Incorporating STEM learning scenarios in mathematics teaching: a study on the effectiveness of a professional development programme

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When teaching mathematics, several academics have emphasised the potential of STEM education for improving students' knowledge and engagement. According to studies, mathematics teachers' perspectives and awareness of this potential affect their instructional practices, and as a result, their perspectives have an impact on whether and how they incorporate STEM lessons in their syllabi. Recent research has shown that teachers must have more expertise on how to incorporate STEM learning scenarios into their classes. This study looked at the effectiveness of a STEM education professional development programme for mathematics teachers with the goal of improving their understanding of STEM education and learning scenarios. This study presents the findings of a programme that comprised specific learning sessions for 267 mathematics teachers on STEM education in general, and various types of STEM learning scenarios, i.e., contributions of programme to teachers.

Keywords: Mathematics teacher, perspectives, CPD programme, STEM education.

Introduction

A plethora of academic literature emphasises the high potential of interdisciplinary pedagogy to enhance students' comprehension and engagement in learning mathematics (Abramovich et al., 2019; Philippou & Pantziara, 2015; Tiflis & Saralar-Aras, 2021, 2022). This pedagogy has found particular relevance in STEM education, which encompasses a vast array of subjects ranging from science to engineering and mathematics (Clements & Sarama, 2023). Moore and Smith (2014) defined integrated STEM education as "an effort to combine some or all of the four disciplines of science, technology, engineering, and mathematics into one class, unit, or lesson that is based on connections between the subjects and real-world problems" (p.38). As reported in numerous studies, there are various approaches to STEM Education (e.g., Barakos et al., 2012). These include:

- no explicit STEM integration, content areas are taught separately; however, connections may be made between disciplines,
- combining two or more STEM content areas using enrichment activities,
- curriculum designed using shared content from all for STEM disciplines - often involving problem-solving projects,
- curriculum combining content and practices of two or more disciplines to support the understanding of both,
- science is central to integration of STEM,
- fully integrated STEM, and
- STEAM: an expended view of integration across the curriculum where art is integrated with STEM disciplines.

Although mathematics education is recognised as an essential component of STEM education, it has not received sufficient support regarding educational resources and pedagogical practices. Among the 141 regular papers presented at the 2014 Vancouver STEM conference, for example, only 16 per cent were devoted to mathematics (Li et al., 2020a, 2020b; Vancouver STEM Conference, 2014). Moreover, the difference in instructional methods between STEM and other traditional mathematical subject areas has led to a challenge for mathematics teachers in implementing STEM (Margot & Kettler, 2019).

For mathematics teachers to effectively apply STEM education to their lessons and overcome their challenges, they need to have a greater knowledge of how to incorporate STEM scenarios into their classes (Papadakis & Stavrakis, 2020; Stuikys & Burbaitė, 2018). For this reason, with these different approaches to STEM in mind, the authors developed a STEM education professional development programme for teachers to introduce various approaches in STEM with a particular focus on STEM learning scenarios. A learning scenario can be described as a model for instructional design that addresses a particular topic or topics based on the context, specifies what students must learn, and outlines all of the materials and instruments that teachers use to develop and practice it. Learning scenarios aim to create a learning situation comprised of various activities to accomplish a specific learning objective using various learning strategies. Instructions for teachers, a theoretical framework for every problem addressed, materials required for implementation, tasks, worksheets for students, and potentially other materials (such as web 2.0 tools and/or lesson plans) are all included in learning scenarios. To teach various types of learning scenarios to teachers, the authors followed a framework which includes seven steps as in Figure 1.

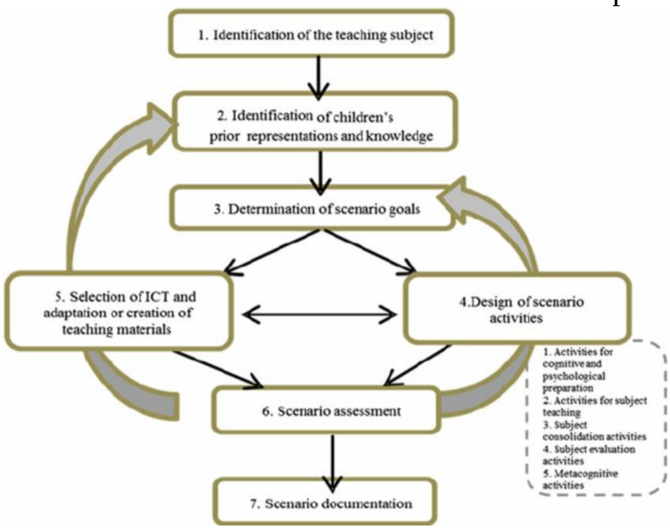

Figure 1. Seven-phase model for designing STEM-based lesson scenarios in mathematics education (Misirli and Komis, 2014)

Within the teaching of learning scenario creation, we emphasised three main components: contemporary pedagogical approach, appropriate content and structure, and contemporary teaching methods.

Following the common components of STEM learning scenarios in the literature, we chose the following structure to follow for the participating teachers:

- Subject
- Real-life questions
- Goals
- Connect with STEM Careers / Skills
- Age of Students

- Time (preparation and teaching time)
- Resources
- Educational Products
- Evaluation
- Feedback (Teacher/ Student)

The STEM education professional development programme developed by the authors included sessions on STEM education and introduction to scenarios, problem-based scenarios, STEM scenarios with 5E, Inquiry-based scenarios, Project-based scenarios and Conclusion and evaluation. The aim of the programme for teachers was to provide them with the knowledge, skills, and tools they need to effectively teach STEM subjects in the classroom. It had several goals, including:

Enhancing teaching skills: Effective teaching of STEM subjects requires specific pedagogical skills, such as the ability to use inquiry-based learning, design meaningful projects, and use technology effectively. Professional development can help teachers develop these skills and improve their overall teaching practice.

Promoting collaboration: STEM subjects often require interdisciplinary approaches and collaboration among teachers. Our professional development program provided opportunities for teachers to work together, share ideas, and develop strategies for integrating STEM subjects across the curriculum.

Incorporating real-world applications: STEM subjects are most meaningful when they are taught in the context of real-world applications. Our professional development program aimed to help teachers develop strategies for incorporating real-world problems and applications into their teaching.

Improving student outcomes: Ultimately, the goal of our STEM professional development program was to improve student outcomes in STEM subjects. By improving teacher knowledge, skills, and practices, such a program can help students develop a deeper understanding and appreciation of STEM subjects, and prepare them for success in future academic and career pursuits.

The aim of this study was to examine the effectiveness of the programme on the mathematics teacher's self-efficacy development for STEM practices. The study sought to answer three research questions:

1. Whether the STEM education professional development programme affects the mathematics teacher's self-efficacy development for STEM practices.
2. Whether there is a significant difference between pre-test and post-test scores in the self-efficacy of mathematics teachers with and without detailed knowledge of STEM.
3. Whether there is a significant difference between pre-test and post-test scores in the self-efficacy of mathematics teachers who engage in STEM activities compared to those who do not engage in STEM practices.

Therefore, the primary aim of this study was to investigate the impact of a STEM education professional development programme on mathematics teachers' self-efficacy for STEM practices, as well as to explore potential differences in self-efficacy between groups of teachers with different levels of STEM knowledge and engagement in STEM practices.

Methods

This quantitative research was conducted with a one-group pre- and post-test research design, focusing a STEM programme specifically tailored for 267 mathematics teachers (188 female and 79 male) who were employed across primary, secondary, and high schools in Turkey in 2021-2022 academic year.

The "Teacher Self-Efficacy Scale for STEM Practices" questionnaire was administered both before and after a comprehensive, three-week-long STEM Education programme. The gathered information was processed and scrutinised utilising SPSS version 26, a statistical software package.

To ensure adherence to ethical standards and procedures, the study's materials—including the questionnaire and the STEM education program—were meticulously assessed and approved by the Research Committee of the pertinent Ministry of National Education. Additionally, informed consent was duly obtained from all participating individuals.

Results and Discussion

To address the research questions, various statistical analyses were performed and presented sequentially in this section. The initial step involved identifying a suitable statistical test for the data, which required a preliminary examination of data normality. The normality test results, utilising Skewness and Kurtosis values, indicated a normal distribution within a -1.5 to +1.5 range for both pre- and post-tests.

Subsequently, to assess the impact of the STEM education program on improving mathematics teachers' self-efficacy in the context of STEM practices, a paired-sample t-test was used because the difference in scores between the pre-test and post-test exhibited a normal distribution (refer to Table 1 for results).

Table 1. The Results of Pair Sample T-Test Analysis

Mean	*SD*	*SE*	*Lower (95% CI)*	*Upper (95% CI)*	*t*	*df*	*Sig*
-17,292	9,267	,567	-18,409	-16,176	-30,491	266	,000

The Paired Sample T-Test revealed a statistically significant difference ($p<0.05$) in mathematics teachers' self-efficacy development and understanding of STEM education and learning situations (pre-test: *M*= 54.39 *SD*=17.69, post-test: *M*=71.69 *SD*=15.51), consistent with Abaci's (2020) and Kendaloglu's (2021) findings. These results demonstrate that the STEM education program is effective in enhancing mathematics teachers' self-efficacy.

After the assumptions were seen to be met, to address the second and third research questions, repeated measures ANOVA was employed as the statistical method for analysis (see result Table 2).

Table 2. The Results of repeated measures ANOVA Test Analysis

Source	Df	Mean Square	F	Sig.	Partial Eta Squared
School-levels	2	3290.937	6.726	0.001	0.048
Error	264	489.310			
Tests	1	28851.669	686.985	0.000	0.722
Tests * School-level	2	167.133	3.980	0.020	0.029
Previous-STEM knowledge	2	35240.680	142.521	0.000	0.519
Error	264	247.266			
Tests	1	36831.707	949.024	0.000	0.782
Tests * Previous STEM knowledge	2	587.874	15.147	0.000	0.103

To provide a response to the second research question, the results regarding the previously identified variables (school levels, tests, and school levels multiplied by tests) were presented in Table 2. It examined the impact of a STEM program on the self-efficacy of mathematics teachers at the primary, middle, and high school levels. Pre-test and post-test scores were collected and compared to investigate any statistically significant changes. The results indicated a significant difference between pre-test and post-test scores, as evidenced by the $F(2;264)= 6.726$ with a *p-value* of < 0.05. These findings suggest that the STEM education program has effectively enhanced the self-efficacy of all mathematics teachers who participated in the programme. The impact of the STEM education programme on mathematics teachers' self-efficacy scores was found to exhibit differences based on the school levels at which the teachers were employed, as evidenced by the statistical results ($F(2; 264)=3.980$; $p<0.05$). To determine the extent to which the STEM education programme influenced the self-efficacy levels of mathematics teachers across different school levels, the Bonferroni test was utilised. The findings revealed that among the mathematics teachers participating in the STEM education programme, primary and secondary school teachers experienced a 39% improvement in self-efficacy, and secondary school teachers demonstrated an average progress of 28%. This might be because of the teaching programmes they previously studies, as teachers participated in different programmes to become mathematics teachers in different levels.

To address the final research question, Table 2, which includes Previous-STEM knowledge, Tests, and Tests * Previous-STEM knowledge, was examined. Based on the results in Table 2, the impact of the STEM programme on mathematics teachers with varying levels of prior knowledge related to STEM education - those with extensive knowledge, limited knowledge, and no knowledge - was investigated. The significance value in Table was found to be 0.00, and statistically significant ($F(2;264)= 142.521$; $p<0.05$). This implies that the STEM education programme has effectively increased the self-efficacy levels of teachers across all three groups. Moreover, upon examining the pre-test and post-test results, it was found that the impact of the applied STEM education program on self-efficacy scores varies for mathematics teachers with different levels of STEM knowledge ($F(2; 264)=15.147$; $p< 0.05$). To determine the extent to which the STEM education programme affected the self-efficacy levels of mathematics teachers with different levels of prior STEM knowledge, the Bonferroni test was employed. According to the results, mathematics teachers who participated in the STEM education programme and had extensive knowledge experienced a 21% improvement in self-efficacy, those with limited knowledge experienced a 42% improvement, and teachers without prior knowledge experienced a 58% improvement in their self-efficacy levels. We believe that the difference in the improvements could be related to their prior experiences as where they start seem to be an important factor.

Conclusion

In conclusion, the statistical analyses conducted in this study provide evidence that the STEM education program is effective in enhancing mathematics teachers' self-efficacy. The findings indicate that the program has a significant impact on improving teachers' self-efficacy levels, regardless of their prior knowledge of STEM education. The study also revealed that the impact of the program varies based on the school levels at which the teachers were employed, as well as their prior knowledge of STEM education. The results suggest that the STEM education program has the potential to be an effective approach to improving mathematics teachers' self-efficacy, which could have a positive impact on their teaching practices and, in turn, on student learning outcomes.

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