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Research Article

The Effect of STEM Education Practices on the Awareness towards STEM Education and Opinions of Preservice Science Teachers*

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Abstract – This study aims to examine the effects of STEM education practices on preservice science teachers' (PSTs) awareness of STEM and STEM education and their views on the implementation process. The study was designed as a one-group pretest/posttest weak-experimental design including a case study. The participants were 30 PSTs enrolling in the Science Teaching Laboratory Applications I course in the 2018-2019 academic year and were determined by convenience sampling. In the study that lasted nine weeks, five STEM activities were practiced. STEM awareness open-ended questionnaire (STEM-A) was administered as pre and posttest, and the obtained data was evaluated with the thematic analysis. At the end of the instructional practices, semi-structured interviews were conducted with ten volunteer participants and the data were analyzed with the content analysis method. According to the findings, it can be stated that the participants' awareness developed positively and they grasped the importance of interdisciplinary relationship and integrated structure of the STEM approach.

Keywords: Preservice science teachers, STEM education, STEM awareness.

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Introduction

In today's rapidly changing society, the quality of education plays a crucial role in enabling societies to adapt to social, economic, cultural, and technological advancements. One of the key factors that determine the quality of education is the proficiency of trained teachers, as well as the successful implementation of contemporary learning and teaching methodologies.

When the innovative educational approaches of countries around the world are examined within the framework of science education in recent years, *STEM education*, which is integrated with different understandings, methods, and techniques of **S**cience, **T**echnology, **E**ngineering, and **M**athematics disciplines and is based on an interdisciplinary learning approach, has attracted attention (Bybee, 2013). Although there are different definitions for STEM education in the literature (Dare et al., 2019; Moore et al., 2020), based on the common features in these definitions, we will define it as STEM education includes purposefully integration of various disciplines used to solve real-world problems integration (Breiner et al., 2012). Roehrig and colleagues (2021) propose seven main characteristics for an integrated STEM unit or curricula: Starting with a real-world problem; centering the engineering cycle; ensuring content integration for interdisciplinary; promoting context integration for interdisciplinary; STEM practices; 21st century skills; creating career awareness about STEM disciplines.

One of the fundamental approaches to keep abreast of developments in STEM education is to provide comprehensive training for teachers as competent STEM practitioners. To ensure that, preservice teachers (PTs) should be recognized as individuals who require education that incorporates interdisciplinary integration during their pre-service period, along with opportunities to design and implement teaching methodologies that include STEM integration (Harlen, 2015). Thus, PTs will be able to develop a comprehensive understanding of how to meaningfully and accurately integrate STEM disciplines into their future class practices (Bartels et al., 2019). If learners are not taught how to effectively integrate different disciplines, they may encounter challenges when exploring related topics and making connections between them (You, 2017). The implementation of STEM education depends largely on factors such as teachers' perceptions, attitudes, educational backgrounds, and competencies (Khuyen et al., 2020; Thibaut et al., 2018). PTs' understanding and experience of STEM education will influence their intentions to implement STEM in their schools. For these reasons, there is a need to investigate preservice science teachers' (PSTs') awareness of

STEM and STEM education and their views about STEM education. STEM awareness is increasing individuals' awareness levels in this field by focusing their interests and perceptions on STEM education (Buyruk & Korkmaz, 2016). When the related literature was examined, it was determined that participants' STEM awareness was generally measured with quantitative data collection tools (Buyruk & Korkmaz, 2016; Çevik, 2017; Faikhamta, 2020; Mai et al., 2023). On the other hand, Radloff and Guzey (2016) examined how PSTs conceptualized STEM education using a data collection tool with a total of 12 questions containing different question types, using a survey method without instructional intervention. Based on the data they obtained, Radloff and Guzey suggested that there was a great diversity in PTs' concepts of STEM education. In addition, Radloff and Guzey (2017) applied a video-based instructional intervention (observing, analyzing, and reflecting on integrated STEM teaching approaches) for a period of time through semi-structured pre- and post-interviews. Aydın-Günbatar et al. (2021) examined the changes in PSTs' concepts of STEM education using the mental model protocol before and after the instructional intervention focused on the engineering-design process. In both studies (Aydın-Günbatar et al., 2021; Radloff & Guzey, 2017), the researchers stated that STEM training was effective in PSTs' conceptualization of the integrated STEM approach. We conducted an instructional intervention and preferred to use a qualitative measurement tool to understand the awareness of future teachers more clearly about STEM or STEM education so that they can become qualified STEM education practitioners. The open-ended data collection tool developed by Tezsezen (2017) to examine the STEM awareness of PSTs differs from the qualitative data collection tools used in aforementioned studies because it also includes the "experience component" dimension regarding STEM awareness. Although developing an understanding of the nature of STEM requires more than the sum of the nature of science, the nature of technology, the nature of engineering, and the nature of mathematics, teachers should have a basic understanding and knowledge of all four STEM disciplines and how to make meaningful explicit connections among these disciplines. They also need to gain experience in creating learning environments that will present this knowledge and connections to their students (Akerson et al., 2018). For this reason, this qualitative case study was preferred to provide PSTs with the opportunity to experience STEM practices and to obtain richer data to reveal how they conceptualize STEM. Moreover, taking into account STEM literacy (Zollman, 2012), which requires the use of scientific concepts, processes and understandings from different disciplines in encountered situations, we aimed to illuminate whether PSTs noticed the relationships between STEM disciplines in two examples presented from daily life. Drawing from Tezsezen's study (2017), our examination of the "knowledge component" of STEM awareness involved analyzing how PSTs describe each STEM discipline. Similarly, to explore the "experience component" of STEM awareness, we focused on how PSTs depict each STEM discipline within the context of everyday STEM-related topics.

STEM teacher training holds immense importance due to the limited or even nonexistent exposure to STEM education during teachers' pre-service training. Moreover, opportunities for professional development in integrated STEM education remain scarce for PSTs (Brown & Bogiages, 2019; Lo, 2021; Wang et al., 2020). Furthermore, PSTs who engage in STEM practices often experience feelings of anxiety, fear, and self-inadequacy regarding the execution of these practices (Eren & Dökme, 2022). For these reasons, to encourage PSTs to receive and apply preservice STEM education has vital importance. This study involved creating an instructional environment where PSTs could experience STEM education practices in both student and teacher roles. The objective of this study, which is part of a larger research investigating the effects of STEM education practice on the PSTs, is to investigate the impact of these practices on their awareness of STEM and STEM education, as well as their perspectives on the implementation process.

This research seeks to address the following questions:

1- Does STEM education have an effect on PSTs' awareness of STEM and STEM education?
2- What are the views of PSTs regarding STEM education?

Method

We designed the study based on the weak-experimental design with a One-Group Pretest-Posttest model (Creswell, 2014) by including a case study. Case study, widely used in qualitative research, is preferred to examine one or more cases (situation, event, individual, group, etc.) in depth within their own conditions (Yıldırım & Şimşek, 2021). Moreover, as mentioned above, we preferred this qualitative case study to obtain richer data to reveal how they conceptualize the concept of STEM and all four disciplines separately, and whether the PSTs can recognize the relationships/connections among STEM disciplines in the daily life examples. Qualitative data were gathered through open-ended questions placed in both questionnaire and interview form.

Participants

This study consists of 30 third-grade PSTs studying in the science teaching program of the faculty of education of a state university in a provincial center located in the north-west of Türkiye in the 2018-2019 academic year. We determined the participants based on convenience sampling method and a voluntary basis to speed up the research and avoid problems in contact, although its reliability and generalizability are lower than other sampling methods (Yıldırım & Şimşek, 2021). The researchers explained the purpose and content of the research to the PSTs enrolled in the Science Teaching Laboratory Applications I course, and 30 PSTs stated that they would participate in the study voluntarily. Participants consisted of 24 female and six male science PSTs with an average age of 20-21. According to the science teaching undergraduate program used in the 2018-2019 academic year when the study was conducted, the participants generally completed physics, chemistry, biology, and mathematics courses and have not yet enrolled in the science teaching methods course (Council of Higher Education, 2018). 40% of the participants stated that they had never heard of the concept of STEM before.

Data Collection Tools

STEM-Awareness open-ended questionnaire (STEM-A)

This questionnaire, developed by Tezsezen (2017), consists of two parts including open-ended questions, and was used as a pre and posttest. The first part contains two questions. Participants were asked to define STEM disciplines in the first question and STEM education in the second question. In the second part, there are reading texts on two situations (*Microbiological corrosion* and *Radioactive verbs*) selected from daily life topics. To reveal whether or not they realize the relationship between STEM disciplines, participants were asked to explain which STEM disciplines are included in these reading texts. The STEM-A was administered as pre and posttest.

Semi-structured interview form

There are four questions in the form. Expert opinions were obtained from two science educators for the content validity of the prepared interview questions. To reveal participants' awareness of the applicability of STEM practicing, interviews were held with ten volunteer PSTs at the end of the instructional intervention. Interview questions are listed below:

1- In which subjects do you think you can include STEM practices within the scope of science courses in your professional life?
2- What do you think you would need if you were to use these practices in your professional life?
3- In your opinion, what is the key to making STEM practices productive (or, what does the efficiency of a STEM practice depend on)?
4- How do you include other STEM disciplines other than science in your practices?

Instructional Implementation Process

The second researcher carried out the practices in the study under the supervision of the first researcher. First of all, a four-week pilot study was conducted on a voluntary basis with 27 third grade PSTs who enrolled in the Science Teaching Laboratory Applications II course in the spring semester of the 2017-2018 academic year. During this study, three activities (*Let's design a thermos, Let's design a wind turbine, and Let's produce bioplastic*) prepared based on the literature (BAUSTEM, 2018; Çepni, 2018; Çorlu & Çallı, 2017; National Aeronautics and Space Administration [NASA], 2018a) were carried out. The data and findings obtained from the pilot study were used in the development of this study. Considering the difficulties encountered during the pilot study and the suggestions of the participants, we thought that it would be useful to prepare a worksheet that PSTs can use during STEM practices, and decided that the materials to be used in the new STEM practices to be designed would be mostly easily accessible and/or recyclable materials.

The study was conducted over a nine-week period with 30 third grade students enrolled in the Science Teaching Laboratory Applications I course in the 2018-2019 academic year. Practices were carried out in heterogeneous groups of five PSTs. While creating the groups, female PSTs were randomly assigned to groups of four PSTs by lottery. Due to the low number of male PSTs, a male PST in each group was included in the groups by lottery as the fifth member to ensure a homogeneous distribution in terms of the number of men and women in the groups. Internet access was available in the laboratory environment where the practices were carried out. The PSTs worked in the same groups in all activities, and at least one computer was provided for each group. Within the scope of the study, five activities that were prepared using various sources were implemented via worksheets based on the literature. The activities were: *Wind turbine design*, *Bioplastic production, Water purifier design, Life on Mars* (supported by augmented reality application), and *My Cell Model* (using the

Minecraft education version). These activities were based on the topics of “energy”, “compounds”, “separation of mixtures”, “space technologies” and “cell”. The topics were chosen according to the middle school science curriculum (Ministry of National Education [MoNE], 2018) so that the PSTs could adapt the general science curriculum to meet the needs of their future students. Because the PSTs will become middle science teachers after graduation. We made plans so that the PSTs could work in cooperative groups of five for each activity. The instructional process was carried out with the help of worksheets prepared using the literature (Aydın-Günbatar, 2019; BAUSTEM, 2018; Çepni, 2018; Çorlu & Çallı, 2017; Moore et al., 2015; NASA, 2018a; 2018b; 2018c; Wheeler et al., 2014). On the first page of the worksheets, there is a table including sections called “*Professions*”, to contribute to creating career awareness and to reveal the importance of interdisciplinary work to solve a problem and “*My Duties and Responsibilities*”, which we provide in a cooperative learning environment. All activities begin with the presentation of a knowledge-based life problem. Then, it is continued through six basic sections in the worksheet, each of which consists of multiple sub-sections: (1) *Getting Knowledge*, (2) *Generating Ideas*, (3) *Developing a Product/Solution*, (4) *Improving/Making Changes and Trying Again, (5) Introducing/Sharing Product (Solution)* and (6) *What I Learned during the Process*. The "*Getting Knowledge*" section consists of three subsections: "*What I Know?*", in which students write down what they have known and experienced to reveal their prior knowledge about the problem and possible solution(s). "*What I Want to Research?*", which creates opportunities to generate questions to find solutions and conduct research in order to find answers to these questions. Also, “*What I’ve Learned*?”, which is the section where they will write the answers they found regarding their questions and the new information they learned as a result of their research. The “*Generating Ideas*” section includes guiding questions. For example, “Write down possible all the different ideas you think of" to make students realize that there may be more than one right path, and "Which of the ideas did you decide to use, why?" to make them aware of the limitations and improve decision-making skills. To improve students' engineering skills, the “*Developing a Product (Solution)*” section is carried out through multiple subsections such as *“Design and Make our plan"*, “*Produce and Implement our plan*”, "*Test and Record our data*", *“Analyze and Assess our product (solution)”* including guiding questions such “Is your solution successful? Have you encountered any problems? What kind of problems did you encounter?*”*. The part “*Improving/Making Changes and Trying Again*” consists of the subsections of *“Make changes (Redesign) and Test again”, “Record our new data” and “Re-evaluate and Assess again”*. For the subsections, there are guiding questions such as “What changes do you plan on your product?*”* and *“*Was your product work?”. The “*Introducing/Sharing Product (Solution)”* section aims to share the product or solution between groups. This part includes the subsections of “*Introduce/Share*” and “*Assess the product between the groups*”. There is a guiding statement such as "Plan how you will promote your product and use your test data to support your claims.". Depending on the type of event, students can promote the product or solution by preparing a commercial film or text, banner, brochure, poster, etc. for marketing purposes. In the "*What I’ve Learned during the Process*" part, we aimed to have students reflect on the knowledge, skills, and experiences they learned during the activity. We presented the “Let's design a water purification device” activity in detail at a conference focusing on teacher training (Durmaz et al., 2020).

Analysis of Data

Data analysis of the STEM-A questionnaire

Data analysis of the STEM-A questionnaire was evaluated with thematic analysis based on Tezsezen’s (2017) study. To comprehensively conceptualize STEM and STEM education, learners should not only understand the nature of science, but also the nature of technology, the nature of engineering, and the nature of mathematics (Akerson et al., 2018). Hence, grounded on the literature (Akerson et al., 2018; Harlen, 2015), we added the themes of the nature of technology and the nature of engineering to the themes of the nature of science and the nature of mathematics existing other themes in Tezsezen's study. 20 % of the data that were randomly selected were evaluated jointly by two researchers, who reviewed the responses together and discussed them until a 100 % consensus was reached. In cases where a definitive decision could not be made, the opinion of a third science education expert was sought to achieve 100 % consensus. the problems were resolved by including the diversity of researchers, together reviewing and repeating the same process. The rest of the data was evaluated by the second researcher and then the evaluation of the data was reviewed by two researchers and arranged according to the final decision by reaching a common opinion. Themes and definitions are presented in Tables 1 -3.

Table 1 illustrates the themes and definitions of STEM disciplines.

Table 1 Themes and Definitions of STEM Disciplines

Discipline	Themes	Definitions
Science	Nature	Features related to the nature of science
	Function	Function or purpose of science
	Method/process	Scientific method
	Relationship	Relationship between science and other STEM disciplines
	Skill	Scientific process skills
	Physics-Chemistry-Biology	Science is defined as Physics, Chemistry and Biology
Technology	Nature	Features related to the nature of technology
	Function	Function or purpose of technology
	Method/process	Describes the process of technological development
	Relationship	Relationship between technology and other STEM disciplines
	Skill	Skills to develop/use technology
	Technology developers	Identifies who developed the technology
Engineering	Nature	Features related to the nature of engineering
	Function	Function or purpose of engineering
	Method/process	It defines how engineering is done
	Relationship	Relationship between engineering and other STEM fields
	Skill	Required skills for the engineering field
	Production/Product	Engineering is defined only by its products.
Mathematics	Nature	Features related to the nature of mathematics
	Function	Function or purpose of mathematics
	Method/process	Mathematical methods
	Relationship	The relationship between mathematics and other STEM fields
	Skill	Mathematical skills

The themes and definitions of STEM education are presented in Table 2.

Table 2 Themes and Definitions of STEM Education

Themes	Definitions
Relationship between disciplines	Defines both connections between other disciplines, and pedagogical paradigm
Integrity/Integrated structure in disciplines	Regarding the nature of STEM education, it refers to the integrated structure in which the boundaries between each discipline disappear.
Cross-domain collaboration	Describes collaborative work across disciplines
Relation to real life	It expresses the importance of STEM disciplines in solving real-life problems.
Separation between disciplines	Considers each discipline separately
Irrelevant Answers	

Table 3 shows the themes and definitions of how STEM disciplines are included in the texts of Microbiological Corrosion and Radioactive Verbs cases

Table 3 Themes and Definitions of How STEM Disciplines are Included in the Texts of Microbiological Corrosion and Radioactive Verbs Cases

Discipline	Themes	Definitions
Science	Contents	Scientific terms mentioned in the text reading are emphasized.
	Explanation	It is stated that science has a role in scientifically explaining/researching the relevant case or making it more clear to readers.
	Investigations	It defines the role of science in conducting studies on a subject.
	Relationship/Collaboration	Collaboration of other disciplines is noted regarding the case.
Technology	General technology	Technology is superficially discussed or exemplified by a product.
	Process/Technology for research	Technology that is thought to be used in researching issues related to the case is mentioned.
	Relationship/collaboration	It is explained using the relationship between technology and other STEM disciplines or products.
Engineering	Superficial engineering	Very superficial explanations are given about man-made structures, engineering names or specific engineering disciplines in the case (such as chemical engineering).
	Function	The function or purpose of engineering is stated.
	Process	It is stated how engineering is done.
	Relationship/collaboration	Engineering is explained using the relationship between other STEM disciplines or products.
	Skills	Modeling, problem solving, etc. engineering skills are indicated.
Mathematics	Nature of mathematics	Calculations related to the nature of mathematics are expressed as concepts such as numbers and statistical data.
	Skills	Mathematical skills such as data analysis, interpretation and synthesis are expressed in defining the mathematics in the event.
	Relationship/collaboration	Mathematics is explained using the relationship between other STEM disciplines or products.

Data analysis of semi-structured interviews

We analyzed data obtained from semi-structured interviews based on content analysis. Content analysis allows the collected data to be organized, summarized and interpreted by dividing them into smaller categories (Yıldırım & Şimşek, 2021).

Frequency (f) values of the data obtained from both data collection tools were determined by descriptive analysis. Since the PSTs could write more than one sentence while making definitions, the number of frequencies in the themes may be higher than the total number of participants.

Results and Discussions

STEM Awareness

To investigate the PSTs' STEM awareness, STEM-A Questionnaire was employed.

Results from the first analysis group (part 1) of the STEM-A

First stage, the pre and posttest data regarding the definition of STEM disciplines are shown in Table 4.

Table 4 Themes and Frequency Values of the Definitions of STEM Disciplines

Discipline	Themes	f	
		Pretest	Posttest
Science	Nature	3	2
	Function	**20**	**20**
	Method/process	4	2
	Relationship	1	**4**
	Physics-Chemistry-Biology	4	4
Technology	Process	7	**10**
	Function	**25**	24
	Relationship	**-**	**3**
Engineering	Process	3	**13**
	Function	9	**12**
	Relationship	6	**11**
	Production/Product	**13**	5
Mathematics	Nature	**23**	17
	Skill	1	**3**
	Method	2	**6**
	Relationship	4	**12**

From the data in Table 4, it is apparent that in PSTs' explanations regarding the definition of science in both the pretest and posttest, they mostly emphasized the purpose or function of science rather than the nature of science, the characteristics of science, or the inquiry process, or the relationship of science with other STEM+ disciplines in terms of content or context. It can be argued that a few participants gained a slight awareness in favor of the posttest in their perspectives on the definition of science by using the relationship or collaboration between science and other STEM+ disciplines when explaining what science is. Since the STEM activities practiced during the study were based on the science curriculum, science discipline was always taken as the central discipline and other disciplines were integrated into science as a context. For this reason, although we cannot put forward any evidence, the PSTs may have stated more of the functionality/purpose of science in the definition of the science discipline, taking into account the program-related aims of the activities in the posttest.

Regarding the definition of the discipline of technology, as in the definition of science, the majority of participants declared the purpose or function of technology in both the pretest and posttest. This result is not surprising to us, because the technology discipline is integrated into the science discipline as a context in the activities. For instance, technology was integrated with augmented reality in the *Life on Mars* activity and with the Minecraft educational version in the *My Cell Model* activity. As a result, we can say that a difference of understanding has developed in favor of the posttest. While some participants conceptualized the technology discipline, they revealed the development processes of technology and the contribution of other disciplines to this process.

Concerning the definitions of the engineering discipline, the participants mostly defined technology as production or product development in the pretest. When we analyzed posttest data, we found that participants defined the engineering discipline by considering engineering thinking, the engineering design cycle, and collaboration with other STEM disciplines, as well as the function or purpose of engineering. The reason for this positive change in understanding in the posttest may be that the engineering design process was integrated into every activity implemented.

As for the definition of the discipline of mathematics, we can say that the participants showed a positive change in their awareness of the mathematics discipline. The PSTs explained the nature of mathematics by including mathematical skills, mathematical process, and its relationship with other STEM disciplines while conceptualizing the discipline of mathematics.

Based on Table 4, we can argue that the biggest increase in awareness is in the disclosure of the engineering discipline. However, we would like to point out that we did not detect any explanations that meet the themes of the nature of technology and the nature of engineering in the analysis of the pretest and posttest responses of the PSTs. Based on the literature review, Faikhamta (2020) argues that STEM teachers' understanding of the nature of technology and engineering is insufficient. Furthermore, the literature indicates that students have some misconceptions such as "*technology is only artifacts*" and "*engineering design is a single process*" about the nature of technology and engineering, as well as about the nature of science (Kruse et al., 2017).

Overall, as shown in Table 4, increases in favor of the posttest were determined in the relationship theme for the science discipline, in the relationship and process themes in the technology and engineering disciplines, and in the skill, method, and relationship themes in the discipline of mathematics. Evidence of change in favor of the posttest regarding PSTs' awareness of the interrelationship or collaboration of STEM disciplines is presented as an example in Table 5.

Table 5 Change in PSTs' Awareness of the Collaboration/Relationship of the Discipline Fields with other STEM Disciplines

Discipline	Pretest	Posttest	Evidence of change from
Science	"….. expresses the laws of the universe …"	"… It is the most helpful discipline for technology, engineering and mathematics disciplines. …"	function of science to relationship/collaboration between other STEM disciplines
Technology	"… Inventing and building new things to understand life …"	"… It is the discipline where new products or new methods are researched and created by interacting with other disciplines (science, mathematics, etc.) in order to facilitate our daily lives. …"	function of technology to relationship/collaboration between other STEM disciplines
Engineering	"… profession that makes houses, bridges, structures …"	"… Engineering includes math and science related skills. What is done, how it is done and what materials to use are decided by engineers. …"	production/product aspect of engineering to relationship/collaboration between other STEM disciplines
Mathematics	"… numbers and figures. The way we use them …"	"… The mathematics covers the numbers, numbers and the relationship between them that we use in engineering and daily lives."	nature of the mathematics to relationship/collaboration between other STEM disciplines

Second stage, the pre and posttest data regarding the PSTs' definitions of STEM education from part 1 of the STEM-A questionnaire are shown in Table 6.

Table 6 Themes and Frequency Values of the Definition of STEM Education

Themes	f	
	Pretest	Posttes
Relationship between disciplines	5	10
Integrity/Integrated structure in disciplines	8	14
Cross-domain Collaboration	-	8
Relation to Real Life	4	6
Separation between disciplines	-	-
Irrelevant Answers	14	-

Table 6 is quite revealing in two ways: First, neither in the pretest nor in the posttest did any PSTs explain STEM education as the sum of individual disciplines. Second, there is a clear trend of shifting to understanding integrated of STEM. The high number of irrelevant answers in the pretest shifted to other themes in the posttest. Considering the increasing frequency values in favor of the posttest, it can be argued that the PSTs realized the relationship between STEM disciplines and the integrated use of disciplines in STEM education. Comparing with the pretest and posttest data, the following two examples of quotes taken from PSTs' responses regarding the definition of STEM education denote the change in PSTs' awareness of the concept of STEM education:

One PST indicated that:

> *‘‘... To raise awareness among individuals about the dominance of these four concepts over human life. ...’’* (pretest)
>
> *‘‘... To make, design and produce something by using science, technology, engineering applications and mathematics collaboratively (sometimes two, three, sometimes all together). ...”* (posttest)

Another PST said that:

> *‘‘... I've heard it a few times. Lego etc. to teach science. create designs with tools ...’’*(pretest)
>
> *‘‘... In order to improve the problems we may encounter on a daily basis, students are asked to find solutions to this event by using science, engineering, mathematics and technology. It is expected to provide group solidarity behavior by interacting with different disciplines of science ....’’* (posttest)

Based on the data obtained from the first part of the STEM-A questionnaire, it was determined that PSTs' awareness of the relationship between STEM disciplines and the integrated use of disciplines in STEM education showed a positive development in favor of the posttest. Literature studies (Aydın-Günbatar et al., 2021; Radloff & Guzey, 2017; Tezsezen, 2017; Wang et al., 2020) also support the positive effect of STEM applications on PTs' conceptualization of STEM and STEM education. Arslanhan (2019), Aslan-Tutak et al. (2017), and Tezsezen (2017) have also stated that, because of the instructional practices they conducted, the most significant change observed in the participants' understanding of STEM was related to how the integration of STEM disciplines is achieved. We note that there is no apparent consensus among stakeholders on how STEM is conceptualized (Dare et al., 2021).

Results from the second analysis group (part 2) of the STEM-A (2 case studies)

This part includes reading texts on two topics encountered in daily life (*Microbiological corrosion and Radioactive verbs*). To investigate the participants' awareness of STEM disciplines, the question "How are the disciplines of science, technology, engineering and mathematics included in the text you read?" is posed. The data obtained for both cases are given in Table 7.

Table 7 Themes and Frequency Values Regarding the Involvement of STEM Disciplines in the Microbiological Corrosion and Radioactive Verbs Cases

Discipline	Themes	f			
		Microbiological corrosion		Radioactive verbs	
		Pretest	Posttest	Pretest	Posttest
Science	Content	15	16	19	20
	Explanation	10	**14**	2	2
	Research	6	3	-	-
	Collaboration	-	-	6	6
Technology	Specific technology area related to the focused issue	17	**19**	-	-
	General technology	13	6	11	12
	Relationship / Connection	-	**6**	3	**5**
	Process	-	-	14	9
Engineering	Skill	-	-	8	**10**
	Process	2	**6**	-	-
	Specific engineering area related to the focused issue / production	16	6	-	-
	Engineering explanations in a superficial sense	-	-	14	6
	Function	10	**13**	-	-
	Relationship / Connection	1	3	2	**4**
Mathematics	Nature	20	14	22	22
	Skills	9	**14**	4	5
	Realitionship / Connection	1	**7**	4	3

As seen in Table 7, there is an increase in favor of the posttest in the statements of the PSTs stating that the science discipline is included in the content and explanation categories in the Microbiological Corrosion case. For example, one participant commented on the presence of the science discipline in the text: *"... the negative effects of microbiological corrosion on metal and metal alloys have been examined. Examples such as the rusting of iron have been given, and it has been observed that it causes damage in the industry ...*". In the pretest, responses regarding the awareness of the technology discipline in the text included superficial explanations about technology in general. However, in the posttest, it was determined that these explanations were replaced by more specific explanations concerning the technology use in the focused issue and its interaction with other STEM disciplines. For example, *"... the structures that make life easier (pipes, houses, vehicles, ...) are all products* *of technology... However... corrosion and its damages, which are problems in modern industry, are also related to technology. ...* ". Regarding awareness of the discipline of engineering in the text, the theme of Engineering/Production (which includes specific engineering fields like man-made structures or chemical engineering) stood out in the pretest. However, in the posttest, it was observed that the responses shifted towards themes of process, function, and relationship. These themes indicate how engineers manage the process, define their function, and work in coordination with other STEM disciplines, rather than providing general information about the field of engineering. For example, it can be argued that a more detailed explanation is given in the sentences *"... detecting electrochemical reactions...*"; *"... investigating the damages of microbiological corrosion on metal and building materials...*". Regarding awareness of the mathematics discipline in the text, the theme of the nature of mathematics stood out in the pretest. PSTs expressed superficial concepts such as calculations, numbers, and statistical data. However, in the posttest, it was discovered that this theme was replaced by the skill theme. Answers related to data analysis, interpretation, and synthesis were coded under this theme, along with the theme of the relationship with other STEM disciplines. For example; "... *calculation of the change in countries' annual corrosion expenditures, calculation of the damages of microbiological corrosion...*"; *"... expressing the results with numbers and evaluating the effects of the probabilities of the processes with numbers...*".

It is somewhat interesting to note that in this case, the PSTs did not include any explanations regarding the relationship/collaboration of science with other disciplines, the development process of technology and engineering skills, neither in the pretest nor in the posttest. In general, the PSTs explained the subject of corrosion only as chemical corrosion in both the pretest and posttest. Two examples of quoted sentences from the responses given are shown below:

> *"Corrosion is included in the text as the deterioration of metals and metal alloys with their environment or by electrochemical reaction."*
>
> *"In the text, how corrosion occurs is explained in relation to chemicals."*

Although we cannot put forward any evidence, we can think that the reason for this may be that the topic of corrosion in chemistry courses is explained only with examples of chemical corrosion. In summary, it can be argued that while the pretest in the Microbiological Corrosion case generally showed PSTs' awareness of the nature of science, technology, engineering, and mathematics, their understanding of the functionality and interrelationships among these disciplines and their effects on each other increased in the posttest. In the case of radioactive verbs, no significant difference was detected in the posttest regarding the participants' answers on how the science discipline was involved in reading the case of radioactive verbs. One participant's answer is presented as an example: *"... explaining the formula developed by the mathematics professor by comparing it to particle physics..."*. Concerning how the discipline of technology is included, it is noteworthy that there was an increase in the relationship theme in favor of the posttest in the participants' answers. An example of direct quotes from participants' answers is that *"... radioactive decay in this process and this process, its half-life process, is an area that can be followed with technology...*". Regarding the engineering discipline, it is worth noting that there was an increase in the theme of relationship and skill in favor of the posttest in the participants' answers. An example of direct quotes from participants' posttest is given: *"... mathematicians act in line with a plan when applying the formula, they have developed and compare new results with old results...*". Additionally, there was an increase in the participants' answers regarding how the discipline of mathematics was included in the skill category, favoring the posttest. One participant stated such as *''... transforms the phenomenon in physics into certain numbers by looking at its English history ...''*.

As seen in Table 7, in the case of microbiological corrosion and radioactive verbs, we see that the number of codes belonging to the same themes is different in both the pretest and posttest. There may be several possible explanations for this result. One possible explanation may be the different subject contents, and another may be the content and levels of PSTs' prior knowledge of the subjects. For these reasons, the PSTs may not have been successful in making comprehensive inferences from the texts in both cases. Overall, when considering the case of microbiological corrosion and radioactive verbs in the second part of the STEM-A questionnaire, it can be claimed that although the participants' performance in recognizing interdisciplinary relationships is poor, there is a slight increase in functionality, inter-relationships of disciplines, and awareness of their effects on each other in the posttest, unlike the pretest.

The finding aligns with the previous research conducted by Tezsezen (2017). Given the composition of the chemistry courses within the science teaching program, it can be noted that the allotted number of lesson hours for addressing corrosion and radioactivity topics is relatively low. Consequently, it is plausible to assume that participants may have had limited knowledge about corrosion and radioactivity from both their everyday experiences and chemistry coursework. Pleasants and colleagues (2021) determined in their study with teachers and PTs that the majority of the participants made very superficial conceptual connections between STEM disciplines. For the two cases in this section of the questionnaire, the participants generally associated STEM disciplines mostly with engineering and mathematics disciplines and they had difficulty in associating technology with other STEM disciplines. This finding corroborates the result of Gül (2019), who reported that mathematics and technology disciplines were not included in the STEM lesson and activity plans prepared by PTs. Further, Değirmenci (2020) highlighted the STEM self-efficacy of teachers with low self-efficacy in integrating technology and engineering disciplines was also low. In this context, Aydın-Günbatar et al. (2021) recommended emphasizing the relationship between STEM disciplines and the engineering design process in STEM education practices for PTs to grasp the concept of integrated STEM education.

Views of the PSTs' Regarding the Process of STEM Practices

To reveal the views of the PSTs about the process of STEM practices, we focused specifically on the interviewees' awareness of the applicability of STEM practice. The data obtained are presented in the order of questions in the interview form:

Question 1: In which subjects do you think you can include STEM practices within the scope of science courses in your professional life? Regarding this question, seven of the participants stated that it could be applied in every subject, while three of them claimed that it could not be applied in every subject. Examples of the PSTs' answers to this question are presented below:

> *‘‘... people and the environment. I would use it too... actually, it can be used in many subjects, actually. In fact, science is used in many, many subjects because it is our life itself and because it is everywhere. In all..."*
>
> *‘‘... It would be very difficult to apply it in biology, for example, our organs and systems, I think these cannot be applied, but there are engineering units in the best force and motion units, for example, they can also be used in engineering applications. In chemistry, substances, properties of substances, acids, and bases can be applied in all of these, but I think I will have the most difficulty in biology... I will have difficulty... I probably cannot apply it in systems at all..."*

The views of participants corroborate previous research. For example, according to the findings of Siverling and colleagues (2017) from their literature reviews, it was claimed that physics and earth science, among the science disciplines, are more commonly involved in

STEM applications, whereas biology is relatively less involved. Similarly, another study expresses that while physical sciences-based integrated STEM instruction has been increasing in recent years, more research is needed in life sciences-based STEM instruction in K-12 classrooms (Anwar et al., 2022).

Question 2: What do you think you would need if you were to use these practices in your professional life? The obtained data by analyzing the answers of the PSTs is shown in Table 8.

Table 8 Answers of the PSTs to the Question "What Do You Think You Will Need if You Were to Use These Applications in Your Professional Life?"

Themes	Codes	f
Professional Competence	Class domination	4
	Preliminary	1
	Time management	4
Method / Experience	Engineering design process experience	3
	Experience integrating technology discipline	2
	Increased STEM activity planning experience	1
	Hands on skills	2
School Environment	Administrator support	**8**
	Colleague (own major/other majors) support	**8**
	Material supply	7
	Laboratory / large area	5
	Ideal class size (Ideal number of students for a class)	2

As in Table 8, we can see the majority of the participants expressed that they may need support and material supplies from the school administration and other teachers when applying STEM education in their professional lives. The findings of our study are consistent with the previous studies. As mentioned in the literature review, administration and collegial support are important factors in teachers' participation in STEM teaching, and one of the main impediments to effective integrated STEM education is the need for materials and resources for both practitioners and students (Dong et al., 2019; Haatainen et al., 2021; Moore et al., 2014a; Navy et al., 2020).

Question 3: In your opinion, what is the key to making STEM practices productive?" or "What does the efficiency of a STEM practice depend on?: Table 9 presents the data obtained from the analysis of the participants' responses.

Table 9. The Answers to the Questions "In your opinion, what is the key that will ensure that STEM practices are effective?" or "What does the efficiency of a STEM application depend on?"

Codes	f
Student's imagination	1
Collaborative work	**5**
Active participation of the student	1
It is a real problem that is meaningful to the student	2
Properly integration of disciplines	1
Giving enough time	3
Correct information acquisition phase	3
Designing the process to enhance creativity	1

In response to Question 3, the majority of participants stated that successful STEM applications depend on the collaborative work of both teachers and students. It is worth noting that this emphasis on collaboration aligns with the results obtained from existing literature, which also emphasize the significance of collaborative approaches in STEM education (Aslan-Tutak et al., 2017; Wang et al., 2020).

Question 4: How do you include other STEM disciplines other than science in your practices? The data obtained from the analysis of the participant responses is displayed in Table 10.

Table 10 Answers of the Question "How do you include other STEM disciplines in your practices?"

Discipline	Codes	f
Technology	Virtual environment to market products	1
	Devices and mobile applications used	**6**
	Simulations	3
	Augmented reality	4
	Virtual reality	1
	Animations	2
	Photo/video shoots	2
	Educational games	1
Engineering	Sketching / drafting	**5**
	Course design for students to work like an engineer	3
	Inventing a product	2
	Getting economically efficient	1
	Material selection	1
	Durable product development	2
Mathematics	Designing activities that develop mathematical competence	**8**
	Matching activities with mathematics in daily life	1

As seen in Table 10, the majority stated that the integration of disciplines can be achieved by using technology, technological devices, and mobile applications, planning design-based applications in engineering, and including activities that will develop mathematical competence in mathematics. For the technology integration, most of the participants expressed that they could integrate the technology discipline by using technological devices and mobile applications. One of the prominent perspectives regarding the discipline of technology in the literature is "*tools and applications used by science, mathematics, and engineering practitioners*" (Ellis et al., 2020). As mentioned in the literature review, various applications, design programs, robotic software, digital probes to collect and analyze data, computer-assisted design (CAD) software, 3-D printers, etc. can be used for technology integration (Moore et al., 2014a; Roehrig et al., 2021). Students can ascertain both the meaning and applications of science, engineering, and mathematics using STEM tools and techniques (Ellis et al., 2020).

Most participants stated that they could integrate engineering into science courses by planning design-based practices. Since applications of mathematics and science are necessary to solve engineering problems, STEM has a natural unifying/connecting role in meaningfully integrating disciplines and learning the content of science, mathematics, and technology (Moore et al., 2014b). According to the literature review, the engineering design process is mostly used in the integration of the engineering discipline. Researchers usually define a problem scenario for engineers as the management of a technology company or a customer task that is a company contract. This scope is compatible with the nature of engineering, as engineers in their real lives design a new product to find a solution to an existing problem, respond to a need, or make changes or innovations to the existing design according to certain criteria. Based on the literature, brainstorming, laboratory activities, and writing activities are mostly used as teaching/teaching methods in the integration of engineering (Arık & Topcu, 2022). Participants stated that they could integrate the discipline of mathematics by including activities that would improve mathematical competence. Mathematically proficient students make better sense of quantities and their relationships in problem situations. According to the literature, the integration of mathematics into integrated STEM education is difficult. It often works in the background as a data measurement and/or data analysis tool, not taken as a conceptual learning goal for mathematical purposes. However, the role of mathematics in an effective mathematics integration should be made clearer. If teachers want to improve students' understanding of scientific phenomena, they should engage their students in mathematical tasks that require high cognitive effort, such as mathematical modeling (Aminger et al., 2012).

Conclusion and Suggestions

This study was designed to determine the effect of STEM education practices on the PSTs' awareness of STEM education and their views on the STEM practicing process.

In the literature review, it was determined that different results were obtained regarding the effect of STEM education or activities on participants' STEM awareness (Aktaş, 2019; Karisan et al., 2019). In the first part of the STEM-A questionnaire, the PSTs' awareness of STEM was examined through their definitions of STEM disciplines and STEM education. Based on the data obtained from the first part of the STEM-A survey, it can be claimed that the explanations provided by the PSTs changed towards recognizing the integrated structure of STEM disciplines after the implementation, and STEM practices had a positive impact on their understanding of the importance of interdisciplinary cooperation in solving problems. In the second part of the STEM-A questionnaire, participants' awareness of STEM was examined through their explanations of how STEM disciplines were included in the two cases presented. The evidence from this study revealed that the participants encountered challenges in understanding the relationship between STEM disciplines. Recent education reforms emphasize STEM education as an interdisciplinary educational approach (National Research Council [NRC], 2014). If PTs can conceptualize STEM education correctly, then their future students could benefit from theirs experiences.

When we examine the PSTs' views about the process of STEM practices, the study has found that generally, the PSTs agree that STEM practices would make a significant contribution to their professional development. While the majority of participants expressed that STEM practices could be implemented in every subject within the science course, there were some participants who mentioned potential difficulties specifically in biology subjects. Further, we found that many PSTs stated that if they were to implement STEM education practices in their professional lives, they would require support from the school administration and their colleagues. Additionally, they anticipated potential challenges in sourcing materials for their STEM activities. The participants in our study highlighted the significance of collaborative work as a key factor for successful STEM applications. Although extensive research has been carried out on integrated STEM instructions, currently, the literature contains differences in how integrated STEM education is implemented or can be implemented (Dare et al., 2021). This study demonstrates the considerable benefits of STEM practices on PSTs' integrated views of STEM.

Although our study has a small sample size and is based on a single case study design, we can say that PSTs' awareness has increased positively towards the integrated structure of STEM, based on the findings of our study. Additionally, the PSTs have demonstrated an understanding of the significance of interdisciplinary relationships and the integrated structure within STEM education. Research indicates that the basis of training a qualified STEM educator is to ensure that they develop the correct conceptual understanding of integrated STEM education (Kelley & Knowles, 2016) and as teachers' content knowledge, experience, and pedagogical content knowledge of STEM disciplines and integrated STEM education increase, their ability to effectively implement integrated STEM education will also improve (Moore et al., 2014a). This study is expected to make a valuable contribution to the existing literature by aiding PSTs in developing awareness and conceptual understanding of STEM education. It also provides an opportunity for PSTs to gain practical experience in implementing integrated STEM education approaches. Considering that what a qualified STEM education is and how it should be implemented is a complex and challenging process (Dare et al., 2019).

Suggestions

We suggest that longer-term studies be conducted to examine PSTs’ STEM awareness and knowledge and skills in integrating STEM disciplines. Pedagogical content knowledge of PSTs to integrate STEM practices into their courses in their future professional lives can be investigated in depth. In future studies, it may be beneficial to examine PTs' knowledge and skills in integrating STEM disciplines and their competence in preparing lesson plans for STEM education. Additionally, for PSTs, sample topics that they are more familiar with from their daily lives can be chosen instead of microbiological corrosion and radioactive verb topics to explore the 'experience component' of STEM awareness. Moreover, to develop a common understanding in the field of education, we recommend that conceptual knowledge and processes related to STEM education be explicitly conceptualized, as in the nature of science and views about scientific inquiry.

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Compliance with Ethical Standards

Disclosure of potential conflicts of interest

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CRediT author statement

The second author developed the initial idea and then the authors both designed the study. The first author supervised the thesis study and provided guiding in the preparation of the lesson plans and STEM activities. The second author conducted the STEM activities under the supervision of the first author and collected all data. First author provided expert guidance all of the data analysis and wrote the manuscript.

Research involving Human Participants and/or Animals

This study was carried out taking into account ethical rules. The participants were informed about the study and asked to sign a consent form based on a voluntary basis. An ethics committee report was not required in studies before 2020. The study was approved with the decision number 2 taken at the meeting numbered 34 and dated 17.09.2018 of the Trakya University Institute of Natural Sciences board of directors. The data of the study was collected in the first semester of the 2018-2019 academic year.

STEM Eğitimi Uygulamalarının Fen Bilimleri Öğretmen Adaylarının STEM Eğitimine Yönelik Farkındalıklarına ve Görüşlerine Etkisi

Özet:

Araştırmanın amacı STEM eğitimi uygulamalarının fen bilgisi öğretmen adaylarının STEM ve STEM eğitimi konusundaki farkındalıklarına etkisini ve uygulama sürecine ilişkin görüşlerini incelemektir. Araştırma tek gruplu öntest/sontest zayıf deneysel desende tasarlanmış olup durum çalışması dahil edilmiştir. Çalışma grubunu 2018-2019 eğitim-öğretim yılında Fen Öğretimi Laboratuvar Uygulamaları I dersine katılan 30 öğretmen adayı oluşturmuştur. Katılımcılar uygun örneklem seçimi ve gönüllülük esasına göre belirlenmiştir. Çalışma dokuz hafta süresince yürütülmüş ve beş STEM etkinliği gerçekleştirilmiştir. Nitel veri toplama araçları olarak STEM farkındalık açık uçlu anketi (STEM-A) ön ve sontest olarak kullanılmış ve elde edilen veriler tematik analiz ile değerlendirilmiştir. Öğretimsel uygulamaların sonunda da on gönüllü katılımcı ile yarı yapılandırılmış görüşmeler yapılmış ve elde edilen verilerin analizinde içerik analizi uygulanmıştır. Bulgulara göre, katılımcıların farkındalıklarının olumlu yönde geliştiği ve STEM yaklaşımının disiplinler arası ilişkinin ve bütünleşik yapısının önemini anladıkları ifade edilebilir.

Anahtar kelimeler: Fen bilgisi öğretmen adayı, STEM eğitimi, STEM farkındalığı.

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