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Ivana Sotáková, Petra Letošníková

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Selected Papers

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Science Education Research, Innovation and Digital transformation of STEM education

EDITORS

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

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

1. Introduction

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

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

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

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

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

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

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

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

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

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

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

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

Present information in the form of a graph (e.g., pie, column, continuous, climate graph, age/food pyramid, etc.)	The pupil can say whether it is possible to create a graph from the given data (e.g., in a table).	The pupil can create a suitable graph or add the required data to the graph according to the instructions or an analogous example.	The pupil can design and create the most suitable type of graph from the given data (e.g., in a table).	The pupil processes and presents data not required in the past (e.g., from field research) in graphs.

But what are the possibilities and ways of developing pupils in the particular areas of working with graphs? Considering the studies devoted to this issue, we find several of them (Al-Balushi & Al-Aamri, 2014; Farárik, 2022; Gillette, 2015; Karolčík et al., 2018). When increasing graphic literacy, it is necessary to look at the issue from two points of view. First of all, it is necessary to teach pupils to read graphs, understand them, and know how to connect information from them and see connections. An understanding of graphic language is a prerequisite. Therefore, the teacher's first step should be to teach the meaning-making systems of graphic representations, such as the importance of headings, labeling of axes, the meaning of colors, and the appropriate type of graph. Only afterward is it possible to move on to work with information explicitly or implicitly expressed in the graph? A suitable strategy to support pupils when working with graphs is the use of unfinished sentences (e.g., This graph shows ...; The x-axis represents ...; The difference between the data in the red and blue columns is ...; The data that interested me the most was ...; Based on the information in the graph, I expect that will happen...; My prediction is supported by data... etc.). As pupils become more adept at interpreting data independently, they can be provided with frameworks to help structure the analysis of the graphs (e.g., introduction, highlights, anomalies, trends, conclusions, and recommendations). Research by Bursal and Yetis (2020) revealed that seventh-grade elementary school pupils have a significantly higher personal perception of graphic literacy for bar graphs than for line and pie graphs. These are more difficult to understand because they require more abstraction, such as proportional reasoning in pie charts and understanding trends of continuous variables in line charts (Tiefenbruck, 2007). Therefore, it is recommended to start working with bar graphs. It is also essential that pupils have ample opportunities to explain and justify their reasoning and receive feedback from others. Therefore, activities in pairs or small groups are recommended (Ozmen et al., 2020). The second point of view is that it is necessary to teach pupils to look for important information in continuous text or tables and to be able to process them in the form of a graph. Pupils' skills to work with information in graphs requires specific essential and integrated abilities of scientific work (e.g. Held et al., 2011), e.g. observing, judging, classifying, interpreting data, controlling variables and describing relationships between them. IBE is aimed at their development. Therefore, pupils can be more successful in classes with this education concept (Ganajová, 2016; Nicolaou et al., 2007; Picone et al., 2007).

4. Goals and research methods

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

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

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

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

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

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

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

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

Note: PT – Partial Task

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

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

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

5. Results

The result of the data analysis from a questionnaire survey (N=56), focused on the frequency of using graphs within the two dominant teaching strategies (TTM vs. IBE) and within individual educational subjects, is that pupils in the class with IBE work on these subjects with graphs much more often, even though the educational program ExpEdícia – try, explore, learn is not explicitly focused on the development of this skills in the subjects of geography and biology. We found that pupils in the classroom with TTM hardly work with graphs in geography and biology (on average, only 9.4% of pupils said that they only "sometimes" work with graphs). This is also related to the frequency of use of individual levels of skills to work with information in graphic form (reading, interpreting, analyzing, creating graphs), then pupils from the class with IBE devoted themselves to these levels several times more often. On the contrary, the frequency of working with graphs in mathematics classes was more significant in the class with TTM than in the class with IBE. In both groups, however, the assumption that pupils solve graphic tasks much more often in the subject of mathematics than in the subjects of biology and geography was confirmed (Fig. 1). Regarding the perception of their abilities when working with graphs, pupils with TTM evaluated them somewhat more positively (76.75% of pupils almost always or often understand graphs and can solve tasks in which graphs are found). Pupils with IBE chose these options in 70.56%.

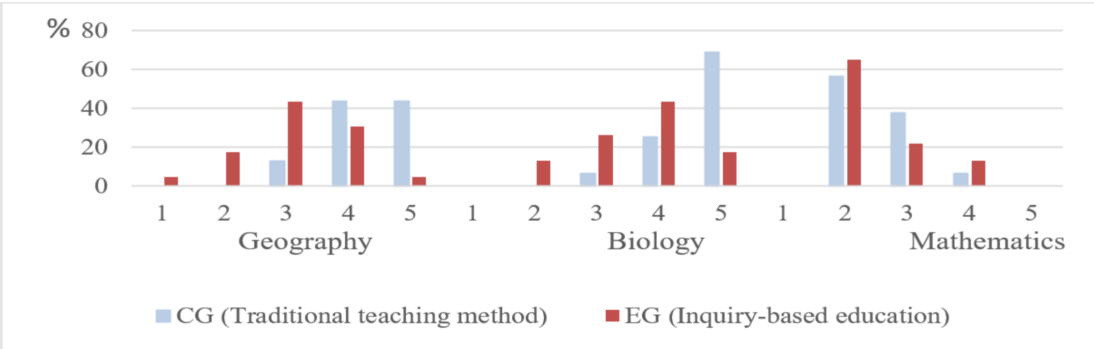

Figure 1. Frequency of working with graphs in the lessons of geography, biology, and mathematics in the classroom with TTM and IBE, explanations: 1 – almost always, 2 – often, 3 – sometimes, 4 – mostly not, 5 – almost never.

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

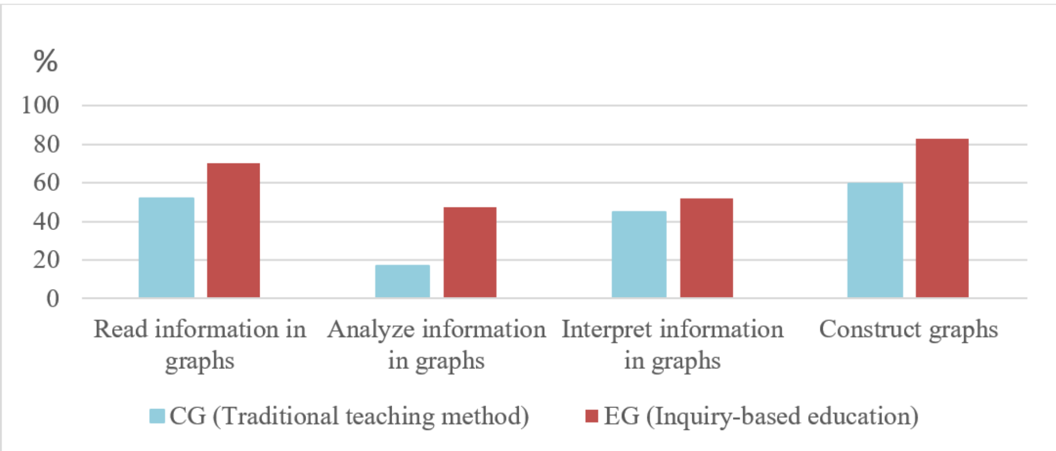

Figure 2. Pupils' success in tasks focused on individual areas of working with graphs.

The lowest level is the skills **to read from the graph the information that is explicitly marked on it**, for example, "In which location did the scientists find the most ticks?", "In which year was there the fewest ticks?" (Task no. 1), "What was the number of tick-borne diseases encephalitis between 2010 and 2012?" (Task no. 6). Pupils often had problems finding and understanding the connections between the question and the data in the graph, even when they were explicitly stated in the graph. Other mistakes were that the pupils did not notice the marking of the axes, wrote their judgments in the answers, not the information they could read from the graph, and added up the found values for no reason. When comparing research samples, EG (IBE) achieved a higher success rate (average score 70.3%) than CG (TTM) (average score 51.85%).

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

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

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

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

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

6. Discussion and conclusion

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

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