The Role of STEM Education in Developing Knowledge and Skills of Primary School Students

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Abstract

The article focuses on the issue of STEM education as an effective teaching method for utilising interdisciplinary relationships. In current education, significant attention is paid to this issue, as STEM education develops students' creativity, technical thinking, and the ability to assess and articulate conclusions. The knowledge and skills acquired by students in solving tasks arising from the application of STEM education are further reinforced by using experiments focused on exploring the properties of materials that students work with. The article presents options for integrating experiments into STEM education in school practice.

Keywords: Experiment, Primary school, STEM education

1 Introduction

The Slovak Republic emphasises implementing innovative teaching methods in educating elementary and high school students. The rapid development and advancement in science and technology influence the necessity of using innovative methods in education, leading to higher demands in student education. Among the benefits associated with the use of innovative education methods is the fact that they motivate students to learn. Students become engaged in problem-solving, working in groups, communicating, presenting their opinions, and applying creativity.

The STEM education program can be classified among the innovative methods of education primarily applied in teaching natural science and technical subjects at primary and secondary schools. The STEM acronym represents four scientific disciplines: S - science, T - technology, E - engineering, and M - mathematics. STEM is an educational approach that prepares primary and secondary students for college, graduate study, and careers in science (Lutkevich, 2022).

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2 STEM Program - Interdisciplinary Approach in Teaching Natural Sciences

In the Slovak Republic, there has been a long-standing lack of interest among students in pursuing studies at technically oriented high schools or universities (Pavelka, 2019). This trend is observable worldwide (Niculae & Niculae et al., 2011). The choice of future careers is closely linked to students' attitudes and interests in individual subjects taught.

Natural science subjects are considered uninteresting and distant from everyday life by students (Sjøberg, 2001; Herich, 2015; Fankovičová & Kubiatko, 2015; Niculae & Niculae et al., 2011; Bellová, 2021). Students cite these subjects' difficulty and perceived insignificance in their lives and future professions as reasons for their lack of interest (Sjøberg, 2001). The lack of interest in science among young people is also influenced by how science is taught in schools (Niculae & Niculae et al., 2011). Teachers play a crucial role in this regard. Fankovičová and Kubiatko (2015) found that students' interest in natural science decreases as they age. Similar conclusions were drawn in the research conducted by Veselský (1999; 2009). The most significant decline in interest in natural science subjects was observed during students' transition from primary to secondary school.

The problem of teaching natural science subjects in schools aligns with the fundamental issue of science itself: the comprehension of the world and nature.

2.1 STEM Education - Preparation of Future Technology Teachers

Besides the low interest of students in natural science disciplines, research has shown a decrease in students' knowledge levels in natural science subjects at the end of primary and secondary school (Niculae & Niculae et al., 2011). Effective interventions supporting improving students' attitudes toward natural science subjects require changes in the curriculum content and teaching strategies. The lack of interest among students in science and technology-oriented careers is one reason for implementing the STEM program in the education of natural science disciplines (Bellová, 2021). Substantial attention has been given to the issue of STEM education in the professional literature (Margot & Kettler, 2019; Bellová, 2021; Pollard et al., 2018; Stohlmann, Moore et al., 2012). STEM education encompasses the content, skills, and ways of thinking of each discipline and an understanding of the relationships between disciplines and how they support and complement each other (Pollard et al., 2018). Bellová (2021, p. 12) states,' in many developed countries, interdisciplinary education in natural science subjects is preferred.'

As mentioned, teachers play a significant role in motivating students. Therefore, it is necessary to orient the content of education at universities, preparing future teachers of natural science disciplines for STEM education. After completing their studies, future teachers should have adopted appropriate teaching practices for effectively using the STEM program.

They should be capable of preparing suitable teaching materials to aid in learning natural science subjects, utilising the STEM program.

Employees of the Department of Technology and Information Technologies at the Faculty of Education in Nitra, as part of the international STEMkey project, innovated the educational content for students - future teachers of technical subjects in primary schools. Through innovative educational content, students learn to utilise interdisciplinary relationships between natural science subjects in solving assigned tasks.

During their studies, they work with sample materials for STEM education. One of the projects focusing on interdisciplinary relationships between natural science subjects was the design of a water reservoir and water purifier for a mountain chalet. The task worksheets represented all four areas of the STEM program (science, technology, engineering, and mathematics). The field of science explored solutions for ensuring water supply to the mountain chalet, ensuring it was helpful and drinkable. Technology was essential in designing materials for the implementation of the technical solution. Engineering represented the area of constructing the water purifier itself. Mathematical knowledge was applied in calculating the costs required for project implementation. The output of the STEM education project was the implementation of the proposed water purifier and verifying its functionality (Fig. 1).

Figure 1: Implementation of the design for a rainwater collection container and a water purifier made from recycled materials (Source: author)

During the project implementation, interdisciplinary relationships were applied between natural science subjects such as Biology, Physics, Chemistry, Ecology, Computer science

(programming the designed device using the microbit Smart Home Kit), Technology, and Mathematics.

2.2 Experimentation as a Part of the STEM Program

STEM education in primary schools enables students to be active in solving assigned tasks or projects. By utilising knowledge and skills from multiple natural science subjects, students gain a sense of satisfaction and self-realisation. Their relationship with these subjects deepens (Niculae & Niculae et al., 2011). They perceive the connection between theoretical information and its practical application. They discover new problem-solving methods and explore differences in tackling tasks, considering alternate approaches, materials, and more. They learn to experiment. Experimentation is a method that enhances students' acquisition of knowledge and skills while simultaneously developing their logical thinking (Porubská & Plavčáková, 2016). The goal of an experiment is to practically test new ideas, collect data, and evaluate it to make decisions based on information. Inquiry-based learning often employs experiments (Wörner & Kuhn et al., 2022). Through conducting experiments, students must actively engage in problem-solving and take responsibility for their learning process to discover relationships between variables and build new knowledge (de Jong & van Joolingen, 1998).

Several types of experiments are used in school practice (Mautushi, 2023): laboratory experiments, exploratory scientific experiments, practical scientific experiments, and field scientific experiments (Fig. 1).

Laboratory experiments are most used in Technology at the elementary school level. However, it is beneficial also to incorporate exploratory and practical scientific experiments. Mautushi (2023) states that teaching science through practical experiments is effective. Practical projects help students grasp scientific concepts and processes, allowing them to envision how these concepts function in the real world. By carrying out practical experiments, students understand that their knowledge can be applied beyond school activities (tests and homework).

The implementation of experiments in education is supported by the fact that they enhance students' vocabulary, enable teachers to access students' knowledge, provide students with opportunities for design and implementation, teach students responsibility, offer practical experiences, connect learning with action, develop their critical thinking, and a sense of accomplishment (Mautushi, 2023).

Figure 1 describes various experiments suitable for student education in Lab experiments, Exploratory Lab experiments, Practical Science Experiments and Fieldwork Science Experiments.

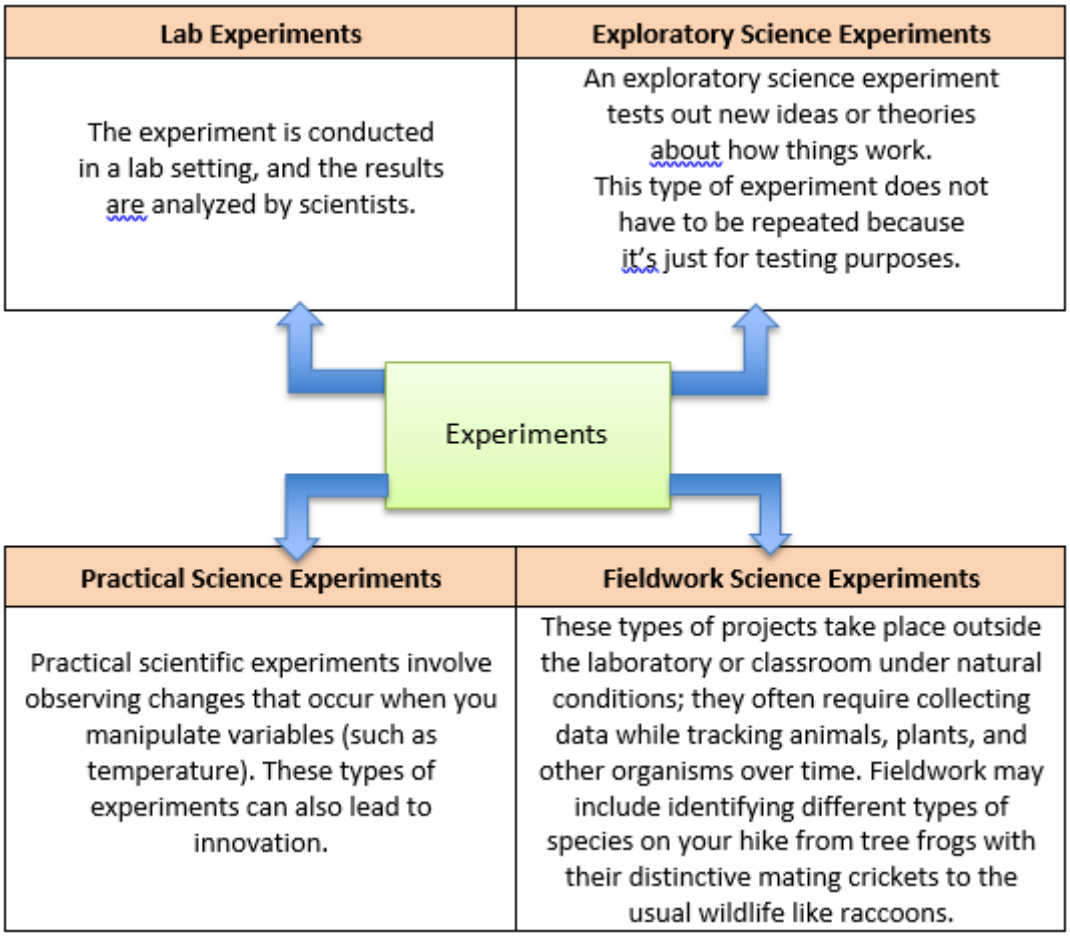

Figure 1: Types of experiments suitable for student education (Source: author)

3 Example of using experiments in carrying out tasks within the STEM program in the subject of Technology at Primary School

Technology is a mandatory part of the curriculum in the Slovak Republic. It was established as a platform for understanding technology and human creative activity in a broad context. Consequently, Technology can serve as a catalyst for developing inter curricular connections, primarily (though not exclusively) between technical and natural science subjects, as traditionally understood in their mutual connections. Table 1 provides an overview of the cross-curricular relations between natural science subjects and the subject of Technology based on an analysis of the SEP for ISCED 2.

Table 1: Cross-curricular relations with the subject technology in the ISCED 2

Subject	Topical units in the given subject	Topical unit in the subject technology	Topical unit in the subject technology
Biology	Life conditions and relations of organisms	People and technology	positive and negative impacts of technology
Physics	Work. Energy	Technology – household – safety	household heating
	Magnetic and physical phenomena	Electric power	simple electrical circuits, schematic wiring diagrams
Chemistry	Organic matters, Chemistry around us, Important chemical elements, and their compounds	Material matters and technologies.	knowledge of basic kinds of technical materials and their characteristics
Informatics	Principles of ICT operation	Graphical communication	use of the software for design activities
Mathematics	Geometry and measurement	Graphical communication	preparation of technical sketches

From the analysis results (Table 1), the subject technology offers many possibilities to create meaningful and purposeful inter-curricular relations with the natural science subjects.

Within the framework of the "Teaching standard STEM topics with a key competence approach (STEMkey)" project and the KEGA project No. 006UMB-4/2022, we have designed activities for STEM education incorporating experiments in the subject of Technology at the primary school level. Our article focuses on a specific task for students in the 8th and 9th grades of primary school (ages 14 to 15). This task is a practical experience for future technology teachers, demonstrating how to implement STEM education in elementary schools. It involves designing a system to provide water supply to a mountain cabin in an area without a natural water source. Solving this task requires students to follow a sequence of steps. Students can access worksheets focusing on different STEM areas for each solution step. In total, six worksheets are developed:

- Worksheet Topic introduction,
- Worksheet Problem to be solved,
- Worksheet Water distribution system,
- Worksheet Model of the water distribution system,
- Worksheet Model of the sand filter,
- Worksheet Financial literacy.

The worksheets follow a consistent structure. Each begins with a designated activity to be solved, for example: "How to provide water for an inherited house?" The worksheet describes the problem and requirements the student must consider while addressing. Students are allotted a specific time to solve the task (20 minutes for the given activity). As students propose solutions, there is room for experimentation. Laboratory, exploratory, and practical scientific experiments have proven to be the most suitable. Within the task's solution, students must propose methods to capture rainwater, transport it to the cabin, ensure its distribution, select the most appropriate material for project implementation, decide on water filtration methods, and ensure the water's drinkability. Figure 3 illustrates an example of a proposed water pumping system from the collection container to the filtration device.

Figure 3: Example of a water pumping system design using the micro: bit Smart Home Kit.

Each partial task requires students to effectively use knowledge from all natural science subjects and practical skills. Students undergo the development of critical thinking and communication skills and utilize analysis, synthesis, and deduction in solving experiments. They learn self-assessment and conclude. Teachers can observe students' thought processes, gaining access to their knowledge and ability to apply it in new situations.

4 Conclusion

In primary schools in the Slovak Republic, the attention given to STEM education is not as significant as in developed countries that prioritise interdisciplinary education in natural science disciplines (Bellová, 2021). Natural science subjects are taught in isolation, causing students to struggle to apply the acquired information in everyday life. In our article, we presented possibilities for utilising STEM education in Technology. Students become active and motivated in their learning by solving specific practical tasks. One of the reasons for the underutilisation of STEM education in primary schools is the lack of competence among natural science teachers to employ interdisciplinary relationships among these subjects

effectively. Published research has shown that 32% of teachers lack sufficient knowledge in the second teaching subject. Furthermore, 51% of teachers identified it as a significant deficiency that similar topics are not covered simultaneously in natural science subjects (Bellová, 2021, p. 15). Improving the current situation can be achieved by integrating STEM education topics into the study plans of future teachers of natural science subjects at the primary school level, specifically aiming to develop their competence in this area.

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