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EVALUATION OF PRE-SERVICE TEACHERS' VIEWS ON STEM EDUCATION

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Abstract: This study aimed to evaluate pre-service science teachers' views on STEM education. Data were collected at the end of each activity and the end of the training with evaluation sheets. The collected data were analyzed with the content analysis method and interpreted with percentage and frequency values. The research method is a case study. Participants received four weeks of practical training, including STEM activities. Based on the data collected, it was determined that teacher candidates did not have a negative perception of STEM activities, that they had difficulty in activities that required handcraft, and that it contributed positively to their interdisciplinary perspectives. They also stated that the training was enjoyable and creative; developed imagination and handicraft skills; increased productivity, self-confidence, design skills, problem-solving skills, and group work; provided practical thinking; ensured permanent learning and field cooperation; and contributed to analytical thinking. Most of the participants stated that they did not find STEM education at their universities sufficient, would apply STEM activities to their students when they became teachers, and wanted to improve themselves in STEM education. Participants stated that they most needed development in the subject of academic knowledge, utilization of technology, handcraft and creativity. In addition, it was determined that positive perceptions and opinions about STEM education were observed.

Keywords: STEM, pre-service teachers, practical training, assessment

1. Introduction

STEM education dates back to the early 19th century (Ostler, 2012) and was first introduced by Judith Rahmaley in 2001 (White, 2014). In the literature, it can be generalized that STEM is a teaching process or educational approach that includes the disciplines of science, technology, engineering and mathematics and builds relationships with each other, and develops skills such as creativity, innovation, production and communication skills through teamwork (Corlu et al., 2014; Meng et al., 2014; Bybee, 2010a; Bybee, 2010b; Dugger, 2010; Morrison, 2006). Different abbreviations are encountered with the addition of different fields to STEM (STEAM, STEM+C, STREAM) or its translation into Turkish (FeTeMM).

Thomas (2014) generalized the aims of STEM education in 4 items. These are: (1) to raise STEM literate individuals for the business world, (2) to have the necessary qualifications in the field of STEM, (3) to be able to produce products that will support the national economy, and (4) to be qualified in the professions of the future. Economic competition between countries, the development of industry and technology, and the gradual decrease in non-renewable energy resources have made it necessary to change the knowledge and skills people need to acquire in our business and daily lives (Roehrig et al., 2012). We can talk about the necessity of integrating STEM education at all levels and processing it up to the knowledge and skills used in daily life to ensure the quality of employment in the countries, to cooperate in many fields, and to bring them together with technology.

The European Union's Horizon 2020 programme was the largest research and innovation initiative ever undertaken by the EU, with a budget of nearly €80 billion from 2014 to 2020, aimed at producing world-class science and technology to drive economic growth2 4. The programme focused on three main pillars: excellent science, industrial leadership, and tackling societal challenges, while also

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fostering collaboration between public and private sectors (Kvarnström & Helsing Västfjäll, 2023; Hogan, 2017). Horizon 2020 also aimed to strengthen the European Research Area (ERA) by building ecosystems through mutual complementation among industries, solving social problems through science and technology, and enhancing the participation of small and medium-sized enterprises (Kim & Yoo, 2019). The Ministry of National Education (MEB) has stated that STEM education is important and should be implemented to increase our country's current success in important international exams such as TIMSS and PISA (YEĞİTEK, 2016).

Çolakoğlu and Günay-Gökben (2017) reported that 16 out of 61 faculties of education offered undergraduate courses on STEM education. In the departments where STEM education was not provided, STEM education was mentioned in the content of other courses, while 30 of them offered STEM education for students in their faculties. The STEM School was established by Istanbul Aydın University in 2015 to increase the competencies of teachers and students in STEM fields and to support the transformation of schools into STEM schools (URL-1).

With the BİLMER Professional Development Project carried out between 2015-2018, many original professional training materials/activities were developed for use in science centers and schools and "BİLMER Teacher Professional Development Package" and "BİLMER Trainer Professional Development Package" were created (BİLMER, 2018).

YEĞİTEK participated in the Scientix Project, which aims to popularize STEM in Europe (URL-2). Within the framework of the 4006 Science Fairs supported by TUBITAK since 2013, 5th-12th grade students gain experience preparing and presenting scientific projects (URL-3). Since 2018, Teknofest Aviation, Space, and Technology Festival has organized technology competitions in various disciplines and categories (URL-4). Our country has trained at different levels for STEM education and competitions to support it. Some of these activities are mentioned above.

It was stated that teacher education is usually focused on one or two fields except for the primary school level and that teachers are not competent in interdisciplinary content and engineering design (Nadelson et al., 2012). At the same time, teachers have difficulty transferring a holistic approach to their lessons because they do not have sufficient command of their field knowledge. (Stinson et al., 2009). It is emphasized in many studies that teachers cannot benefit from these places because they do not have any professional training in science centers and such learning environments (BİLMER, 2018). To achieve these goals and to train teachers capable of implementing STEM education, it is important that prospective teachers are trained in their faculties to make them knowledgeable and experienced (Tarkın Çelikkıran & Aydın Günbatar, 2017; Wang, 2012).

2. Literature review

Tosmur-Bayazıt et al. (2018) aimed to examine the experiences and opinions of teachers about STEM activity. It was concluded that the participants mostly reported positive views about the activity and that the activity was intriguing, economical, fun, holistic, collaborative, and reinforced engineering skills. Bakırcı and Kutlu (2018) aimed to determine science teachers' views on STEM education. The teachers concluded that STEM education will increase students' desire and interest in the course, enable them to think in multiple ways, improve their research, decision-making, design, inquiry, creativity and scientific process skills, and that teachers do not have the necessary knowledge in STEM education. It was suggested that schools should be improved with the required materials and teachers should be given in-service seminars about STEM education.

Sarı and Yazıcı (2019) examined science teachers' views on Science and Engineering Practices. The participants believed the applications improved their problem-solving, creative and productive skills. At the same time, the participants stated that they needed training in this field. Kızılay (2018b) determined the views of pre-service science teachers about STEM fields and education. Pre-service teachers generally mentioned the benefits of STEM education and stated that their fields are interrelated. Biçer et al. (2019) stated that there was no significant difference between educational status and gender in teachers' views on STEM. It was concluded that teachers with 16-20 years of experience had more positive opinions about STEM and most of the teachers had previously learned about STEM education from MEB resources, but they had not received training in STEM.

Tarkın-Çelikkıran and Aydın-Günbatar (2017) evaluated the opinions of pre-service teachers about STEM activities. It was stated that STEM activities were effective in providing a holistic perspective, deepening chemistry knowledge, permanent learning and reinforcement, and were very effective in teaching design steps. It was also stated that the participants had difficulties in procuring materials, design process and obtaining the necessary information. Kurup et al. (2019) conducted a study on increasing the capacity of teachers in STEM education. They emphasized that STEM education should start from primary school and young people should be prepared for the future. It was found that pre-service teachers' comprehension skills were not high, but their beliefs and awareness towards STEM education in their careers were high. In the study, it was stated that STEM-oriented courses should be given at the university.

Margot and Kettler (2019) conducted a literature review on teachers' perceptions of STEM education. Teachers cited barriers such as pedagogical, curricular and structural challenges, concerns about students and assessments, and lack of teacher support when valuing STEM education. However, teachers indicated the need for assistance to improve STEM education implementation, collaboration with peers, quality curriculum, district support, and effective professional development. Ryu et al. (2019) developed a STEM education methods course for pre-service teachers and examined their experiences and practices at the end. It was stated that pre-service teachers successfully developed STEM courses but experienced difficulties in current school practices, limited interdisciplinary understandings and lack of role models. The study suggested ways to reduce the challenges and strengthen the strengths identified by pre-service teachers in the current education system and structure. Çetin and Şeker (2022) examined the effect of science courses taught with STEM applications on students' academic achievement. It was concluded that STEM education applications with the 5E model increased achievement and retention.

When the literature is examined, it is seen that teachers and pre-service teachers in Turkey and abroad do not have sufficient knowledge and experience about STEM education, cannot establish a relationship between STEM disciplines, and want to improve themselves. According to the studies examined, the studies on STEM education in Turkey have gained increasing momentum in recent years. It was thought that teachers, students and teacher candidates were mostly selected as participants, and the studies conducted with teacher candidates remained in the minority compared to the others. The studies examined participants' views and attitudes towards STEM education more than other subject areas. This study aimed to introduce STEM education to pre-service science teachers through a practice-based education and to evaluate their views on STEM education. It is an important study to eliminate the deficiencies in the literature and support the literature.

3. Methodology

The method of this study was determined as an illustrative case study. Case study is used in research that evaluates a program or focuses on an event in depth (Marshall & Rossman, 2006). It is defined as solid-based studies that aim to qualitatively describe cases occurring in their natural conditions with various data collection tools with time and place limitations (Hancock & Algozzine, 2006). Illustrative case studies aim to explore and analyze many factors and situations to help construct a causal explanation for the case study as a STEM activity.

3.1.Participants

The participants in the study were determined according to easily accessible case sampling, one of the purposeful sampling methods. This sampling method facilitates the determination of the study group and accelerates the study (Yıldırım & Şimşek, 2011). Ninety-four pre-service science teachers studying in the 3rd year grade at the faculty of education of a state university participated in the study.

3.2.Data collection tools

The data were collected regarding the evaluation of STEM Implementation Training and the activities in the training.

With the STEM Activity Evaluation sheet, data on the design drawings of the model made by the participants, the degree to which they could explain the model scientifically, the difficulty level of the activity and the STEM fields used in the activity were collected. This sheet was distributed to the participants at the end of each activity in the training.

With the Training Evaluation Paper, data were collected on the participants' opinions about the applied training and STEM education at their universities, whether they would apply STEM education to their students, and their needs for STEM. Three expert instructors evaluated the validity and reliability of the data collection tools. In addition, it was decided that drawings should be added to the training evaluation sheet, and the number of open-ended questions should be as few as possible. Experts in science education agreed that questions should include drawings and answers that can reveal interdisciplinary elements related to the STEM subject. In this process, it was decided that both activity-specific explanations and ideas about general STEM education should be determined. This sheet was distributed to the participants at the end of the four-week training.

3.3. STEM implementation training process

In the STEM Implementation Training, participants were made to do a different activity every week, lasting four weeks. In this study, activities for different learning areas were preferred because teachers generally see STEM activities closer to the field of physics than science (Eroğlu & Bektaş, 2016). It was important that the activities selected in the training were related to the subject areas of Living Things and Life, Physical Phenomena, Matter and Its Nature, Earth and the Universe in the MEB Science Curriculum (2018). Artificial Hand, Let's Build Our Bridge, Balloon Inflation without Blowing, and Solar System Model activities were carried out with the design-based learning model stages. Stages of construction of activities in this model;

- Dividing participants into groups
- Explanation of the researcher's role in the design of the event
- Planning the design by groups
- Initiation of the class discussion by the researcher and participants sharing their thoughts
- Model presentations by the participants by testing, evaluating, and revising the model
- The researcher investigates STEM education through the models made (Penner et al., 1997; Penner et al., 1998).

The activities to be carried out for the participants to create their models with their creativity, knowledge, and skills were not mentioned beforehand. Each activity was selected to correspond to a learning outcome in the middle school science course. For example, the Artificial Hand activity corresponds to the outcome "Explains the structures of the support and movement system with examples" in the Systems in Our Body unit in 6th grade. Let's Build Our Bridge activity corresponds to the outcome "Shows the direction, direction, and magnitude of the force acting on an object by drawing" in the Force and Motion unit in 6th grade. Balloon Inflation without Blowing activity corresponds to the outcome "Explains the differences between physical and chemical change by observing various events" in the Physical and Chemical Changes unit in 6th grade. Solar System Model activity corresponds to the outcome "Compares the planets in the solar system with each other" in the Solar System and Eclipses unit in 6th grade. In addition, they were prevented from getting help from their cell phones during the activity and were directed to group work. Care was taken to ensure the activity materials were easily available, cheap, and ergonomic. Table 1 shows the list of materials used during the four activities.

Tablo 1. *Materials used in STEM education activities*

Activity Names	Materials
Artificial Hand	12 craft sticks, cardboard, ruler, scissors, 10 syringes, 5 serums each 20cm long, glue, foam cups
Let's Build Our Bridge	Spaghetti, wooden sticks, thumbtacks, play dough, paper, cardboard, tape, craft paper, string, glue, paper clips, ruler, pin, scissors
Balloon Inflation without Blowing	Vinegar, baking soda, lemon, baking powder, balloon, erlenmeyer, balloon jug
Solar System Model	Play dough (8 colors), thin wire, deep container, fondant cardboard, cardboard box, straws

Figure 1 shows examples of designs and models randomly selected from the participants for each activity.

Figure 1.*Examples of activity design and models*

4. Findings

The findings of the study are given under two headings: opinions about STEM activities and opinions about STEM Implementation Training.

4.1. Opinions about STEM activities

The pre-service teachers ' opinions were taken after the four STEM activities in the training. Opinions about each activity are given below.

4.1.1. Opinions about the artificial hand activity

The answers given to the STEM Activity Evaluation sheet at the end of the Artificial Hand activity are given in Table 2 with the number (n) and percentage (%). 93 participants participated in the activity.

Table 2. *Frequency values of the answers given to the evaluation sheet of the artificial hand activity*

Questions	Frequency
1. Draw the design of your model.	Able to draw %100 (n=93)
2. Can you explain the working principle of your model scientifically?	Cannot explain %4,3 (n=4) I can partially explain %46,2 (n=43) I can explain %47,3 (n=44)
3. How much difficulty did you have while making your model?	Never had any difficulty %6,4 (n=6) I had some difficulty %62,3 (n=58) I had a lot of difficulty %30,1 (n=28)
4. Mark which areas of science, technology, engineering and mathematics you think you used while creating your model.	Science %96,7 (n=90) Technology %33,3 (n=31) Engineering %60,2 (n=56) Mathematics %31,1 (n=29)

For the Artificial Hand activity, all participants could draw the model design they made. Most participants stated that they could explain or partially explain the working principle of their model scientifically and that they had some or much difficulty making their models. This activity aimed to make an artificial hand with materials used in daily life. In addition, it was requested that the model be able to move each finger independently of each other and that the hand be able to grasp and lift a foam cup. Figure 1 shows the products of the activity evaluation form filled out by the prospective teachers at the end of this activity. Participants stated that science, engineering, technology and mathematics from STEM fields were used in cooperation in the activity.

4.1.2. Opinions about the Let's Build Our Bridge activity

After the second activity, Let's Build Our Bridge, a STEM Activity Evaluation sheet was distributed to 96 participants. The answers are given in Table 3 with the number (n) and percentage (%).

Table 3. *Frequency values of the answers given to the evaluation sheet of the Let's Build Our Bridge activity*

Questions	Frequency
1. Draw the design of your model.	Able to draw % 100 (n=96)
2. Can you explain the working principle of your model scientifically?	Cannot explain %3,1 (n=3) I can partially explain %39,5 (n=38) I can explain %57,2 (n=55)
3. How much difficulty did you have while making your model?	Never had any difficulty %10,5 (n=10) I had some difficulty %64,2 (n=61) I had much difficulty %25,2 (n=24)
4. Mark which areas of science, technology, engineering and mathematics you think you used while creating your model.	Science %88,5 (n=85) Technology %46,8 (n=45) Engineering %97,9 (n=94) Mathematics %73,9 (n=71)

For the Let's Build Our Bridge activity, all participants could draw the model design they made. Most of them stated that they could explain the working principle of their models scientifically and had difficulties in making their models. They stated that the fields of engineering, science, mathematics and technology were mostly used in the activity, respectively.

4.1.3. Opinions about the balloon inflation without blowing activity

After the third activity, Balloon Inflation without Blowing the STEM Activity Evaluation sheet was distributed to 94 participants. The answers were given in Table 4 with the number (n) and percentage (%).

Table 4. *Frequency values of the answers given to the evaluation sheet of the balloon ınflation without blowing activity*

Questions	Frequency
1.Draw the design of your model.	Able to draw %100 (n=94)
2. Can you explain the working principle of your model scientifically?	Cannot explain %4,3 (n=4) I can partially explain %16,0 (n=15) I can explain %79,8 (n=75)
3. How much difficulty did you have while making your model?	Never had any difficulty %76,6 (n=72) I had some difficulty %22,3 (n=21) I had much difficulty %1,1 (n=1)
4. Mark which areas of science, technology, engineering and mathematics you think you used while creating your model.	Science %100 (n=94) Technology %11,7 (n=11) Engineering %6,4 (n=6) Mathematics %57,5 (n=54)

For the Balloon Inflation without Blowing activity, all participants could draw the model design they made. Most of them stated that they could explain their model's working principle scientifically and did not have any difficulty making their models. They stated that science, mathematics, technology, and engineering fields were used in the activity, respectively.

4.1.4. Opinions about the solar system activity

After the Solar System activity as the third activity in the training, a STEM Activity Evaluation sheet was distributed to 95 participants. The answers were given in Table 5 with the number (n) and percentage (%).

Table 5. *Frequency values of the answers given to the evaluation sheet of the solar system activity*

Questions	Frequency
1.Draw the design of your model.	Able to draw %100 (n=95)
2. Can you explain the working principle of your model scientifically?	Cannot explain %3,2 (n=3) I can partially explain %29,5 (n=28) I can explain %67,4 (n=64)
3. How much difficulty did you have while making your model?	Never had any difficulty %55,8 (n=53) I had some difficulty %36,8 (n=35) I had much difficulty %7,4 (n=7)
4. Mark which areas of science, technology, engineering and mathematics you think you used while creating your model.	Science %100 (n=95) Technology %44,2 (n=42) Engineering %52,6 (n=50) Mathematics %58,9 (n=56)

For the Solar System activity, all participants could draw the model design they made. It was stated that the majority could explain the working principle of their models scientifically and that they did not have any or partial difficulty making their models. They stated that the fields of science, mathematics, engineering, and technology were mostly used in the activity, respectively.

4.2. Opinions about STEM Implementation Training

At the end of the training, 95 participants were given a STEM Implementation Training Evaluation sheet. The answers were given in Table 6 with the number (f) and percentage (I%).

Table 6. *Answers to the STEM ımplementation training evaluation sheet*

Questions	Frequency
1. What are your views on practical training?	Positive opinions (n=94) %99,9 Negative opinions (n=17) %17,9 (16 people expressed both positive and negative opinions.)
Positive opinions	Creative, improves handicraft skills, enjoyable, develops imagination, increases problem-solving skills, practical thinking, active participation, field combination, permanent learning, design skills, productivity, self-confidence, suitable for middle school level, analytical thinking, group work
Negative opinions	Laborious, difficulties in classroom management, noise, planning difficulties, academic weakness, economy, time, manual dexterity
2. What is your opinion about the training for STEM at your university?	I do not find it sufficient at all % 25.3 (n=24) I find it partially sufficient % 50.5 (n=48) I find it sufficient % 24.2 (n=23)
3. Would you like to apply STEM to your students when you do your job as a teacher?	Yes %98,9 (n=94) No %1,1 (n=1)
4. What supports, if any, do you need for your development about STEM?	I do not need (n=0) Academic knowledge % 86.3 (n=82) Utilization of technology % 71.6 (n=68) Handicraft % 70.5 (n=67) Developing creativity % 90.5 (n=86) Other % 4.2 (n=4) (engineering, use of materials, student involvement)

The majority of the participants expressed positive opinions about STEM education, including statements such as creative, improves handicraft skills, enjoyable, develops imagination, increases problem-solving skills, provides practical thinking, active participation, provides field integration, provides permanent learning, increases design skills, increases productivity, increases self-confidence, mobilizes even students with low achievement, suitable for middle school level, contributes to analytical thinking, increases group work. Negative opinions include being challenging, being unable to dominate the classroom, being noisy, having difficulty in planning, academic inadequacy, having economic concerns, time management, and requiring manual skills. While some participants stated that the education at their universities was sufficient for STEM, most of them stated that it was not sufficient and that most wanted to implement STEM education in their classrooms and needed support. The areas of need in the STEM field are listed in descending order as academic knowledge, technology utilization, handicraft, creativity development and other (engineering, use of materials, student participation).

5. Discussion and Conclusion

As a result of the activities implemented during the training, it was determined that the pre-service teachers were generally able to draw the designs of the models they made and explain their working principles. They had the most difficulty in Artificial Hand and the slightest difficulty in Balloon Inflation without Blowing. When the construction phase of the activities is examined, it is seen that in the process of creating models in STEM activities, it is necessary to have a certain degree of handicraft as well as field knowledge, and in this sense, pre-service teachers may experience difficulties. In the activities carried out in the training, it was stated that most of the participants used the fields of STEM (science, engineering, technology and mathematics) by integrating them. It is thought that the selection of STEM activities from different learning areas contributed positively to the participants' interdisciplinary perspectives. Çınar et al. (2016) showed that after STEM education, there was a significant increase in pre-service teachers' ability to establish relationships between some disciplines such as mathematics, technology and engineering. There are studies in the literature indicating that pre-service teachers can see different branches as integrated at the end of STEM education (Aslan-Tutak et al., 2017; Gökbayrak & Karışan, 2017b; Ortiz et al., 2015; Tarkın-Çelikkıran & Aydın-Günbatar, 2017). Most of the participants expressed positive opinions about STEM applications, including statements such as: the training is enjoyable and creative; it develops imagination and handicraft skills; it increases productivity, self-confidence, design skills, problem-solving skills, group work; it provides practical thinking; it is active participation; it provides permanent learning, field integration; it is suitable for middle school level; it contributes to analytical thinking. Negatively, the opinions that it would be laborious, noisy, would cause financial difficulties, difficulty in planning, academic inadequacy, would cause problems in class domination and time, and that people without manual skills might have difficulties were included. It was revealed that the majority of the participants found the STEM education at their universities partially sufficient, that they would like to apply STEM activities to their students and improve themselves in this field when they do their professions in the future, and that they needed improvement in the fields of academic knowledge, technology, manual skills, and creativity the most.

There are studies in the literature to support positive views about STEM activities. STEM approach will make positive contributions to science teaching, science lessons will become more remarkable and increase the motivation of students, STEM activities provide permanent learning, STEM education is fun, instructive and provides the link between science and life, and increases the desire and interest of students, It has been reported that STEM education improves scientific process and psychomotor skills, develops productivity and creativity, provides a positive perspective, enables students to get efficiency and enjoyment from lessons, increases success in many areas, raises awareness of responsibility, and makes STEM education effective, easy and fun (Altan et al., 2016; Bakırcı and Kutlu, 2018; Bozkurt-Altan et al., 2016; Eroğlu and Bektaş, 2016; Özçakır-Sümen and Çalışıcı, 2016). Pre-service science teachers' and teachers' positive opinions about STEM education and activities will contribute to science education and students (Eroğlu and Bektaş, 2016).

There are also studies in which participants have negative opinions about STEM-based activities (Wang, 2012). It has been stated that the qualities that should be present in STEM applications in our country are not yet at the desired level, such as time, lack of materials, the necessity of making it a goal and mastering the subject, cost and equipment in schools, crowded classrooms (Eroğlu & Bektaş, 2016; Gülgün et al., 2017; Siew et al., 2015; Timur & İnançlı, 2018).

Although the participants did not have a course on STEM education at their universities, most of them stated that they found STEM education partially sufficient. In their universities, information on the subject was provided only as additional information in other courses, which was insufficient for pre-service teachers. The fact that STEM-related courses are offered in very few faculties of education today shows that pre-service teachers are not sufficiently informed about STEM education (Çolakoğlu & Günay-Gökben, 2017). Aşık et al. (2017) mention the need to develop sustainable methods, models and projects in teacher education related to STEM education. In the report published by the Ministry of National Education on STEM education, it was stated that teachers wanted to start STEM teacher training programs in faculties of education (YEĞİTEK, 2016).

Participants stated that they would like to apply STEM activities to their students when they do their teacher jobs. By selecting the implementation training given to the participants, especially for the middle school science program, pre-service teachers were given experience in their professional lives. In addition, it is thought that the participants adopted STEM education by making the activities applicable in their professional lives and making them aware of the positive or negative aspects throughout the process. Çınar et al. (2016) stated that pre-service teachers think that STEM education will positively affect both the personal and social development of students and that they will use integrated applications; Özbilen (2018) stated that the majority of teachers show positive attitudes toward implementing STEM education. In addition, the students also stated that the lessons taught with STEM activities in science lessons were instructive, fun, motivating and mind-enhancing (Gökbayrak & Karışan, 2017a). Chachashvili-Bolotin et al. (2016) found that STEM education experiences have a positive effect on students' orientation towards STEM fields in higher education, and pre-service teachers' willingness to apply STEM education will be one of the first steps in the future generations' orientation towards STEM fields.

Regarding STEM education, all participants stated that they wanted to improve themselves, and the areas they needed improvement in were academic knowledge, utilization of technology, handicrafts, and creativity. In addition, engineering, use of materials and student participation were identified as other areas of need. The fact that the participants were not informed about the activities before the implementations required them to use their creativity skills and existing field knowledge. Although the activities were selected at the middle school level, the pre-service teachers felt inadequate using handicrafts. One of the critical results of the study is that the participants felt inadequate in academic content knowledge in the activities related to the subjects in the science curriculum at the middle school level despite being in the 3rd grade.

In the literature, the factors that cause teachers to feel inadequate in STEM education are; lack of engineering and design skills and inexperience, lack of interdisciplinary knowledge and skills, and the education they received at university (Sarı & Yazıcı, 2019; Tosmur-Bayazıt et al., 2018; Çorlu, 2014). Wang et al. (2011) stated that teachers need detailed information about STEM. Tarkın-Çelikkıran and Aydın-Günbatar (2017) found that there were problems in determining how to design the product and which materials to use in STEM education. Similarly, Bozkurt-Altan et al. (2016) found that the most common problem was determining solutions to problems. Siew et al. (2015) stated that teachers had difficulties regarding time, materials and associating subjects in STEM activities. Stohlmann et al. (2012) reported that teachers had difficulties implementing engineering practices in the classroom and did not consider themselves competent.

Educating prospective teachers about STEM education during their undergraduate education has become increasingly important in terms of increasing students' interest in STEM fields, their orientation towards professions in STEM fields, their ability to produce solutions to problems encountered in daily life in the light of science and technology, and the country's economic competitiveness (Çolakoğlu and Günay-Gökben, 2017). To achieve a certain level of holistic, collaborative learning in our country, courses on STEM education should be organized for pre-service teachers in teacher training programs (Akaygun & Aslan-Tutak, 2016; Aslan Tutak et al., 2017; Bracey & Brooks, 2013; Nadelson et al., 2012; Sarı & Yazıcı, 2019; Hacıoğlu et al., 2016). It is thought that opening STEM-related undergraduate courses in cooperation with other faculties (faculty of science and letters, engineering, etc.) will be important for prospective teachers to internalize interdisciplinary teaching (Tezel & Yaman, 2017).

According to the results of the research, the following items are recommended to the relevant institutions and individuals for STEM education;

- Teaching this approach to students by opening courses related to STEM education in the undergraduate programs of faculties of education at universities

- Ensuring that faculties of education and other faculties (engineering, science, and literature, etc.) cooperate in providing an integrated STEM approach in the training to be held at universities

- Since the STEM approach has become widespread in recent years, teachers in all branches should be trained in this subject, and STEM education centers should be established to provide the necessary environment for students at all levels.

- Conducting this study with pre-service teachers from different departments other than pre-service science teachers.

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