# Level of Graphic Skills of Elementary School Students

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***Abstract* – Slovak students have been consistently achieving low scores in international PISA assessments in the areas of mathematical and scientific literacy. It has been found that students lack adequate graphic competencies necessary for problem-solving. In an effort to improve the education of students in primary schools, a school reform was implemented. The aim of the study is to investigate the impact of the school reform and online education during COVID-19 on the level of graphical skills of 9th-grade primary school students. The authors also examined the relationship between the level of graphical skills of boys and girls. The research sample consisted of 92 9th-grade primary school students (15 year olds). The research tool was a test consisting of 10 tasks focused on various aspects of students' graphical skills. The results of the study pointed to the need to pay attention not only to the graphical competencies of primary school students but also to the graphical competencies of future teachers during their undergraduate preparation.**

***Keywords* – Education, student, graphical skill, graphical literacy.**

## 1. Introduction

In the Slovak Republic, the main goal of the lower secondary education 2 (ICSED) is for students to acquire:

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– "appropriately age-developed key competencies, meaningful fundamental knowledge, and cultivated interest in lifelong learning,"
– clear awareness of national and world cultural heritage,
– interest in and the need for meaningful activity and creativity [1, p. 6].

In simplified terms, the aim of educating students in primary school is to develop their literacy, specifically functional literacy. Literacy is a complex and variable phenomenon. In the past, it referred to an individual's ability to read, write, and possibly do basic arithmetic [2]. However, in the present, this understanding of literacy is insufficient, as the concept continually expands [2], [3], [4]. Its content and definition respond to specific social contexts, reflecting the development of societal conditions and changing needs, culture, language, and norms. Literacy now means the ability to master various forms of communication and numerical operations to use textual information in diverse life situations [2]. According to the Organisation for Economic Co-operation and Development (OECD), literacy is a lifelong learning process. Developing literacy skills leads to acquiring new abilities for more effective learning [3]. It is evident from the above that an individual's literacy development does not end after completing primary, secondary, or higher education; it continues through lifelong learning and has an impact on an individual's employability [5]. Different models and theories of literacy express changes in the approach to literacy [2].

In the context of education, the term "functional literacy" is increasingly used in the professional literature. The goal is no longer just flawless reading and writing of texts but also the ability to work with information. Students are expected not only to master the techniques of reading and writing but also to comprehend, evaluate, analyze, connect with other cognitive operations, knowledge, stimuli, and more. A strict and unequivocal definition of functional literacy is not found in the available literature.

Several authors perceive functional literacy as the ability of students to apply knowledge and attitudes in real-life situations [2], [6], [7], [8], [9].

Functional literacy consists of several components, including not only reading, mathematical, and scientific literacy but also cultural, social, travel-related, geographical, digital, environmental, and others. Among these components, reading literacy holds the most prominent position, as it influences the development of other partial literacies.

Thanks to the rapid development of information and communication technologies in the last decade, graphic literacy has come to the forefront as one of the components of reading literacy. It also holds significant importance in the development of mathematical and scientific literacy. In general, people in modern society are capable of reacting faster and better understanding the meaning of information when data is presented visually [2]. As a result, the importance of graphical representation of information and the ability to interpret data from graphically encoded messages has increased.

## 2. Graphic Communication as a Form of Pedagogical Communication

In simplified terms, the concept of pedagogical communication means conveying any information from the teacher to the student and vice versa. In the teaching process, the teacher and the student have different roles. The teacher imparts knowledge to the student, which the student is supposed to assimilate. The teacher's communication skills are necessary to improve the students' learning process [10], [11], [12], [13], [14]. The teacher must possess communication competencies since they constantly communicate with the students during the teaching process. This communication process is referred to as a communication act [12], [13].

The quality of the educational and teaching process depends on the quality of communication as the "most vulnerable" component of teacher-student interaction [12], [14], [15]. Zlatic *et al.* [15] state that communication competence is a fundamental skill for teachers. It comprises a system of knowledge, skills, abilities, attitudes, and motivational capacities.

The effectiveness of transferring information from the educator to the student is also influenced by the teacher's ability to interpret the information. This is referred to as pedagogical interpretation, which Obdržálek [12] defines as the teacher's ability to "highlight" the required information from the information source and name it.

Other authors share a similar approach to the teacher's ability to "highlight" the necessary information (educational content) and share it with students using appropriate communication means, avoiding pseudo-communication, i.e., distorting the content of information [16]. Okoli [13] describes the effectiveness of teaching as the result of two main factors: knowledge (content) and communication. Worley *et al.* [17] state that in education, soft skills, including communication skills, are often more important than the educational content itself. Similarly, Bambaeeroo and Shokrpour [14] argue that a scientifically competent teacher who cannot effectively communicate the subject matter to students is unable to teach satisfactorily, meaning they may not achieve adequate educational outcomes.

Communication in education is not only realized through words, but also the non-verbal component of communication carries meaning. We refer to this as non-verbal communication (NVC) [14], [18], [19]. It includes paralinguistics, proxemics, posture, facial expressions, gestures, haptics, and other significant elements that complement non-verbal communication, such as space, time, speech arrangement, image, etc. Since non-verbal communication is subconscious, communicators often remain unaware of it. Subconscious body language is challenging to control, making it difficult to deceive through body language. A teacher who pays attention to the non-verbal cues of their students can deduce whether they are bored, understand the subject matter, or are motivated from their gazes, sitting style, and listening behavior [11], [13], [14]. Similarly, students can infer from the teacher's body language whether they are enthusiastic about education and the topic at hand, and if they feel comfortable discussing it [11], [13], [14]. We agree with Hamm's view [20], who claims that the success of a speaker's presentation depends on their NVC. She points out that when verbal and non-verbal messages contradict each other, most people tend to believe the non-verbal cues.

In their research, Bambaeeroo and Shokrpour [14] examined the barriers to effective non-verbal communication (NVC) and identified effective NVC methods during teaching. Their findings indicate a significant and positive relationship between the communication skills of academic staff and the academic success of students. They demonstrated a significant correlation between the non-verbal and verbal communication of teachers and the students' achievements. They concluded that there is a significant relationship between NVC, as one of the communication skills, and the effectiveness of education.

The points raised by Okoli [13] emphasize that teachers must effectively use not only spoken language but also gestures, symbols, signs, questions, and other techniques to share information with students and enhance their understanding. They should possess the ability to convey information to students effectively and accurately comprehend the expressions of students' opinions and feelings. Okoli declares that images, maps, diagrams, and practical examples improve communication.

It is possible to agree with the presented facts about the significance of verbal and non-verbal communication in education. However, it is important to note that this perspective on communication in education is relatively narrow. In subjects related to natural sciences and technical fields, the teacher's competence in effectively communicating through various graphic representations (diagrams, technical drawings, graphs, tables, symbols, maps, etc.) is crucial. This is referred to as non-verbal graphic communication (NGC) [11], which is a significant form of communication between teachers and students and among students themselves.

The increased demand for creating non-verbal visual information, especially in more abstract forms, aligns with the needs of the modern school, where there are escalating requirements for speed, accuracy, complexity, and high-quality information transmission [12].

Using graphic representations created by teachers directly in front of students on the chalkboard or whiteboard offers numerous advantages that contribute to the development of their imagination and understanding. These advantages enhance the effectiveness of education compared to static images found in textbooks, photographs, and maps, as the teacher can emphasize the essence of a phenomenon and, if needed, supplement it with verbal explanations, creating a connection between the concept and the visual representation. This process is known as "mind mapping," which translates verbal material into a form graspable by visual memory [21]. Another benefit of employing non-verbal graphic communication (NGC) in education is that by sketching observed phenomena on the board, students learn to project three-dimensional (spatial) objects onto a two-dimensional plane and vice versa. Teachers often depict plane images from textbooks on the board and redraw them as three-dimensional objects, helping students understand the shape and arrangement of the depicted plane objects and their relationships more easily.

By actively and purposefully incorporating various types of graphic representations into the teaching process (NGC), students not only learn to create them but also develop the ability to interpret symbolic representations of real objects or phenomena (e.g., a schematic of a simple electrical circuit). Redrawing these representations from the board helps develop the previously mentioned spatial and abstract imagination, as well as abstract thinking, attention, visuomotor skills, estimation, precision, and patience. Therefore, integrating elements of non-verbal communication into the teaching process fosters the overall development of students' personalities and makes them graphically literate. As Rose [22] adds, freehand drawing is usually not taught as an essential skill, even though students often produce hand-drawn sketches for higher-level course assignments, depicting dimensions and design details. He suggests developing this aspect of graphic communication skills by practicing sketching through field and classroom tasks. These tasks not only improve students' ability to sketch but also enhance their approximation skills. Their sense of proportion, size, and arrangement of the depicted structures is developed [22], [23].

## 3. Approaches to Students' Graphic Literacy

In professional literature, there is no clear definition of the concept of graphic literacy. Koršňáková [24] defines it as the ability to perceive, process, and understand information presented in the form of various visual elements, such as images, sketches, symbols, diagrams, graphs, tables, and charts. Graphic literacy is also defined as 'the ability to both comprehend and draw graphs' [25]. As Sofo [25] points out, graphic literacy is an essential component of professional education. It is part of textbooks, manuals, and workshop guides. Despite this, the field of graphic literacy is considered neglected in both the content of education and in professional aspects. The same situation can be observed in education in the Slovak Republic.

Some authors limit the concept of graphic literacy to understanding and interpreting graphs and working with them. Proper interpretation of a graph often depends on the students' knowledge about graphs [26], [27], [28]. Ozmen-Guven and Kurak [29] perceive graphic literacy as the skill of students to understand graphs in a way that enables them to be successful and efficient in their lives. They emphasize the growing importance of graphs in all areas of our lives and express the opinion that there is a need to determine the level of students' graphic literacy in various aspects. Existing research generally examines aspects of reading, drawing, and interpreting graphs [26], [27], [28].

Important aspects in the mathematics curriculum also include comparing graphs, recognizing errors in graphs, and evaluating graphs [29].

Ozmen-Guven and Kurak [29] conducted a study on graphic literacy with a sample of 8th-grade students. They focused on examining three levels of graphic understanding based on Curcio's studies [28]: reading the data, reading between the data, and reading beyond the data. The evaluation of the research results revealed that the tested students were successful only in one level of graphic understanding, which was reading graphs. In reading between the data, students struggled to determine the relationship between the given data and desired more information about the graphs. Similarly, students achieved low scores in drawing graphs. The most common errors identified in drawing graphs were: incorrect choice of graph form, mistakes in scaling, and an inability to place the data correctly [29].

Curcio [28] also conducted research focused on understanding mathematical relationships expressed in graphs. The research sample consisted of students from the 4th and 7th grades. He examined whether prior knowledge of the topic, mathematical content, and graph forms were independent of understanding mathematical relationships expressed in graphs, as well as if graph reading comprehension depended on the student's grade or age. The research did not find significant differences in the observed abilities between boys and girls. Curcio recommends that elementary school students actively engage in collecting data from the real world and creating simple graphs.

Based on the findings, it is evident that the level of graphic literacy can be improved when students actively create and interpret graphs, extract necessary information correctly, and choose the appropriate type of graph. All these skills can be developed through training and practice.

Rose [22] also emphasizes the importance of graphic literacy and the need to develop students' ability to communicate graphically. His research focused on the communication skills of future civil engineers. According to his findings, hand-drawn sketches remain an essential tool used by civil engineers for graphically communicating technical information. However, he notes that new engineers often lack sufficient experience in hand-drawing sketches, which can hinder their effectiveness in graphically conveying information. While written and oral communication skills are paramount, he points out that graphic communication is also crucial when interacting with both technical and non-technical individuals.

The level of graphic literacy directly impacts students' success in problem-solving tasks that require extracting information from graphical data or where the student is expected to sketch a situation described in the problem or illustrate possible solutions [11], [22], [26], [27], [28].

## 4. The Relationship Between Students' Graphic Literacy and Their Scores in OECD PISA Testing

The achieved level of students' graphic literacy in primary school also influences the performance of Slovak students in OECD PISA testing, especially in tests of mathematical and scientific literacy. In mathematical literacy, students are expected to demonstrate: communication, representation/ presentation, strategy development, mathematization, reasoning, and argumentation, use of symbolic, formal, and technical language and operations, and utilization of mathematical tools [30]. In scientific literacy, students should be capable of recognizing, proposing, and evaluating explanations for a wide range of natural and technical phenomena; describing and evaluating scientific research and suggesting a scientific approach to answering questions; analyzing and evaluating data, claims, and arguments in various forms and drawing appropriate scientific conclusions [30].

From the evaluation of the PISA 2018 testing, it is evident that Slovak students have improved in mathematical literacy and achieved a score of 486, which is at the level of the OECD average (score of 489) [30]. The test tasks are designed in a way that requires students to apply their graphic competencies during problem-solving.

Figure 1 presents one of the released tasks from the 2012 test, assessing mathematical literacy [31].

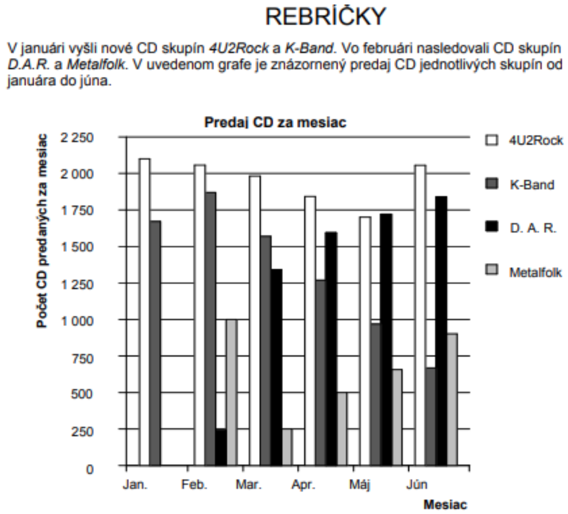



*Figure 1. Sample task from the PISA 2018 mathematical literacy test [31]*

The task was as follows: In January, new CDs were released by the bands 4U2Rock and K-Band. In February, the CDs of the bands D.A.R. and Metalfolk were released. The graph provided illustrates the sales of CDs for each band from January to June. The x-axis represents the Months, and the y-axis represents the Number of CDs sold per month. Students were required to determine how many CDs the band Metalfolk sold in April. They had the options A, B, C, and D to choose from. The task focused on reading information from a bar graph. 86.1% of Slovak students correctly solved the task, which is approximately at the average level of OECD countries (87.3%). Next, students were asked to determine in which month the band D.A.R. sold more CDs than the band K-Band for the first time. They had to read the bar graph and compare the heights of two columns. 74.8% of Slovak students answered correctly, which is 4.7% lower than the OECD countries' average. In the third part of the task, students had to evaluate the bar graph and estimate the number of CDs sold, assuming that the same negative sales trend for the K-Band continued. They had four options to choose the correct answer from.

The success rate was only 68.5%, and the difference compared to the average of OECD countries increased to 8.2% (OECD average = 76.7%). From this, it is evident that Slovak students face the same challenges with comparing values in graphs and interpreting graphical information as indicated in their previous works [26], [27], [28], [29].

In the area of scientific literacy, the average performance across OECD countries decreased to 489 points in the PISA 2018 cycle. Slovak students achieved a score of 464 points, which is below the OECD average [30]. By comparing the individual scores that Slovak students achieved throughout the testing period of scientific literacy, it is evident that the performance of Slovak students in this area does not show improvement – as shown in Figure 2.

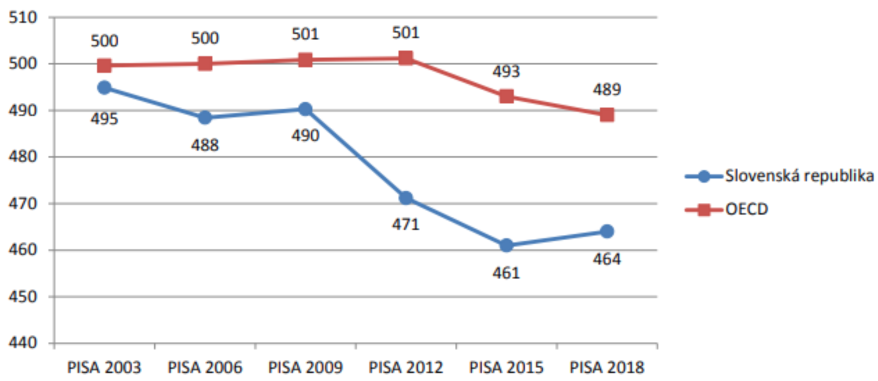
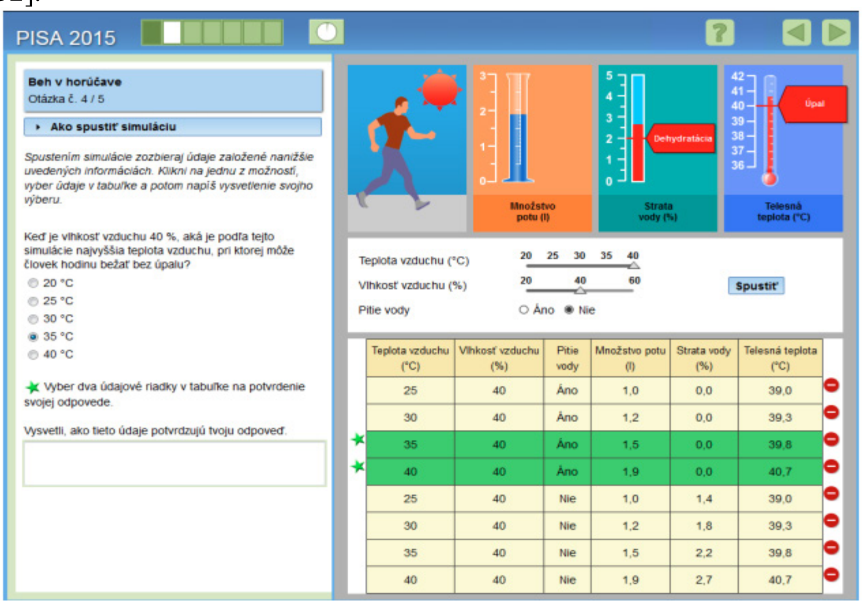



*Figure 2. The average score of Slovakia (SR) and OECD countries in scientific literacy in the individual cycles of the PISA study [30]*

Figure 3 presents a sample task from the released measurement of scientific literacy in the OECD PISA 2015 assessment [32].




| Teplota vzduchu (°C) | Vlhkosť vzduchu (%) | Pitie vody | Množstvo potu (l) | Strata vody (%) | Telesná teplota (°C) |
|---|---|---|---|---|---|
| 25 | 40 | Áno | 1,0 | 0,0 | 39,0 |
| 30 | 40 | Áno | 1,2 | 0,0 | 39,3 |
| 35 | 40 | Áno | 1,5 | 0,0 | 39,8 |
| 40 | 40 | Áno | 1,9 | 0,0 | 40,7 |
| 25 | 40 | Nie | 1,0 | 1,4 | 39,0 |
| 30 | 40 | Nie | 1,2 | 1,8 | 39,3 |
| 35 | 40 | Nie | 1,5 | 2,2 | 39,8 |
| 40 | 40 | Nie | 1,9 | 2,7 | 40,7 |

*Figure 3. Sample task from the PISA 2015 scientific literacy test [32]*

The student launched a simulation on the computer and, based on the data in the table, had to determine the highest air temperature at which a person can run for an hour without heat stroke, knowing that the air humidity is 40%. The student was also required to provide their answer in written form. The input information for the task was obtained by reading values from three graphical representations expressing sweat quantity (l), water loss (%), and body temperature (°C). The student also took into account the possibility that the person either drank water or did not drink water. Unfortunately, information about the success rate of students in solving this task was not available.

The success of students in solving this task depended on their ability to read graphical information, compare values given in tables, and interpret them correctly (in 2015, Slovak students ranked with a score of 461 below the average performance of OECD countries in scientific literacy).

## 5. Research on the Graphic Skills of 9th-Grade Elementary School Students

We have been focusing on the issue of the level of graphic skills of elementary school students in education, especially in the subject of technology, for a long time. In the years 2005 and 2007, we conducted testing on a sample of 5th to 9th-grade elementary school students [11], [33], [34]. In both tests, a separate test was created for each grade level, ensuring that the test tasks were based on the curriculum content for that specific grade. The test was divided into subtests that assessed various aspects of graphic skills (e.g., reading information, creating graphs, redrawing objects, etc.).

We conducted another testing of students' graphic skills in 2011. In this case, we used the same test for grades 5 to 9 of elementary school, which also consisted of subtests. The tasks in the test were not based on the curriculum content for each specific grade. The research objective was to examine how students' graphic skills improve during their education (considering the influence of students' development on their graphic skills). In the mentioned testing, in the subtest focused on solving graphic tasks, 9th-grade students achieved a success rate of only 16.20%. The same subtest was part of the testing for 9th-grade students in 2005, where the success rate in the same subtest was 40.30%. This result was significantly influenced by the introduction of the educational reform in 2008, which had a negative impact on technical education in elementary school.

To verify the validity of the results of our research in 2011, we compared our obtained results with the results of the nationwide Testovanie 9 from 2011. Students' success rate in graphic tasks in the nationwide Testovanie 9 was 19%, which means that there was no statistically significant difference between the results.

Based on the mentioned facts and the low scores that Slovak 9th-grade students achieve in the OECD PISA testing, in 2021, we once again examined the level of graphic skills of Slovak 9th-grade students. The reason for this testing was to determine whether the further educational reform from 2015 had an impact on the development of graphic skills of elementary school students. The testing of students was originally planned for the end of the 2019/2020 school year. This would ensure that the tested students were educated only according to the educational reform that came into effect in the 2015/2016 school year. However, the original plans were altered due to the global pandemic, and as a result, we conducted the testing in 2021.

It is evident that at the level of students' graphic skills, besides the educational reform of 2015, the impact of the global COVID-19 pandemic can also be observed, which affected the education of students at all levels of schools. Education was conducted in the online space and was limited by several factors: computing technology, inadequate internet connectivity, inexperience with online learning, and others. The teaching subject of technology, which is the main area of our research, was not taught at all during that period in the Slovak Republic, and even in other science subjects (such as mathematics, physics), it was not possible to carry out practical activities that would contribute to the development of students' graphic skills.

We posed research questions: Does the educational reform and online education have a negative impact on the level of graphic skills of 9th-grade elementary school students? Is there a statistically significant difference in the level of graphic skills between the results of girls and boys?

The research sample consisted of 92 students from four elementary schools (boys - 41; girls - 51). The research tool used was a test that was also used in previous tests in 2005 and 2007. The test tasks were designed in a way that they were based on the prescribed curriculum but presented in different types of exercises than what students were accustomed to in their regular school lessons. The test consisted of ten tasks, and each task was scored on a scale of 1 to 5 points, depending on the difficulty level and the parameters being observed. The total possible score was 18 points. The tests were anonymous, and the students were given a time limit of 45 minutes to complete them.

Each task was focused on various aspects related to students' graphic skills, including testing the level of perception, testing graphic skills, testing the acquisition of concepts and their application in tasks, testing the ability to manipulate objects in imagination, and testing the level of acquisition of necessary graphic skills for solving geometry tasks. All these aspects were assessed through multiple tasks in the test.

## 6. The Evaluation of the Research and Interpretation of the Results

We decided to compare the results obtained from testing in 2021 with the students' performance in 2007 when they achieved an overall success rate of 52.51%. In 2007, 21 students participated in the testing (G – 14, B - 7).

To address the research questions, we set the following null hypotheses:

$H_{01}$: There is no statistically significant difference in the scores of the graphic skills test between the results of the 9th-grade students in 2007 and 2021. Against the alternative hypothesis:

$H_{A1}$: There is a statistically significant difference in the scores of the graphic skills test between the results of the 9th-grade students in 2007 and 2021.

$H_{02}$: There is no statistically significant difference in the scores of the graphic skills test between the girls and boys in the 9th grade (in 2007 and 2021).

Against the alternative hypothesis:

$H_{A2}$: There is a statistically significant difference in the scores of the graphic skills test between the girls and boys in the 9th grade (in 2007 and 2021).

An overview of the scores obtained in the individual tests is presented in Table 1.

*Table 1. Overview of test scores in 2007 and 2021*

| | | mean | median | st. devation | Count |
|---|---|---|---|---|---|
| 2007 | G | 9,82 | 10 | 3,58 | 14 |
| | B | 8,71 | 8 | 4,11 | 7 |
| | together | 9,45 | 10 | 3,70 | 21 |
| 2021 | G | 10,76 | 11 | 3,76 | 51 |
| | B | 8,95 | 9 | 3,82 | 41 |
| | together | 9,95 | 10 | 3,88 | 92 |

*Notice: G - girls, B – boys*
*Source: authors*

We can also observe the comparison of test scores in 2007 and 2021 in Figure 4. It is evident that the medians of both datasets are the same, and the averages are approximately at the same level, with a slightly higher average visible in 2021. Additionally, in this year, we can see a larger variation in the spread of values.

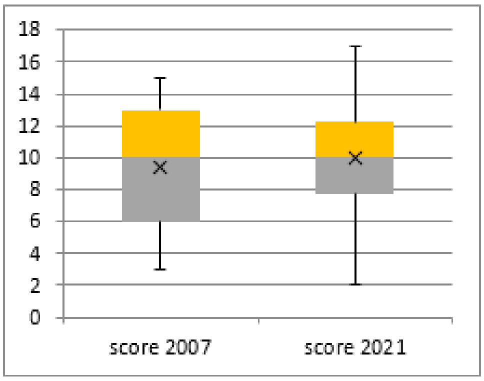



*Figure 4. Box-plot for the scores achieved in the graphic skills test in the years 2007 and 2021*

Based on the results of the Shapiro-Wilk test of normality (2007: W=0.94, p=0.26; 2021: W=0.97, p=0.04), we choose the non-parametric Mann-Whitney test to compare the means. At a significance level of 0.05, the p-value of this test is 0.63, which means that we do not reject the null hypothesis. Therefore, there is no statistically significant difference in the scores of 9th-grade students between the years 2007 and 2021. Thus, we can conclude that there is no evidence of a negative impact of online education on the level of graphic skills of 9th-grade students in primary school.

Based on the results of the Shapiro-Wilk test of normality for girls (W=0.95, p=0.56) and boys (W=0.95, p=0.77) in 2007, we conducted a parametric independent two-sample t-test to test the differences between girls and boys. The p-value for the t-test is 0.56, which indicates that we do not reject the null hypothesis H02 (2007) of the equality of scores for girls and boys in the 9th grade in 2007.

Based on the results of the Shapiro-Wilk test of normality for girls (W=0.95, p=0.04) and boys (W=0.95, p=0.07) in 2021, we conducted a non-parametric Mann-Whitney test to compare the differences between girls and boys. The p-value for the Mann-Whitney test is 0.04, which means that we reject the null hypothesis H02 (2021) of the equality of scores for girls and boys in 2021. Therefore, their scores can be considered statistically significantly different. Specifically, the 9th-grade girls achieved statistically significantly higher scores in the graphic skills test compared to the 9th-grade boys.

## 7. Evaluation of Selected Tasks on Students' Graphic Skills

For testing graphic skills, the test focused mainly on tasks 1, 5, 6, and 8. We evaluated these tasks separately as well.

In task number 1, students were asked to draw the position of the Earth during a solar eclipse and depict the direction of light (Fig. 5).

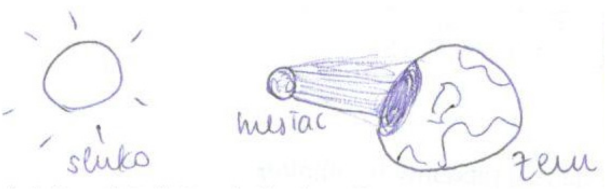


*Figure 5. Sample solution of task number 1 (girl)*

The task was evaluated for 2 points. During its completion, students were required to use interdisciplinary connections. The assessment criteria included the accuracy of the position of the Earth, Sun, and Moon; their proportional representation, and the indication of the direction of light/shadow. In the year 2007, the success rate for solving the task was 26.19% (boys - 16.67%, girls - 42.86%). In the year 2011, the success rate was 44.02% (boys - 76.47%, girls - 67.07%). Comparing the results, there is a statistically significant difference in solving task number 1 in favor of the students from 2021. Improvement can be observed both among girls and boys. While in 2007, boys were more successful in solving the task, in 2021, it was the girls who performed better.

In task number 5, students were required to draw the elevation, side view, and plan view of an object in the correct placement (Fig. 6). The task assessed the ability of students to depict spatial objects according to the principles of orthogonal projection in technical drawing. It was evaluated for 3 points. The assessment criteria included correctly drawing all three views of the object, their proper placement on the plane, accuracy of dimensions, and shapes of representation.

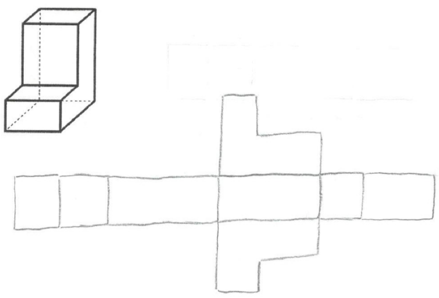


*Figure 6. Sample solution of task number 5 (boy)*

In Fig. 6, we see an incorrectly solved task; nevertheless, the student demonstrated the ability to mentally manipulate the object (drew a wireframe of the object), and we positively acknowledge his ability to perceive shapes and the arrangement of the object's forms.

The overall success rate for solving task 5 in 2007 reached 49.21% (girls - 55.56%, boys - 28.57%), while in 2021, it was only 30.07% (girls - 41.83%, boys - 32.52%). We observe a decrease in success rate to the disadvantage of the year 2021.

In both observed years, girls were more successful in solving the task. However, in 2021, their success rate was lower by more than 13%, while boys showed a slight improvement.

Students' ability to create graphs was tested in task number 6, where they were asked to draw a suitable graph based on given temperature and time values (Figs. 7, 8).

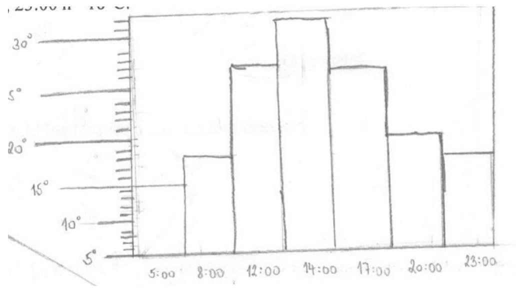



*Figure 7. Sample solution of task number 6 (girl)*

In Figure 7, it can be seen that the girl placed the values at the origin of the graph axes. This was a common mistake in graph creation. Out of the entire research sample, only one student (a boy) used a line graph type (Figure 8), which we considered the most suitable type as it can express the smoothness of temperature changes throughout the day. As seen in the figure, the student did not utilize this property of the graph.

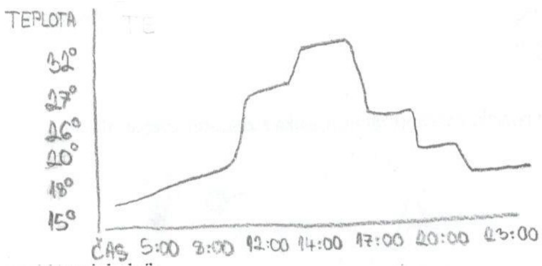



*Figure 8. Sample solution of task number 6 (boy)*

For a correct solution to the task, students could obtain 2 points. The evaluation criteria were selecting an appropriate graph type and correctly representing the data on the graph. The overall success rate for solving the task in 2007 was 69.05% (girls - 56.67%, boys - 85.71%). However, in 2021, the success rate was significantly lower, only 35.33% (girls - 74.51%, boys - 52.44%). Comparing the success rates of girls and boys, it is evident that in 2021, the success rate of girls increased, while the success rate of boys decreased by more than 30%.

Task number 8, in our opinion, was the simplest for students as they could apply their knowledge from mathematics, physics, and technology. Solving the task did not require higher-level thinking operations from students as they only had to draw and label familiar shapes: a cone, cylinder, and cuboid.

For drawing and naming each shape, a student could earn 1 point, totaling 3 points for a correct solution. The student needed to demonstrate the ability to accurately depict the shapes on the plane to make them easily identifiable. In Figure 9, we can see the correct solution. The student connected the terms given in the task with the drawn shapes graphically using lines.

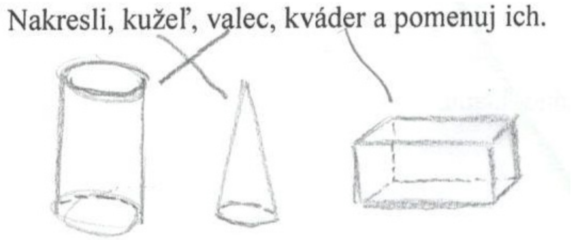



*Figure 9. Sample solution of task number 8 (girl))*

The overall success rate for solving task number 8 in 2007 was 61.90% (girls - 60.00%, boys - 57.14%). However, the success rate for solving the same task in 2021 was only 21.45% (girls - 27.45%, boys - 24.39%). In both years, girls and boys achieved comparable performance levels.

We also tested the overall data (girls and boys combined) using the Shapiro-Wilk test. The normality of the input data files was not confirmed; therefore, the differences in the obtained points for individual tasks between the years 2007 and 2021 were tested using the non-parametric Mann-Whitney test (Table 2).

*Table 2. The results of the non-parametric Mann-Whitney test*

| | 2007 | 2021 | Mann-Whitney |
|---|---|---|---|
| Task 1 *(max. 2 points)* | Mean = 0,52<br>Median = 0 | Mean = 1,45<br>Median = 2 | **p < 0,001** |
| Task 5 *(max. 3 points)* | Mean = 1,48<br>Median = 1 | Mean = 1,13<br>Median = 1 | p = 0,19 |
| Task 6 *(max. 2 points)* | Mean = 1,38<br>Median = 2 | Mean = 1,29<br>Median = 2 | p = 0,69 |
| Task 8 *(max. 3 points)* | Mean = 2,38<br>Median = 3 | Mean = 2,32<br>Median = 3 | p = 0,37 |

From Table 2, it is evident that a statistically significant difference in the obtained points by 9th-grade students was observed only in the first task, favoring students in 2021.

## 8. Conclusion

The research was focused on determining the level of graphic skills of 9th-grade students in the basic sample.

The selection of the research sample was influenced by the fact that it is the final year of compulsory school attendance in Slovakia, and students are expected to have acquired all the necessary competencies for successful studies at various types of secondary schools (such as grammar schools, conservatories, vocational schools, etc.).

Graphic skills are a significant communication tool in education. This applies not only from the students' perspective but also from the teachers' perspective. It is necessary to pay attention to the graphic skills of future teachers during their pre-graduate preparation. They should also acquire communication competencies related to the preparation and creation of visual sketches and images. Their ability to communicate with students through visual images also manifests in the effectiveness of education, especially for students preferring a visual learning style.

From our research, it is evident that in the year 2021 (34.84%), the success rate of students in the test for graphic skills was lower compared to the year 2007 (52.51%). Despite this finding, it is not possible to conclusively state that the graphic level of students significantly decreased compared to the testing in 2007. On one hand, this difference could be influenced by the fact that in 2007, only 21 students were tested, while in 2021, there were 92 students. On the other hand, the results of the non-parametric Mann-Whitney test demonstrated that there was no evidence of a negative impact of the educational reform in 2015 or online education during the COVID-19 pandemic on the graphic skills of 9th-grade students in Slovakia.

Differences in the level of graphic skills between girls and boys were tested using the non-parametric Mann-Whitney test. In 2007, no statistically significant difference in graphic skills was found between girls and boys. However, in 2021, there is a statistically significant difference in the level of graphic skills between girls and boys, indicating that girls outperformed boys in this aspect.

The most common causes of students' failure in the 2021 testing were insufficient mastery of the theoretical content of education. It was also evident that students were unable to select the appropriate graph type, used incorrect axis labeling in graphs, and were not able to plot the described phenomenon accurately. When creating graphs, students most commonly use bar charts.

The research on graphic skills has resulted in the demand for actively incorporating tasks into the education of elementary school students that require demonstrating solutions, plotting solution processes, or obtaining information in graphic form.

The analysis of the test tasks highlights deficiencies related to maintaining proportions and shapes of plotted objects and phenomena. In education, it is necessary to pay attention to the given area. To improve the understanding of dimensions and representation of reality, it is advisable to incorporate field tasks and classroom exercises into students' education.

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