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Research Article

The Effect of Problem-Based STEM Implementations on Pre-Service Science Teachers' Views on STEM Education

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Abstract
STEM educators' views on STEM education shape their use of methods and tools required to enable students to acquire 21st-century skills. Therefore, STEM educators' views on 'STEM education, interdisciplinary connections and integration of STEM disciplines into the curriculum' are essential. This study examines the effect of problem-based STEM implementations on pre-service science teachers' views on STEM education. For this purpose, a pre-test-post-test design without a control group was used as the research design. The study participants were 3rd-year pre-service teachers (19 female, 8 male) registered in the science teaching programme at a state university. To determine pre-service teachers' views on STEM education, individual interviews were conducted with pre-service teachers before and after the implementation. According to the study results, it was determined that the problem-based STEM implementations positively improved pre-service teachers' awareness of STEM education, their perspectives on the connections between the four fundamental disciplines of STEM, and their views on integrating the STEM approach into the curriculum.

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Araştırma Makalesi

Probleme Dayalı STEM Uygulamalarının Fen Bilgisi Öğretmen Adaylarının STEM Eğitimine İlişkin Görüşlerine Etkisi

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Özet
STEM eğitmenlerinin STEM eğitimine yönelik görüşleri öğrencilerin 21. yy. becerilerini kazanmalarını sağlamak için gereken yöntem ve araçları kullanmalarını şekillendirir. Bu nedenle STEM eğitmenlerinin 'STEM eğitimine, disiplinler arası ilişkilere ve STEM disiplinlerinin öğretim programına entegrasyonuna' yönelik görüşleri önemlidir. Bu çalışmanın amacı probleme dayalı STEM uygulamalarının fen bilgisi öğretmen adaylarının STEM eğitimine yönelik görüşlerine etkisinin incelenmesidir. Bu amaca yönelik araştırma deseni olarak kontrol grupsuz ön test-son test desen kullanılmıştır. Çalışmanın katılımcılarını bir devlet üniversitesindeki fen bilgisi öğretmenliği programına kayıtlı 3. sınıf öğretmen adayları (19 kadın, 8 erkek) oluşturmaktadır. Öğretmen adaylarının STEM eğitimine yönelik görüşlerini tespit etmek için uygulama öncesi ve uygulama sonrası öğretmen adayları ile bireysel görüşmeler yapılmıştır. Araştırmanın sonuçlarına göre probleme dayalı STEM uygulamalarının öğretmen adaylarının STEM eğitimine yönelik farkındalıkları, STEM'in dört temel disiplini arasındaki ilişkilere bakış açıları ve STEM yaklaşımının öğretim programına entegrasyonuna yönelik görüşlerinin pozitif yönde bir gelişim gösterdiği tespit edilmiştir.

Atıf için
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INTRODUCTION

Today's primary purpose of education is to equip individuals with the knowledge and skills necessary to adapt effectively to various circumstances (Krista, 2018). These skills, often referred to as "21st-century skills", include the capacity to solve complex problems, think critically about tasks, communicate effectively with people from diverse cultures, work collaboratively, adapt to rapidly changing environments and conditions to accomplish tasks, manage work effectively, and learn new skills and knowledge independently (National Research Council, 2011, p. 1). These skills are crucial for people to succeed in the modern world. The business world and society are constantly changing, especially with globalisation and the rapid development of technology. Therefore, having these skills provides a competitive advantage. At the same time, people with such skills are more preferred by employers and are more successful in their careers. Education in today's societies is primarily related to providing people with the necessary knowledge and skills to handle the complexities and challenges of their working lives (Hurd, 2000). Therefore, gaining 21st-century skills is critical for education. The concept of 21st-century skills refers to a contemporary collection of competencies necessary for students to effectively engage and navigate in the digital age (Wan Husin et al., 2016). Although these skills have many contents and definitions, they generally emphasise what students can do with their knowledge and how to apply it in real-life situations (Larson & Miller, 2011).

21st-century skills include not only technology-based knowledge and skills but also skills such as communication, collaboration, critical thinking, problem-solving, and creativity. These skills allow students to analyse, synthesise and develop creative solutions instead of simply memorising information. Problem-solving skills are an essential part of 21st-century skills that emphasise how students will apply the knowledge they have acquired in real-life situations and give them the ability to analyse, synthesise and produce creative solutions. One of the essentials of problem-based learning (PBL) methods is associating the problem with real life (Chen, 2008). PBL allows students to research to increase their knowledge and permanent learning while teaching problem-solving (Wong & Day, 2009; Yew & Schmidt, 2012). Although there are many customised PBL environments, there is a need for PBL environments to acquire 21st-century skills (Lapek, 2018). A comprehensive STEM education requires developing 21st-century competencies such as problem-solving, critical thinking, and practical communication skills (Chen et al., 2022; Hacıoğlu, 2021; Lee et al., 2019; Lynch et al., 2018). Therefore, PBL is one of the appropriate methods for the STEM approach. According to Asunda and Mativo (2015), students can only fully adopt STEM-related concepts if PBL environments are created. STEM education is an approach that integrates the disciplines of science, technology, engineering, and mathematics with a focus on problem-solving (Wu & Anderson, 2015). According to Bybee (2010), STEM education should aim to create a society that can face the challenges of the 21st century. Therefore, PBL is an essential tool in enabling teachers to participate in STEM education effectively. PBL allows students to develop the skills necessary to solve real-world problems and apply STEM disciplines. In this way, students can gain essential skills such as critical thinking, communication, collaboration, and problem-solving while learning actively.

STEM education has an essential place in today's world. In this period, when experts in fields such as science, technology, engineering, and mathematics are needed, STEM education plays a role in shaping the future of individuals (Kennedy & Odell, 2014; Vennix et al., 2018). STEM education helps students solve problems by improving their analytical thinking skills and prepares them for the challenges they will face in the real world. From this perspective, students' and teachers' awareness of STEM education is essential because it enables students to explore their interests and abilities in STEM disciplines (Knowles et al., 2018). At the same time, it helps teachers increase their knowledge and skills in STEM education and provides a more effective education. Therefore, it contributes to training qualified individuals needed by the future workforce. One of the most critical issues at the beginning of STEM education is the integration of STEM disciplines into the curriculum (Roehrig et al., 2021). Although there are different studies on adding STEM disciplines to curricula, the integration process is challenging for educators (English, 2016). Guzey et al. (2016) noted that teachers must be proficient in integrating STEM disciplines into the curriculum. International curricula are analysed, it is seen that interdisciplinary approaches are included under the title of 'associating with other disciplines' (Çınar et al., 2016). The nature of interdisciplinary connections is one of the significant problems of STEM education (Tytler et al., 2021). Many studies stated that students and teachers have challenges establishing connections between STEM disciplines (Pimthong & Williams, 2018; Şahin et al., 2018). Therefore, students' knowledge about the connections between STEM disciplines should be supported (NRC, 2014). For a meaningful learning process, students must establish a connection between previous and new knowledge and between STEM disciplines (Şen et al., 2018). STEM educators' views on STEM education, interdisciplinary connections, and integration of STEM disciplines into the curriculum are essential. Because STEM education helps students develop 21st-century skills such as critical thinking, problem-solving, and creativity. STEM educators' views on STEM education also shape their use of methods and tools to help students acquire these skills. The reasons for taking into consideration teachers' views on STEM education can be summarised as 'teachers being the first source that students refer to, being able to provide learning motivation to students in the process of teaching STEM subjects, having negative views on STEM education causes students to have limited or no encounter with STEM education' (Sarıoğlu et al., 2022). Therefore, it is valuable to determine pre-service science teachers' (PSSTs) views on STEM education. This study sought to the effect of problem-based STEM (PB-STEM) implementations on PSSTs' views on STEM education. Therefore, answers were sought to the following questions.

1. How do PB-STEM implementations affect PSSTs' awareness of STEM education?

2. How do PB-STEM implementations affect PSSTs' explanations of the connections between STEM disciplines?

3. How do PB-STEM implementations affect PSSTs' views on curriculum integration?

METHOD

Research Design

This study examines the effect of PB-STEM implementations on PSSTs' views on STEM education. For this purpose, a pre-test-post-test design without a control group was used as the research design. Over the 12 weeks, the participants engaged in four PB-STEM activities, each for three weeks. The PB-STEM activities implemented were designed to enable the creation of diverse solutions using STEM disciplines. Each activity comprised three stages: (1) research and inquiry, (2) prototype product development, and (3) advertisement. The pre-service teachers conducted individual research in the research & inquiry stage (Week 1). Then, they came together and decided on the best solution through group work. In the prototype product development stage (Week 2), they realised the best solution using different technological tools and materials. In the last stage (Week 3), the pre-service teachers prepared and presented commercial films for their products.

Participants

The study participants were third-year PSSTs (19 female, 8 male) registered in a science teaching programme at a state university. Participants were selected through convenience sampling. In this method, the researcher selects a situation that is appropriate for the purpose and easy to access. Convenience sampling is often used for situations where the researcher does not have the opportunity to use other qualitative sampling methods (Yıldırım & Şimşek, 2016).

Data Collection Tools

Following the purpose of the study, individual interviews were conducted with PSSTs before and after the implementation to determine their views of STEM education. The researchers prepared the interview questions and reorganised them after the evaluation of two field experts. The shortened version of the interview questions is given below.

1. Have you taken a course on the STEM approach? What do you know about the STEM education approach?

2. Is there a relationship between science, technology, engineering, and mathematics? Explain.

3. Please answer the following questions, considering the courses based on the STEM education approach,

a. For which subjects is it appropriate or not?
b. For which grade level is it appropriate?
c. How can students have challenges in courses based on the STEM education approach?

Data Analysis

The descriptive analysis method was used to analyze the pre-and post-intervention interviews. Descriptive analysis involves summarising and interpreting acquired data based on pre-established themes (Yıldırım & Şimşek, 2016). The data obtained from the interview were evaluated under three main themes: 'STEM awareness,' 'Interdisciplinary connections,' and 'Curriculum integration.'. The expert review method was used to ensure validity. According to this method, an expert from the outsider provides feedback to the researcher by analysing the research from many perspectives (Yıldırım & Şimşek, 2016). To ensure consistency and confirmability (reliability), two field experts analysed the original and edited data and provided feedback.

FINDINGS

The research data were analysed by descriptive analysis and findings are shared in this section.

Table 1 shows the statistical data on the main theme of 'STEM Awareness' obtained from the pre and post-intervention interviews.

Table 1: *The status of PSSTs' awareness of STEM education*

Sub-theme	Code	Pre-intervention interview	Post-intervention interview
Description	Combining disciplines	12	22
	Doesn't know	5	-
	Culture of production	3	1
	Education method	2	2
	Arduino	1	-
	STEM is everywhere	-	1
	Salad	-	1
Contributions	Mind-set	7	7
	Skills	6	10
	Academic achievement	5	6
	Career development	2	1
	The productive society	2	4
	Connection to daily life	1	-
	Skills development	1	-
	Self-confidence	-	4
	Holistic perspective	-	3
	Encouraging research	-	2
	Attracting attention	-	2
	Awareness	-	1
	Creativity	-	1
Barriers	Cost	6	7
	Access to materials	5	8
	Time	4	7
	Student count	4	4

	Readiness	3	6
	Teacher qualification	2	2
	Hand dexterity	1	2
	Classroom environment (physical area)	-	2
	Group communication	-	1
	Subject	-	1

This study analysed PSSTs' views on STEM education under three sub-themes. The findings of the 'Definition' sub-theme were examined; 19% of the PSSTs stated that they did not know the definition of the concept of 'STEM' before the implementations, while this rate was 0% after the implementations. 44% of PSSTs stated STEM education as 'combining disciplines' in the pre-intervention interview, and the rate was 81% in the post-intervention interview. Before the implementation, a PSST expressed STEM as *'I know STEM as a combination of physics, chemistry, biology'. In contrast, after the implementation, he/she said, 'STEM is science, engineering, technology, design, mathematics. It is a combination of all of these. We call the thing that contains them all STEM' (PSST9)*. Another PSST expressed it as *'Something like combining science, technology, mathematics, and engineering and displaying them in the same field' before the implementation. After the implementation, he/she said, 'STEM, in short, combines mathematics, engineering, technology, science and their connections. Here is how they affect each other. I think it is like this' (PSST22)*.

The data on STEM education's contributions to students were analysed under the sub-theme of 'Contributions'. According to these data, while the most references (26%) among the answers to the pre-intervention interview questions were made to the contributions to the mind-set, the most references (37%) were made to the skills after the implementation. Some contributions were not mentioned before the implementation but expressed by the PSSTs after the implementation: 'Self-confidence (15%), Holistic perspective (11%), Encouraging research (7%)'. For example, PSST20 addressed the contribution of STEM education to students before the implementation as *'Students need to adapt to this slowly. I think they can become more capable of engineering and technology skills development. That's why it is important'*. After the implementation, the same PSST said, '*They can use all disciplines together and use their past knowledge here. It can be useful in that respect. The materials we will use here may be things that students may face. These will also improve their psychomotor skills at later stages. This is already a development process. I think it will definitely be useful. They will learn to research at the information stage. They will realise how they can reach the right sources'*, referring to both the development of students' psychomotor skills and learning to do research. One PSST expressed the development of self-confidence after the implementation: '*I think it increases their self-confidence because they are themselves when they are designing, the teacher is more in the background, so it increases their self-confidence' (PSST3)*.

The data obtained from the pre and post-intervention interviews on the barriers to STEM education were analysed under the sub-theme of 'Barriers'. According to these data, while the PSSTs referred to the barrier of 'Cost' the most (22%) before the implementation, the issue expressed as the biggest barrier after the implementation was 'Access to material' (30%). There were also issues expressed as barriers only after the implementation (Classroom environment (7%), Group communication (4%), Subject (4%)). A PSST expressed the barrier on the cost before the implementation as follows: *'Exactly, countries with poor economies may not be able to use these things. They cannot buy the materials to be used in the STEM approach' (PSST2)*. The same PSST expressed the limited access to materials after the implementation: *'For example, if there is such a thing in rural schools, STEM implementation, there may be trouble finding materials'*. While 11% of the PSSTs mentioned students' readiness as a barrier before the implementation, this rate was 22% after the implementation. For example, PSST13 expressed the barrier related to readiness before the implementation: '*It may be difficult for them to handle all of them simultaneously. Making connections with each other and so on*'. Another PSST expressed the same barrier after the implementation as follows: *'I think their learning speed is a little bit limited for STEM. You know, some of them can perceive it in one week, while others can analyse it in two weeks. I think I see it as a barrier in this class' (PSST9)*.

Table 2 shows the statistical data on the main theme of 'Interdisciplinary connections' obtained from the pre and post-intervention interviews.

Table 2: *The status of PSSTs' explanations of the connections between STEM disciplines*

Code	Pre-intervention interview	Post-intervention interview
Valid explanation	7	21
Incomplete explanation	20	6

In this study, PSSTs' views on the connections between the four main disciplines of STEM education were analysed under the theme of 'Interdisciplinary connections'. While examining the views of PSSTs, the views that mentioned the connection between the four main disciplines of STEM education were evaluated as 'Valid explanation,' and the views that mentioned three or fewer disciplines or could not fully explain the interdisciplinary connections were evaluated as 'Incomplete explanation'. According to Table 2, 30% of the PSSTs could explain interdisciplinary connections before the implementation, and this rate became 70% after the implementation. As an example of a valid explanation, a PSST stated before the implementation: '*I think engineering actually includes both mathematics and science. In fact, engineering may be designing something by using them, for example, when a civil engineer or a mechanical engineer approaches a construction, they use something from science to prevent it from collapsing, for example, or they use something from mathematics to draw it. In other words, engineering includes all of them. Technology is also in these, so when these three come together, they develop something in technology. This is how it develops technological tools, whether a phone or a mobile phone, technology seems to develop thanks to these three' (PSST8)*. After the implementation, PSST9 '*Engineering seems more like drawing something and making a design. For example, science teaches you something theoretically. Then engineering draws it. You know,* *there is photosynthesis that we learned in science. We have a piece of knowledge. We said that if we apply this to this, it will be like this, we made a drawing in the engineering field. Then, we combined it with a water motor and a nine-volt adapter as a technology. This is a technology. In mathematics, how much electricity we spent, how much electricity was lost, or the increase in the number of leaves, how long the length of the greenhouses should be, etc.*'.

While the rate of PSSTs who could not fully explain interdisciplinary connections was 74% before the implementation, this rate was 22% after the implementation. Before the implementation, PSST12 stated, '*Anyway, mathematics is indispensable in life. I think, in general, I should answer these questions as follows. Science and mathematics are indispensable for life, they are in every field*'. After the implementation, PSST25 explained incompletely as follows: '*Between science, technology, and engineering, the things we find in science, technology, and engineering, we already need to have engineering in order to apply technology to our lives through engineering, and mathematics cannot be separated from each other*'.

Table 3 shows PSSTs' views on curriculum integration of STEM education.

Table 3: *The status of PSSTs' views on curriculum integration of STEM education*

Sub-theme	**Code**	**Pre-intervention interview**	**Post-intervention interview**
Appropriate Subject	Physics	10	14
	All subjects	5	5
	Chemistry	1	6
	Biology	-	2
Inappropriate Subject	Biology	11	12
	Chemistry	1	2
Grade Level	Middle School (5,6,7,8)	9	7
	High School	5	1
	7th grade	2	4
	1st grade	2	3
	4th grade	2	4
	University	1	-
	8th grade	-	1
	Kindergarten	-	2
	3rd grade	-	2
Challenges	Producing prototypes	8	12
	Integrated Viewing	4	2
	Finding a solution to the problem	3	7
	Skills	2	-
	Mathematics	2	-
	Planning	1	-
	Financial problems	1	-
	Group work	1	1
	Defining the problem	-	7
	Supply of materials	-	5
	Conducting research	-	3
	Imagination	-	2
	Tool usage	-	2
	Creativity, originality	-	2
Student Role	Exploring Knowledge	7	4
	Active	3	4

	The learner	2	1
	Product producer	2	-
	Problem solver	1	4
	Researcher	-	3
	Generating solution ideas	-	3
	The Questioner	-	1
Teacher Role	Guiding	10	19
	Presenting information	5	-
	Attract students' attention	2	-
	Process manager	1	4
	The implementer	1	-
	Helper	1	1
	Observer	-	2
Assessment	Observation	5	7
	Process assessment	3	19
	Report	3	-
	Individual assessment	2	3
	Exam	2	6
	Project	1	-
	Peer assessment	-	4

In this study, 'appropriate and inappropriate subjects, grade level, situations where students may have challenges, student-teacher roles and assessment' issues related to STEM education were examined under the main theme of 'Curriculum Integration'. According to the data obtained, 37% of the PSSTs stated that the subjects appropriate for STEM education were physics subjects before the implementation. After the implementation, this rate was 52%. For example, a PSST stated before the implementation: '*Something about matter and its properties may be appropriate. Topics related to electricity may be appropriate. Subjects related to optics may be appropriate*' *(PSST1)*. After the implementation, another PSST stated, '*I think most of the physics subjects are appropriate. I mean, all of them are appropriate*' *(PSST15)*. The rate of PSSTs who stated that all subjects in the science course (physics, chemistry, biology) could be appropriate for STEM education before and after the implementation did not change (19%). While the rate of PSSTs who stated that biology subjects would not be appropriate for STEM education was 41% before the implementation, this rate was 44% after the implementation. One of the PSSTs stated that biology subjects would not be appropriate for STEM education before the implementation: '*STEM cannot be applied in biology, for example, in the biology parts of science*' *(PSST17)*. After the implementation, another PSST stated: '*Well, for example, the subjects in biology cannot be shown with STEM. Since biology is a little more theoretical, they may not be put into practice. (PSST26)*' and stated that biology subjects would not be appropriate for STEM education.

The PSSTs' views on which grade level STEM education should start were analysed under the sub-theme of 'Grade Level'. According to Table 3, 33% of PSSTs said STEM education should begin in middle school, but this rate reduced to 26% after the implementation. For example, a PSST stated an opinion about the grade level required to start STEM education before the implementation: '*I mean, I think it can progress in a familiar way starting from the 5th grade, even if it is not entered much*' *(PSST8)*. The same PSST stated after the implementation: '*I think, for example, if science lessons* *are started in the 5th grade, I think they should be taken step by step from the 5th grade onwards. According to their levels*'. It is seen that he associated 'science lesson' with 'STEM education'. Two PSSTs expressed that STEM education should start from the kindergarten level. For example, PSST24 expressed his view on this issue after the implementation: '*I think it should be started from kindergarten. I say so because children's curiosity is at a high level. They can think of everything*'.

The views on the challenges encountered in STEM education were analysed under the sub-theme of 'Challenges'. Table 3 shows that the PSSTs' view expressed before (30%) and after (44%) implementation is the realisation of the designed solutions in real life, also known as prototyping. Before the implementation, PSST2 expressed her/his view: *'I mean to produce a product. They have a design, but they have trouble with hand dexterity'*. Another PSST expressed her/his view about the issues that may be challenging in the process: '*They definitely have difficulties in the production phase because we also had difficulties. For example, since the teacher will not tell him/her not to do this, you are going the wrong way here. In order to progress in a usual, the student may have difficulty in the production phase' (PSST13)*. The subjects that students may have challenges only after the implementation were expressed as 'Defining the problem (26%), Material supply (19%), Researching (11%), Imagination (7%), Using tools (7%), Creativity (7%)'. For example, PSST10 stated the following about defining the problem: '*We had a little trouble in defining the problem. The main thing is not to make good projects or good activities, but when we could not understand the problem, we sometimes had trouble'. Another PSST stated the following about providing materials: 'The most problematic thing here is the material part. In supplying materials. For example, we could not find the water motor here. We ordered it from the internet' (PSST12)*.

PSSTs' views on the roles of teachers and students in STEM education were analysed under the sub-themes of 'Student role' and 'Teacher role'. Before the implementation, 26% of the PSSTs stated that students were in the role of exploring knowledge in this process. After the implementation, this rate was 15%. One of the PSSTs expressed this view before the practice as follows: '*For example, the student should tell the teacher when he/she needs, for example, he/she has a deficiency somewhere, he/she cannot find a solution, then he/she can get it from the teacher's knowledge*' *(PSST19)*. One of the PSSTs, who expressed the student in the role of problem solver, expressed this view after the implementation '*I think the student should be at the centre. The child should do the implementation. The teacher should state the problem. The student should produce solutions in the centre*' *(PSST10)*. The PSSTs expressed the concepts of 'Researcher (11%), Solution Producer (11%), and Questioner (4%)' for the roles of students only after the implementation.

When the opinions about the roles of the teacher are analysed, it is seen that the most frequently expressed concept before (37%) and after (70%) the implementation is the concept of 'guiding'. A PSST stated the following about the role of the teacher before the implementation: '*The teacher can help us in our course, but he/she does not get involved in it like that, but he/she helps us to create something original. We design materials. He/she does something like showing the way' (PSST7)*. After the implementation, PSST7 said, '*The teacher should only look at them from a higher perspective. In other words, they should show them the way. That is, they should show them that there are different options*'. Only two PSSTs expressed opinions about the observer role after the implementation. For example, PSST9 said, *'I think the teacher should be in the background, only as an observer inside. I do think it is not guiding either*'.

Finally, the sub-theme of 'Assessment' was examined under the 'Curriculum integration' theme. When the views on how the assessment should be in STEM education were examined, 19% of the PSSTs stated that the assessment should be done by observation before the implementation. In comparison, 70% of the PSSTs, after the implementation, stated that there should be process assessment. Before the implementation, PSST8 expressed his/her view on this issue: '*Instead of grading and shaping it like an exam, I think that if it is happening in the laboratory environment, I think there should be an assessment based on its implementation. As a result of the observation of the experiment as a result of observation*'. After the implementation for the process assessment, PSST6 said: '*I mean, I think it should not be the result of what is done, but how it is done, that is, to learn what he/she thought. Not whether a mechanism works or not. What he/she thinks and how much he/she understands science*'. While the rate of PSSTs who stated that the assessment in STEM education should be by exam was 7% before the implementation, this rate was 22% after the implementation. For example, after the implementation, a PSST stated the following about the assessment: '*I do not think students should be assessed through an examination that includes close-ended questions. There should not be answers that can be copied from each other. Everyone should have their ideas, and answers should be different. It is based on open-ended explanation' (PSST7)*. Regarding peer assessment (15%), mentioned only after the implementation, PSST21 said: '*Assessment, that is, students should assess each other. For example, other groups through groups. There can be peer assessment*'.

CONCLUSION, DISCUSSION AND RECOMMENDATIONS

This study sought to determine how PB-STEM implementations affected PSSTs' views on STEM education. The findings indicated that STEM implementation enhances STEM awareness of PSSTs.

At the end of the implementation, almost all PSSTs defined STEM education as integrating fields. STEM education is generally expressed by researchers as the combination of science, technology, engineering, and mathematics disciplines (Breiner et al., 2012; Koonce et al., 2011; Marrero et al., 2014). In this study, PB-STEM implementations allowed PSSTs to organise their research processes and prepare their study reports by paying attention to science, technology, engineering and mathematics disciplines in their problem solutions. So, it may be said that PSSTs' views on the definition and content of STEM education were shaped in the process through their experiences. Similarly, some studies reported that PSSTs define STEM education as interdisciplinary work and combining disciplines. (Brown et al., 2011; Cinar et al., 2016; Çalışıcı & Özçakır Sümen, 2018; Siew et al., 2015; Yıldırım & Selvi, 2016).

PSSTs noted that STEM education could enhance skills and mindsets, increase academic achievements and self-confidence, build a holistic perspective, and create a productive society. In PB-STEM implementations, PSSTs participated in different processes such as defining the problem, finding alternative solutions, group work, producing prototypes, preparing advertisement videos and product presentations. The PSSTs' views who took an active role in each phase were also shaped according to their own experiences. For example, during the group work process, each PSST presented his/her solution with its advantages and disadvantages to the other group members. The different solutions presented in the group contributed to developing PSSTs' mindsets through brainstorming. In a study by Baran et al. (2018), PSSTs similarly referred to developing their mindsets by listening and discussing different ideas with group work. The PSSTs mentioned different skill developments, from hand dexterity development to problem-solving skill development for skill development. In the implementation process, they need to choose the best solution from more than one solution proposal in group work. A continuous problem-solving situation is encountered from the beginning to the end of the implementation process in this study. Different problems were encountered at every phase, from the beginning of facing the problem to the production of the prototype and even to the presentation of the prototype. Due to this reason, PSSTs claimed that STEM education enhances the development of skills for problem-solving. Similarly, they used tools such as drills, hot silicone, electric jigsaws, and soldering during the prototype production process. The PSSTs' learning by doing and experiencing shaped their thoughts about the contributions of STEM education to students. In the studies, it is stated that STEM education increases academic achievement as well as improves students' problem-solving skills and hand dexterities (psychomotor) (Chang et al., 2022; Chang & Chen, 2022; Çetin, 2020; Erdogan & Ciftci, 2017; Sarican & Akgunduz, 2018). In addition to all these, the situations that the PSSTs tried to do individually and succeeded may have caused their self-confidence to increase. For example, a PSST learnt the use of Arduino through her/his research on problem-solving and used it to solve another problem. For this reason, PSSTs stated that since their self-confidence would increase, the self-confidence of future students would also increase. Educators need to know the subjects in depth and be confident in themselves to improve the effectiveness of STEM education (DeCoito & Myszkal, 2018). Some studies have also reported that STEM education contributes positively to individuals' self-confidence (Bal & Bedir, 2021; Karademir & Yıldırım, 2021).

PSSTs mentioned various barriers that may arise due to the nature of STEM education. In contrast to classical science courses, factors such as time, cost, access to materials, amount of students, and readiness levels may be required more in STEM education. Kubat (2018) found that science teachers have a favourable view of STEM education but have difficulty implementing it because it requires more time than classical science courses. According to the results of the meta-analysis study conducted by Kanadlı (2019), it was stated that the factor seen as the most significant barrier in STEM education is 'time'. In addition, factors such as cost, difficulty of preliminary preparation and implementation, and crowded classes were also mentioned. Similarly, Shernoff et al. (2017) pointed out in a study that teachers need more time to conduct interdisciplinary studies. In addition, the educational materials required to implement STEM education successfully will require additional financial resources (Honey et al., 2014). In the current study, financial barriers, specifically cost, emerged as a significant barrier, according to PSSTs' views. In STEM implementations, while producing solutions to problems, concrete products, in other words, prototypes, are usually produced (Bozkurt Altan & Tan, 2021; Culén & Gasparini, 2019; Simeon et al., 2022). The materials necessary for the production of these prototypes may not always be at the ready. In this context, especially in a society with low socio-economic status, STEM implementations can be challenging for teachers and students regarding economic aspects. In addition to economic difficulties, sometimes it is not easy to access materials in small cities and rural areas. Although this barrier can be overcome with internet shopping in the age of technology, it is still considered a barrier since it will take time for the material to reach your hand. According to Thorndike (1913), the concept of readiness expressed by PSSTs as a barrier refers to the individual's holistic readiness for learning. When individuals feel ready in cognitive, social, affective and psychomotor aspects, it is possible to talk about learning (Yenilmez & Kakmacı, 2008). For this reason, learning environments should be designed by considering students' readiness. The factors mentioned earlier affect teachers' use of traditional or alternative educational approaches (Dancey & Henderson, 2008). In this context, we can say that an effective education process cannot be mentioned without eliminating the barriers to STEM education.

One of the biggest problems in STEM education is teaching the connections between the four main disciplines and how to apply them in the classroom (Çınar et al., 2016). According to the results of this study, while PSSTs had trouble explaining the connections between the four main disciplines of STEM education before the implementation, most of the PSSTs could explain the connections between the four disciplines after the implementation. In their study, Pimthong and Williams (2018) stated that PSSTs believed that STEM education integrates science, technology, engineering, and mathematics disciplines but could not explain their connections. In this study, PSSTs generally explained interdisciplinary connections through explicit examples and drew attention to the interconnectedness and inseparability of the four disciplines. We can summarise the explanations about interdisciplinary connections: ' Science: the part of this process that needs to be known in terms of knowledge.

Technology: All the tools and software we use in the process are technology. Besides, the prototype produced is also a technology. Engineering: The general prototype design planned for this process is defined as engineering. Mathematics: All calculations made during the process are mathematics. Mathematics is already everywhere in life'. Similarly, Faikhamta (2020) reported that PSSTs expressed views regarding the scope of STEM, such as 'new scientific knowledge improves technology, mathematics serves as a tool for understanding engineering'. Tseng et al. (2013) discovered that university students described STEM disciplines as ‘highly interrelated’. STEM education, which combines four disciplines, facilitates understanding the connection between students' knowledge of these disciplines (Martín-Páez et al., 2019). In this context, STEM education shows students how science, technology, mathematics and engineering disciplines are related to each other and how they can be used as a tool.

When the views of PSSTs on the integration of STEM education into the curriculum were examined, it was seen that they generally stated that physics subjects were more appropriate for STEM education before and after the implementation. In addition, a small number of PSSTs stated that all subjects in the science subject are appropriate for STEM education. In the studies conducted, it was determined that PSSTs' view that STEM education is more appropriate for physics subjects was dominant (Erdogan & Ciftci, 2017; Eroğlu & Bektaş, 2016; Kanadlı, 2019; Yıldırım & Selvi, 2016). Since most of the studies on STEM education are related to physics subjects, PSSTs' views may have been affected by this situation (Eroğlu & Bektaş, 2016). In addition, prototypes were developed according to the steps of the engineering design process. In the engineering design process, PSSTs produced solutions to problems from an engineer's point of view. In the studies, it is seen that students generally associate engineers with physical events such as 'vehicle production, assembly, building, repair works, etc.' (Capobianco et al., 2011; Hacıoğlu et al., 2016; Karatas et al., 2011; Silver & Rushton, 2008). For this reason, the PSSTs' selection of physics subjects that may be appropriate for STEM education may be due to their perspective on engineering. The subjects they did not see as the most appropriate for STEM education before and after the implementation belong to the biology discipline. For the above reasons, PSSTs thought biology subjects would not be appropriate for STEM education. Erdogan and Ciftci (2017) found that PSSTs did not consider chemistry and biology subjects appropriate for STEM education. In their study, Yıldırım and Selvi (2016) stated that PSSTs developed misconceptions in the STEM education process and saw only physics subjects as appropriate for STEM education. Contrary to all these, we can say that STEM implementations can be developed for all science subjects (Eroğlu & Bektaş, 2016).

A study examining STEM centres in Türkiye (Bircan et al., 2019) underlined that students at all grade levels cannot benefit sufficiently from STEM centres. However, STEM centres should be educational bases from which students at all grade levels should benefit. According to the results of this study, PSSTs stated that STEM education should generally start at the middle school (5th, 6th, 7th, and 8th grade) level. On the contrary, STEM education is an educational approach used at all levels, from preschool to postgraduate education (Ejiwale, 2013; Granovskiy, 2018). Considering PSSTs' explanations of this issue reveal that the reason for this is that STEM implementations will be challenging for children in lower grade levels. The cognitive and psychomotor workloads STEM implementations require at different grade levels will also differ (Christensen et al., 2015). In this context, we can say that STEM education will be appropriate for every grade level as long as the levels of STEM implementations are adapted according to the grade level to be applied.

The PSSTs emphasised that 'producing a prototype' could be one of the most challenging tasks for students in a designed PB-STEM environment at the primary level. According to the PSSTs, students at the primary education level will have challenges in supplying and using the tools (e.g., hot silicon, electric jigsaw, cutter, drill) to be used in the production phase of the prototypes that are likely to be made in the process of STEM implementations. Since the STEM implementations in our study were at the university level, the PSSTs may have thought that implementing a STEM activity at the primary education level would also require such metacognitive and psychomotor skills. In their study, Ozkan and Topsakal (2017) found that PSSTs also had challenges in the stages requiring psychomotor skills in the STEM education process. Similarly, educators state that students' weak skills are one of the most significant barriers to using alternative educational approaches (Dancy & Henderson, 2008). After the implementation, the PSSTs stated that one of the issues that students may have the most trouble in STEM education may be 'producing solutions to the problem'. When the PSSTs' explanations are evaluated it is discovered that the students' lack of experience may be the cause for this situation. However, the focus of science education today has shifted towards students' understanding of phenomena and designing solutions to problems rather than just teaching science knowledge (Krajcik, 2015). In addition, one of the most crucial contributions of STEM education is that students learn to solve problems (Bybee, 2010; Hebebci & Usta, 2022). For this reason, an effective STEM education should teach students to produce solutions, especially for real-life problems.

Engineering serves as a natural connector for integrating STEM disciplines into the learning environment (Moore et al., 2014). In addition, it should be recognised that engineering is a problem-definition activity as well as a problem-solving activity (Downey, 2005). According to the results, PSSTs stated that one of the phases that students may have the most challenges in STEM education is 'defining the problem' in their views after the implementation. Defining problems is a part of the problem-solving process in which the scope of the problem and the point to be reached are clearly determined (Pretz et al., 2003). In PB-STEM implementations, PSSTs searched for solutions to poorly defined problems. Therefore, their primary goal was to define the problem for which they would produce solutions. The thoughts of the PSSTs, who learnt by doing and experiencing that they could produce wrong solutions when they did not define the problem well, may have been shaped by their experiences.

The role of the teacher in STEM education has been characterised by different concepts such as 'coach, risk-taker, collaborator, facilitator' (Morrison et al., 2021; Shernoff et al., 2017; Slavit et al., 2016). According to the study results, PSSTs characterised the role of the teacher in STEM education dominantly as 'guiding'. According to the study conducted by El Nagdi et al. (2018), teachers defined themselves as students who continue to learn regarding their roles in STEM education. According to STEM pedagogy, teachers should guide students' learning (Margot & Kettler, 2019; Rozhenkova et al., 2023; Xiaoqing & Rose, 2023). Since STEM education involves many disciplines, following current information about the relevant disciplines is necessary. For this reason, teachers should constantly update themselves and guide their students. Students take an active role in learning environments instead of passively receiving information from teachers in STEM education (Keiler, 2018). In an effective STEM education, students are expected to establish new and productive connections between two or more disciplines (English, 2016). This can be possible with students actively trying to explore knowledge. In addition, especially in PB-STEM implementations, students have the opportunity to become problem-solving individuals (El Sayary et al., 2015). According to the constructivist paradigm, learners are responsible for structuring knowledge in their learning (Arslan, 2007). In this context, teachers guiding students should help them to construct new knowledge using their knowledge and experience. While students actively develop their problem-solving skills, they also become aware of their learning processes. In light of this information, we can define the teacher as a guide and the student as an explorer of knowledge in STEM education.

In STEM education, where science, technology, mathematics and engineering disciplines are carried out together, assessment methods should also be unique (Aşık et al., 2017). Since combining these disciplines focuses on complex, analytical problem-solving skills, assessment methods should also be oriented towards these skills. Traditional exams and tests may not be sufficient to provide a realistic assessment of STEM education. More process-oriented assessment approaches are used in STEM education rather than outcome-oriented assessment (Capraro & Corlu, 2013). According to this study's results, most PSSTs stated that alternative assessment methods that measure different knowledge and skills should be used instead of outcome-oriented assessment approaches. Outcome-orientated assessment approaches allow students to be evaluated only based on the results obtained in exams or tests. However, STEM education requires students to understand broader concepts and apply skills in science, technology, engineering and mathematics. Process-oriented assessment approaches aim to measure how students use these skills and how they solve problems. This approach provides a more comprehensive perspective to assess how students apply STEM skills in real life and how they use their creativity. Therefore, process assessment methods should be used in STEM education, not outcome-oriented assessment.

As a result, this study determined that PB-STEM implementations positively improved PSSTs' awareness of STEM education, their perspectives on the connections between the four fundamental disciplines of STEM, and their views on integrating the STEM approach into the curriculum. According to the results, when the views of PSSTs were examined in general, it was determined that STEM should be combined with disciplines, STEM disciplines are interconnected and inseparable, physics subjects are appropriate for STEM education, biology subjects are not appropriate for STEM education, in STEM education, students may have the most difficulty in the prototype production process, in STEM education, teachers should be in the role of guide and students should be in the role of explorer knowledge, and process-oriented assessment approaches should be used as assessment in STEM education. In light of this information, knowledge and studies can be carried out for future studies that show that STEM implementations can be appropriate for every grade level and every subject in science. Studies on process-oriented evaluation approaches to be used in the evaluation of STEM education can also be conducted.

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