcový Vzdělávací Program – RVP) at all levels of education in the Czech Republic is becoming a priority in the education system (edu.cz, 2022), (Metodický portál

RVP.cz, 2023). The CF adjusts educational objectives and contents to reflect the need to develop computational thinking. Currently, the CF BE (Curriculum Framework Basic Education – in Czech Republic means Primary and Secondary Schools) and the Curriculum Framework for Grammar schools (CF G) have been adapted.

Czech schools face increasing pressure and the need to find qualified computer science teachers who can teach according to the new curriculum. With the growing importance of the digital world and technology, pupils and students must have the opportunity to learn about computing concepts and acquire the skills that will enable them to apply themselves in the digital society fully. However, a shortage of qualified computer science teachers means that many primary schools struggle to find qualified teaching staff with sufficient knowledge and skills. Therefore, the pressing need to find and recruit computer science teachers is essential if schools effectively implement new curricula and provide opportunities for pupils and students to develop the computing thinking and skills essential for their future careers and personal development in the digital era.

### ***Computational thinking***

If we type Computational thinking (CT) into any search engine, we will find a lot of information (web pages). When entering this keyword on Google scholar, the search engine will provide us with over 2 million publications on this topic.

The reason for introducing Computer Science as a compulsory subject in education at home and the world is that technology is an inseparable part of everyday life; therefore, understanding these processes is crucial.

### ***Computational thinking in the world***

The first author to introduce Computational thinking is Jeannette M. Wing in her publication (Wing, 2006), which since then has over 11 thousand citations.

Wing defines Computational thinking (Wing, 2006) as:

Conceptualizing, not programming. Computer science is not computer programming. Thinking like a computer scientist means more than being able to program a computer. It requires thinking at multiple levels of abstraction;

Fundamental, not rote skill. A fundamental skill is something every human being must know to function in modern society. Rote means a mechanical routine. Ironically, not until computer science solves the AI Grand Challenge of making computers think like humans will thinking be rote;



A way that humans, not computers, think. Computational thinking is a way humans solve problems; it is not trying to get humans to think like computers. Computers are dull and boring; humans are clever and imaginative. We humans make computers exciting. Equipped with computing devices, we use our cleverness to tackle problems we would not dare take on before the age of computing and build systems with functionality limited only by our imaginations;

Complements and combines mathematical and engineering thinking. Computer science inherently draws on mathematical thinking, given that, like all sciences, its formal foundations rest on mathematics. Computer science inherently draws on engineering thinking, given that we build systems that interact with the real world. The constraints of the underlying computing device force computer scientists to think computationally, not just mathematically. Being free to build virtual worlds enables us to engineer systems beyond the physical world;

Ideas, not artifacts. It's not just the software and hardware artifacts we produce that will be physically present everywhere and touch our lives all the time, it will be the computational concepts we use to approach and solve problems, manage our daily lives, and communicate and interact with other people; and

For everyone, everywhere. Computational thinking will be a reality when it is so integral to human endeavours it disappears as an explicit philosophy.

How we can see, Wing (Wing, 2006) wrote: "Thinking like a computer scientist means more than being able to program a computer. It requires thinking at multiple levels of abstraction."

In 2011 Wing wrote new article about Computational thinking, where she defined benefits:

for everyone means being able to (Wing, 2011):

- Understand which aspects of a problem are amenable to computation,
- Evaluate the match between computational tools and techniques and a problem,
- Understand the limitations and power of computational tools and techniques,
- Apply or adapt a computational tool or technique to a new use,
- Recognize an opportunity to use computation in a new way, and
- Apply computational strategies such divide and conquer in any domain.

for scientists, engineers, and other professionals further means being able to (Wing, 2011):

Apply new computational methods to their problems,

Reformulate problems to be amenable to computational strategies,

Discover new science through analysis of large data,

Ask new questions that were not thought of or dared to ask because of scale, but which are easily addressed computationally, and

Explain problems and solutions in computational terms.

The next most cited article is the article (Grover & Pea, 2013), which follows up on Wing's work: The following elements are now widely accepted as comprising CT and form the basis of curricula that aim to support its learning as well as assess its development:

Abstractions and pattern generalizations (including models and simulations)

Systematic processing of information

Symbol systems and representations

Algorithmic notions of flow of control

Structured problem decomposition (modularizing)

Iterative, recursive, and parallel thinking

Conditional logic

Efficiency and performance constraints

Debugging and systematic error detection

Among other important publications dealing with research on Computational thinking are (Lu & Fletcher, 2009), (Aho, 2012), (Selby & Woollard, 2013), (Shute et al., 2017), or the latest publication (Denning & Tedre, 2019), (Kite et al., 2021), (Tsarava et al., 2022).

Other authors (Saidin et al., 2021) report that computational thinking in education can improve critical and analytical thinking skills among students.

An example here can be the application of the Computational thinking, especially the Algorithm thinking, in cross-curricular relationships, specifically in mathematics subject using GeoGebra (Ferdianová et al., 2021), which has become a modern teaching tool during the epidemiological situation of COVID-19 in the world.

However, it is important to note that computational thinking goes beyond just problem-solving. It also encompasses pragmatic, sociocultural, and political dimensions. By considering these dimensions, computational thinking can address critical issues and challenges in education (Kafai & Proctor, 2022). This expanded framing of computational thinking ensures that students not only develop technical skills but also understand the broader implications and societal impact of their work. The recognition of the importance of computational thinking has led to the rapid development of educational efforts and programs focused on integrating computational thinking into various subjects and disciplines. These initiatives aim to equip students with the necessary skills to navigate the digital age and contribute meaningfully to society (Li et al., 2020).

In any case, thinking skills are critical 21st-century skills needed for pupils' and students' success (Kafai & Proctor, 2022).

### ***Computational thinking in the Czech Republic***

In the Czech Republic, activities for the development of IT thinking have been incorporated into the teaching of informatics and programming in recent years. Daniela Růžičková (in Czech NÚV – Národní ústav pro vzdělávání; National Institute for Education) is the protagonist of the change in subject of Computer Science on schools and the introduction of Computational thinking into teaching in the Czech Republic. Růžičková and her team worked on a complete revision of the Curriculum Framework (in Czech RVP - during 2017-2019, and various documents and lectures were gradually created: (Růžičková, 2017), (Růžičková, 2018), (Růžičková, 2019).

During this period, many projects and organizations were also created that support the teaching of programming and Computational thinking from Elementary school (Elementary school is divided into two stages in the Czech Republic: Primary school 5-10y (ISCED 1) and Secondary/Middle school 10-16y (ISCED 2)), not only as part of formal education, but also in an informal environment.

## Development of Curriculum Framework



Figure 1. Development of curriculum documents

According to the current Curriculum Framework Basic Education (CF BE 2017 modified from 2013) (Rámcový vzdělávací program pro základní vzdělání, 2017) for some types of schools, the educational area of Information and Communication Technology (ICT) is mandatory for both levels of Basic Education (BE – Elementary schools), for Grammar schools (CF G 2007) (Balada, 2007) includes the basics of computer science as a field and an educational area with named Computer Science, and Information and Communication Technology. As we can see, the state curriculum documents (Vzdělávací oblast Informační a komunikační technologie, 2017) focused purely on the area of information literacy and practically supplanted ICT content in the mandatory teaching of Secondary (and to a large extent High) schools. The consequence of this is that high school graduates who have applied to university to study computer science have a problem with the basics of the field, as they often have no idea what computer science is and what problems it deals with. In 2017, an amendment to the Curriculum framework (Vzdělávací oblast Informační a komunikační technologie, 2017) was published, which regarding today's education, does not correspond to the reality and needs of modern times. In the introduction it is written: "... to acquire elementary skills in the control of computer technology and modern information technologies, to orientate in the world of information, to work creatively with information and to use it in further education and in practical life."

### Currently status in Czech Republic

As mentioned above, the compulsory subject of Informatics is gradually being introduced in Elementary schools. This implementation is defined by a document ("Postupné zahájení vzdělávání se ŠVP upraveným podle RVP ZV s novou vzdělávací oblastí Informatika s účinností od 1. září 2021", 2021) from the Ministry of Education, Youth and Sports of the Czech Republic with effect from the 1st of September 2021. In the Curriculum framework Basic Education ("Rámcový vzdělávací program pro základní vzdělávání", 2023), the educational area of Information and Communication Technology is thus replaced by the educational

area of Informatics with new content. At the same time, digital competence is added to the key competences. In some educational areas, proposals are made to reduce the educational content. Dates for starting education according to the revised Curriculum framework Basic Education: Elementary Schools can start education according to the revised CF BE from the 1st of September 2021 at the earliest. Then from the 1st of September 2023 at the latest in all grades of the first grade and from the 1st of September 2024 in all grades of the second grade. As we can see, the introduction of changes can be gradual, the decision is up to the primary school principals.

The current version of Curriculum framework for Grammar schools is from 2007 Pedagogical Research Institute in Prague (“Rámcový vzdělávací program pro gymnázia”, 2007). It is stated here that the area of Informatics and information and communication technology at the grammar school follows on from the area of ICT in basic education aimed at mastering the basic level of information literacy, i.e. at achieving the knowledge and skills necessary to use digital technologies.

This situation again does not correspond to reality, therefore the Ministry of Education, Youth and Sports of the Czech Republic bring the new Curriculum framework up to date in 2021 (“Rámcový vzdělávací program pro gymnázia”, 2021), valid from the 1st of September 2025.

### ***Analysis readiness of the Czech schools for new Informatics (Computer Science)***

#### *Analysis of study programs*

For the analysis, we selected all study programs of all schools-universities where you can study a field with a focus on teaching programs. Specifically, we focused here on the teaching of Informatics (ICT, Computer Science) according to the information available on the Internet. We divided the selected study programs into three groups. The first group of teaching study programs are programs where students study a complete teaching program, which consists of a bachelor’s degree – (three years) and a master’s degree (2 years, which follows the bachelor’s degree).

According to Czech law, only graduates of a master’s study program (either a combined 3+2 years or a complete master’s program – 5 years) can teach at the respective school. In addition, a graduate of the study program Teaching for High schools can teach at both schools (Secondary and High) according to the law.

There is no 5-year teaching program focusing on Computer Science in the Czech Republic.

Table 1. Bachelor study programs with a focus on education

<b>Name of bachelor study programs</b>	<b>Count</b>
Teaching for Secondary schools	5
Teaching for Secondary and <u>Hight</u> schools	3
Teaching for High schools	6

Table 2. Master's degree programs for teachers

<b>Name of bachelor study programs</b>	<b>Count</b>
Teaching for Secondary schools	7
Teaching for Secondary and <u>Hight</u> schools	1
Teaching for High schools	8

The second group are scientific and scientific-pedagogical degrees.

Table 3. Scientific and scientific-pedagogical degrees

<b>Study program</b>	<b>Count</b>
PhD program (doctoral education) in Computer Science	3 + 1 study of STEM*
Associate professor of Computer Science Education	2**
Professor of Computer Science Education	1***

\* STEM – Science, Technology, Engineering and Mathematics

\*\* Information and communication technology in education,  
Didactics and history of mathematics and computer science.

\*\*\* Information and communication technology in education

The last group is special (lifelong) studies for current teachers who would like to obtain a new qualification either in a whole new field or at a different school level (from Secondary to High school). We did not include the last type of study mentioned in the analysis, because teachers who are interested in this study are already qualified to teach computer science.

Table 4. Scientific and scientific-pedagogical degrees

<b>Study program</b>	<b>Count</b>
Additional Teaching Qualification in Computing Studies for Primary schools	1
Additional Teaching Qualification in Computing Studies for Secondary schools	4
Additional Teaching Qual. in Computing Studies for Secondary and <u>Hight</u> schools	6

## *Method of study composition analysis*

In order to compare and analyse the analysis of the individual studies from the previous point, we had to set points. We selected these points as the main areas of study from the curriculum documents (Curricular Framework BE and G). The fields of study are: Data and information, Data encoding and transmission, Algorithmizing, Block programming, Programming, Robotics, Information Systems, Database, Hardware and software, Computer networks, Safety, Digital identity.

Based on freely available information about study programs, we will monitor whether individual studies cover the main points from the previous chapter. Considering that the main points contain other sub-points in the curriculum documents, we decided on the following evaluations:

YES, the study fully covers a certain main point,

PARTIALLY covers,

NO, the study does not cover a certain main point from the curriculum documents.

Due to the fact that the study of teaching in the Czech Republic is divided into bachelor's and master's degrees, we will work in the analysis as with one connected program.

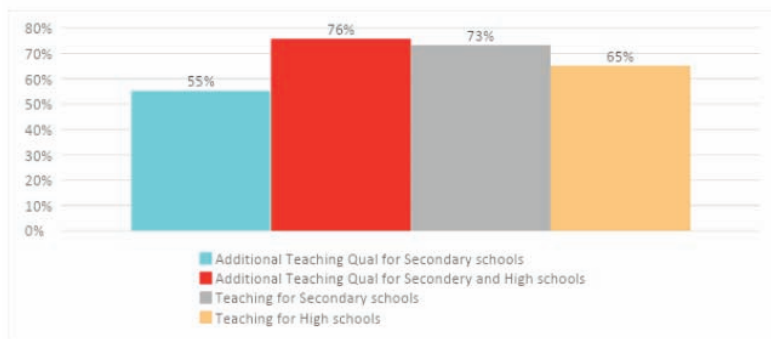
Overall results of the analysis

The following studies were excluded from the above procedure:

two programs of elementary school teaching,

one program of high school teaching.

The reason for exclusion was the unavailability of information on the Internet. The studies contained only basic general information.



*Figure 2. Average CF content coverage of all studies*

From the above-mentioned figure 2, it is clear that the best prepared for the change of curriculum documents in the field of Computer Science are studies of Additional Teaching Qual for Secondary and High schools. On the other hand, studies of the type of Additional Teaching Qual for Elementary schools are the worst off.

### ***The analysis further revealed:***

Programming (Java, Python, etc.) and Computer Networks are the best covered points in all studies. Although Programming, Block Programming and Robotics work closely together, Block Programming and Robotics have fared significantly worse. This is very interesting because these two points are considered very important point.

With the growth of the digital world (e.g. social networks), the emphasis in curriculum documents is on Security and Digital Identity. All studies cover these points at least, or even these two points are not included at all in the studies of Additional Teaching Qual for Secondary schools.

## **Conclusion**

The aim of the article was two analyses. The first analysis was focused on the possibility of studying teacher programs with a focus on Computer Science, increasing the qualifications of teachers or academic/scientific workers in the Czech Republic. The analysis showed a sufficient number of these teaching fields at universities throughout the Czech Republic. There are also studies where teachers can expand their qualifications with a new field or a different level or type of school.

Although the subject of Computer Science has become an equal subject in Elementary and High schools, we still believe that the Czech Republic has a minimum number of associate professors and professors. Moreover, the names of these studies do not correspond to the current situation in the world. The most recent development of didactics is Didactics of Computer Science, but in the Czech Republic there are still procedures focused on Didactics of Information and Communication Technologies in Education.

The second analysis is oriented to the content side of these studies and whether they correspond to new and mandatory changes based on curriculum documents. As we can see from the results of this analysis of all types of teaching studies, individual studies contain 55-76 % of the areas defined in the CF. From our point of view, these are low values. The reason for these low values will be that, in general "Computer Science" is the fastest growing field and the system for new accreditations is very lengthy. The higher number (76 %) for studies of Additional Teaching Qualification is due to the faster accreditation system in the area of



life-long learning, where educational institutions have newly accredited their programs (1 x program in 2021, 5 x 2022 and 1 x 2023).

Currently, several facts are happening during the change of Informatics in schools. Current unqualified teachers do not want to teach according to the new documents. And therefore, there is a great demand for Computer Science teachers in the market. Another fact is that very few students at universities study teaching majors with a focus on Computer Science. And if they graduate, they go into practice, where they are much more financially valued.

We see a further continuation of the work in a more comprehensive analysis of topics from Curriculum documents and analysis of documentaries for other types of schools, which will only gradually be created.

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### ***Ethics Statement***

The ethics committee confirmed to the corresponding author that this research did not require ethics approval because of the full anonymization of the publicly available data and because the data are not sensitive.

### ***Conflicts of Interest***

The authors declare no conflict of interest.

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