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HOW HIGH SCHOOL STUDENTS ASSESS THE IMPORTANCE OF STEM WORKSHOPS FOR ACQUIRING NEW KNOWLEDGE[1]

Aleksandar Milenković*
Faculty of Science, University of Kragujevac, Kragujevac, Serbia

Aleksandra Maksimović
Faculty of Science, University of Kragujevac, Kragujevac, Serbia

Dalibor Rajković
Faculty of Science, University of Kragujevac, Kragujevac, Serbia

Dragutin Ostojić
Faculty of Science, University of Kragujevac, Kragujevac, Serbia

Abstract: Striving to support students in choosing to study STEM subjects more intensively, one of the challenges for a teacher is to create an educational environment in which students can acquire new theoretical and practical knowledge and improve and enrich their competencies. Within the implementation of the STEM workshop *Mission (Im)possible*, first and second grade high school students, aged 15 and 16 (N = 108), were introduced to the basic cryptography concepts, lasers, sensors, various electronic components, their connections, and programming. Through group work, within a supportive environment and competitive atmosphere, students created an alarm system to protect a document with a previously encrypted message. After the workshop, participants took part in a survey, through which they expressed their agreement using a five-point Likert scale regarding statements related to the educational nature of the implemented workshops. The focus of the research is to determine to what extent students agree with the three statements: 1) I acquired new knowledge in mathematics, physics, and computer science during the workshop; 2) I believe that this way, I can learn more compared to traditional teaching methods; and 3) I believe that the activities during the workshop are significant for my education. Since the mean scores for all three statements were higher than 4.2, it can be concluded that students completely agree with all three statements on average. The results support the idea that STEM workshops can be

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* aleksandar.milenkovic@pmf.kg.ac.rs

designed and implemented to be accessible to students and that they can recognize their educational character.

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INTRODUCTION

Encouraging students' interest and motivating them to become more involved in studying content in the field of natural sciences is one of the most current topics among researchers and practitioners in education, as well as educational policy-makers globally (Committee on STEM Education, 2018; Japan Society for STEM Education, 2018; Japashov et al., 2022; John et al., 2022; Luo et al., 2021). However, certain paradoxes have been observed**:** although modern social, economic, and technological circumstances indicate the need for more experts in STEM fields, research shows that students' interests in subjects within these areas have been continuously declining (OECD, 2008). For instance, in Australia, students' interests, particularly in mathematics, but also in biology, chemistry, and physics have significantly declined over the past 20 years, accompanied by a loss of students' confidence in engaging with these subjects (Thomson et al., 2017).

In that context, the question arises regarding the approach to teaching STEM subjects and the possibilities of using an integrated approach to engage and empower students to further participate in these fields. Over the past few decades, in Western countries, there has been an insistence on the functional use of knowledge from the teaching of natural science subjects and the creation of an integrated curriculum in these areas. The term "Integrated STEM education" is defined as an approach that combines teaching and learning from: a) two or more STEM subjects or b) one STEM subject and one or more subjects from other areas (Sanders, 2009). With the idea that real-world problems are rarely solved using knowledge from a single subject, teaching and learning based on specific connections between natural science subjects are promoted (Chiriacescu et al., 2023; Kelley & Knowles, 2016; Sanders, 2009; Stohlmann et al., 2014; Wieselmann et al., 2020).

Students' participation in STEM workshops significantly enhances their interest, knowledge, and practical skills in STEM fields, supporting their academic and personal development. For instance, students who attended computer science workshops reported an increase in interest of nearly half a point on a five-point Likert scale, with more than two-thirds expressing a desire to continue learning programming (Bruckhaus et al., 2024). In addition to better interest, students demonstrated substantial gains in domain-specific knowledge, with average scores improving from nearly 64 to 88 points (out of 100) after participating in the workshops (Bruckhaus et al., 2024).

Beyond acquiring new knowledge, STEM workshops emphasize learning through practical activities and projects, strengthening students' conceptual understanding and enhancing their problem-solving and critical-thinking skills. Such hands-on experiences are particularly beneficial for students who demonstrate talent in STEM fields, as they foster the ability to apply acquired knowledge to real-world challenges (Wu, 2019).

Research also highlights the effectiveness of STEM learning through projects and workshops in supporting students with lower performance in mathematics, as these students show greater progress in mathematical competencies compared to their peers with higher and medium achievements (Han et al., 2015). Additionally, integrated STEM education allows teachers to better observe and support individual student progress (Priatna et al., 2020).

Active learning, which is present in STEM workshops, leads to greater effectiveness in promoting long-term retention of knowledge and encouraging positive emotional responses from students compared to traditional teaching methods. This approach to learning through active participation not only enhances cognitive understanding but also fosters a positive attitude toward STEM fields (Mateos-Núñez et al., 2020). STEM programs and workshops that emphasize the application of knowledge in real-world settings and engaging activities have shown significant increases in students' motivation, engagement, and intentions to pursue STEM careers (Chittum et al., 2017).

In summary, STEM workshops, especially those focused on active learning, play a crucial role in improving students' academic achievements, increasing their interest in STEM careers, and enhancing their ability to apply acquired knowledge.

This research focuses on promoting an integrated approach to knowledge in mathematics, physics, and computer science, as essential areas for acquiring the knowledge and skills necessary for successful engagement in numerous activities in modern society, but also as a foundation for motivating students to further engage in related fields and possibly consider a career in the STEM fields themselves (Smith, 2011; Shwartz et al., 2021)

RESEARCH QUESTIONS

The research question is whether and to what extent students in the first two years of high school consider STEM workshops, designed, and implemented so that students learn about cryptography, lasers, sensors, and their integration and programming through play and collaboration, to be significant for their education.

Within this research question, three research tasks are distinguished:

1. to determine to what extent students believe they have acquired new knowledge in mathematics, physics, and computer science during the workshop;
2. to determine to what extent students believe that participating in the workshop can help them learn more compared to traditional teaching; and
3. to determine to what extent students believe that the activities they conducted during the workshop are significant for their education.

RESEARCH METHODOLOGY

STEM workshops titled *Mission (Im)possible* were implemented as part of an eponymous project that was approved for funding by the Center for the Promotion of Science of the Republic of Serbia and was the highest-rated project in the K1 category competition out of 85 proposed projects in 2020. The workshops were conducted in the fall of 2021 due to delays caused by the COVID-19 pandemic. Namely, in collaboration with the Science Club Kragujevac and the Science Club Užice, first and second-year high school students actively participated in the workshops. During the workshops, students first learned from the facilitators, who are also co-authors of this paper, about the basic concepts of cryptography, its historical development, and its applications of cryptography, with a special focus on the use of computers for (de)ciphering messages. They were then introduced to the laws of optics, the operation of sensors and lasers, and how these components are connected with others. Subsequently, the students were divided into two teams. The representatives of one team left the room while the representatives of the other team first encrypted a message of agreed length using a previously established rule, wrote it on paper, and placed it in the part of the classroom farthest from the entrance. They then assembled an improvised alarm system, using their newly acquired theoretical and practical knowledge, by connecting sensors, lasers, and other electronic components in various locations in the classroom to make it as difficult as possible for the other team members to reach the encrypted message. After setting up the alarm system, the second group, through negotiation and collaboration, tried to discover where the alarm system components were placed, to avoid them skillfully through incessant communication, and to reach the message together, which they then had to decipher. Afterward, the groups switched roles – the first group encrypted the message and set up the alarm system, while the second group overcame obstacles and deciphered the message. This created a competitive atmosphere that stimulated students to collaborate and communicate intensively to complete the common task successfully.

The sample consisted of students randomly selected from high schools in Užice (by the Science Club Užice) and Ćuprija (by the Science Club Kragujevac). Immediately after each workshop, printed questionnaires were distributed to the students. Before the students began filling out the surveys, it was explained to them that the survey was anonymous and that the results would be used exclusively for planning new, similar projects, as well as for scientific research purposes. Among other things, the survey included questions about the students' gender, the grade, and their grades in mathematics, physics, and computer science. Students were then asked to indicate their level of agreement with three statements regarding the significance of the STEM workshop they participated in for their education on a five-point Likert scale.

The sample included 58 boys and 50 girls, with 59 first-year and 49 second-year high school students. 12 students had a D, 19 students a C, almost a quarter (25 students) had a D, and nearly half (52 students) of them had an A in Mathematics. 9 students had a D, 8 students had a C, 36 students had a B, and nearly half (55 students) had an A in Physics. In Computer Science, the lowest grade was C (only 5 students); 14 students had Bs and more than four-fifths (89 students) had the highest grade.

RESULTS

The data obtained from the survey were processed with SPSS software for statistical data analysis.

Based on the responses on the first statement, students believe they acquired new knowledge in mathematics, physics, and computer science during the workshop; only 1 student somewhat disagreed, and there were no students who completely disagreed with the statement. There were 17 undecided students, while the remaining six-sevenths agreed with the statement to varying degrees: 40 students somewhat agreed, and 50 students completely agreed.

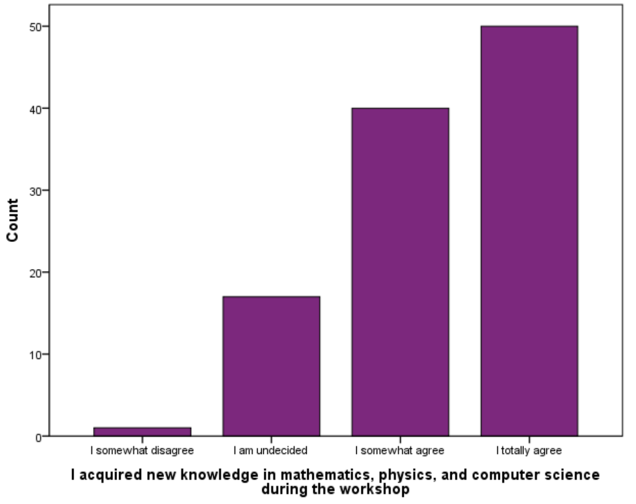

Figure 1: Students' agreement with the first statement

Analyzing the degree of agreement among students with the second statement, it can be concluded that high school students believe they can learn more through this method compared to traditional teaching. 4 students somewhat disagree with this statement, while 11 students are undecided. Furthermore, 39 students somewhat agree with this statement. Exactly half of the students (54 of them) completely agree that through active participation in these structured STEM workshops, they can learn more than in classes where teaching is conducted traditionally.

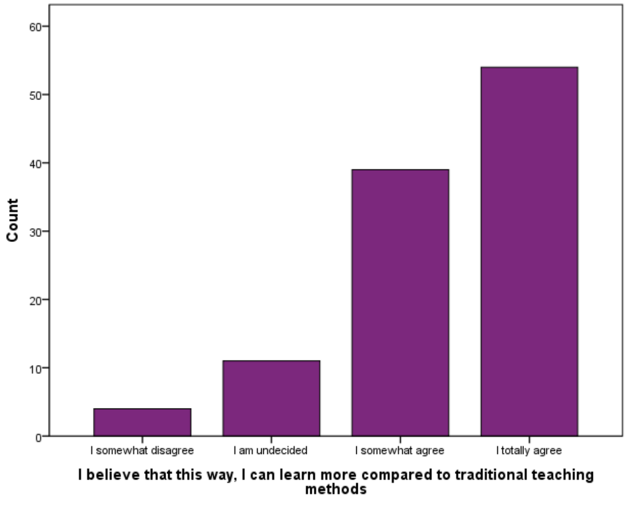

Figure2: Students' agreement with the second statement

It is easy to observe that no student has stated that he or she absolutely disagree with the previous two statements (*Figures 1* and *2*). Furthermore, by analyzing the degree of agreement among students with the statement that they believe the activities implemented during the workshop are significant for their education, it can be determined that not only is there no student who completely disagrees with this statement but there is also no student who partially disagrees with it (*Figure 3*). Specifically, slightly more than 10% of students (11 of them) are undecided; all others agree. Among them, 37 students somewhat agree, while a remarkable number of 60 students (55.55%) completely agree that by participating in STEM workshops, they acquired new knowledge from various subjects, interconnected and integrated into a meaningful whole.

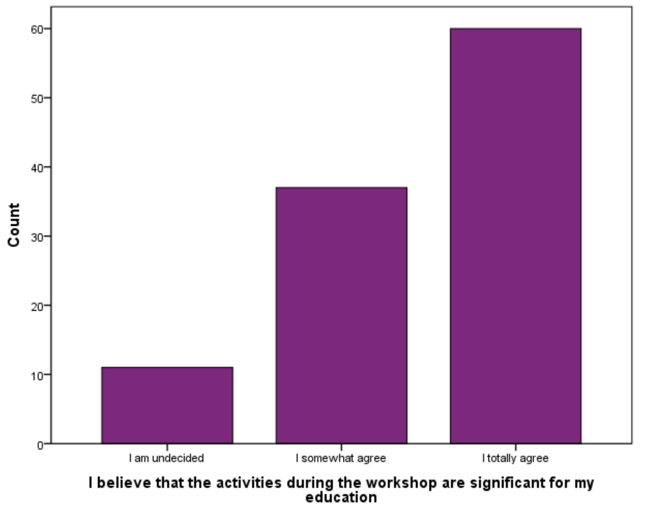

Figure 3: Students' agreement with the third statement

Table 1: The results of the descriptive statistics

Statements	N	Mean	SD	Skewness	Kurtosis
I acquired new knowledge in mathematics, physics, and computer science during the workshop	108	4.29	0.76	-0.67	-0.53
I believe that this way, I can learn more compared to traditional teaching methods	108	4.32	0.81	-1.10	0.70
I believe that the activities during the workshop are significant for my education	108	4.45	0.68	-0.85	-0.42

To determine the extent to which students generally agree with three statements provided, we calculated ranges for each of the five degrees of agreement. The determination of these ranges was proposed by Narli (2010), and they are determined by dividing the total range from 1 to 5 into 5 parts. Therefore, for average degrees of agreement from 1 to 1.8, students generally completely disagree with the statement; from 1.81 to 2.6, students generally disagree to some extent; from 2.61 to 3.4, students are undecided; from 3.41 to 4.2, students generally agree to some extent; and finally, from 4.21 to 5, students generally completely agree with the statement. Based on the arithmetic means of the degrees of agreement with three aforementioned statements (*Table 1*), as the arithmetic means for all three degrees of agreement are greater than 4.2, we can conclude that students generally completely agree that they acquired new knowledge in mathematics, physics, and computer science, believe that they can learn more in this way compared to traditional teaching methods, and consider the activities they conducted to be significant for their education. It is worth noting that the degree of agreement with the last statement is the highest (*Table 1*).

CONCLUSION

The results of this study indicate that students involved in the workshops have assessed that by implementing an integrated STEM approach and workshop-based teaching methods, they have made progress in understanding the content of subjects in the fields of mathematics, physics, and computer science. The results align with the findings from previous studies, which demonstrated an increase in students' interest and competencies in learning subjects such as mathematics (Han et al., 2015), physics (Astuti et al., 2021), and computer science (Bruckhaus et al., 2024) after participating in STEM workshops. Although the sample of students is insufficient for making generalizations, based on the obtained findings, we can raise questions related to promoting a research approach to teaching and learning natural sciences and creating conditions in which students can improve and enrich the competencies needed for a research approach (Sotiriou et al., 2017). In this context, the possibilities for developing interest in STEM fields involve reforming education in a way that content in natural sciences is closely linked to everyday life situations and actively guiding students on how knowledge from these subjects advances society (Trna et al., 2012). To meet these needs, it is significant to improve communication among teachers, establish interdisciplinary connections between teaching contents, and design, create, and implement project activities together with students (Anić & Pavlović Babić, 2015; Golubović Ilić & Mihailović, 2015; Popović

& Beara, 2022). Additionally, it would be desirable for collaborative activities to be multidisciplinary, so that students can connect acquired knowledge from different subjects and use it to solve specific problems (Antonijević & Vujisić Živković, 2015; Vujisić Živković et al., 2016).

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