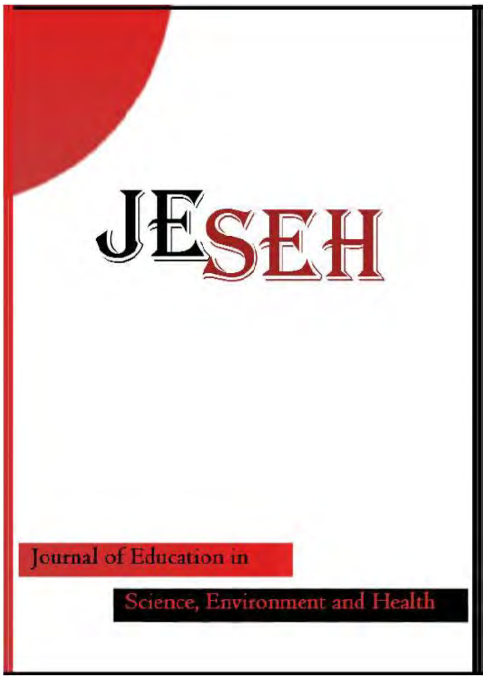

ISSN: 2149-214X

Journal of Education in Science, Environment and Health

www.jeseh.net

The Design, Implementation, and Evaluation of a STEM Education Course for Pre-Service Science Teachers

Kibar Sungur-Gul[1], Mehmet Fatih Tasar[2]
[1]Nevşehir Hacı Bektaş Veli University
[2]Gazi University

To cite this article:

Sungur-Gul, K. & Tasar, M. F. (2023). The design, implementation, and evaluation of a STEM education course for pre-service science teachers. *Journal of Education in Science, Environment and Health (JESEH), 9*(2), 85-100. https://doi.org/10.55549/jeseh.1272793

Journal of Education in Science, Environment and Health
Volume 9, Issue 2, 2023 https://doi.org/10.55549/jeseh.1272793

The Design, Implementation, and Evaluation of a STEM Education Course for Pre-Service Science Teachers

Kibar Sungur-Gul, Mehmet Fatih Tasar

Article Info

Article History

Published:
01 April 2023

Received:
10 June 2022

Accepted:
05 November 2022

Keywords

Educational design research
Pre-service teachers
STEM education
STEM course design

Abstract

The purpose of this study was to design, implement, and evaluate a course according to a STEM education approach for pre-service science teachers. The study was conducted in three phases according to an educational design research method: preliminary research, development or prototyping, and assessment (Plomp & Nieveen, 2013). The STEM education pre-knowledge form, STEM lesson plans, the STEM lesson plan evaluation form, STEM self-evaluation, and peer-evaluation forms, and a semi-structured face-to-face interview form were used as qualitative data collection tools. Data were analyzed by methods of content analysis. The results suggest that pre-service science teachers need education in the dimensions of the theoretical structure of STEM education, STEM disciplines and integration, 21st-century skills, sample STEM activities, current science curriculum, STEM learning/teaching methods and techniques, measurement and assessment for STEM education, collaboration with peers, and planning-implementing a lesson according to STEM education. The findings showed that the STEM course design developed through this study was seen to be effective in responding pre-service teachers' needs. In STEM course design, six activities were prepared in the context of designing a 21st-century house and designing a vehicle according to the trans-disciplinary model and hands on-minds on method. According to the relevant literature, the findings were discussed and future studies should provide collaboration with pre-service teachers, students, and in-service teachers. Future studies should also focus on developing the knowledge and skills of pre-service teachers about engineering and technology discipline and show how to integrate these disciplines into their real-life problems.

Introduction

STEM (Science, Technology, Engineering, Mathematics) is an educational approach that emerged in the 1990s to train 21st-century individuals (Sanders, 2009), and is defined as learning and teaching interdisciplinary knowledge practices involved in science and/or mathematics by integrating technologies related to engineering design/practices (Bryan et. al., 2016). To accomplish this vision, it is crucial to increase the number of well-educated teachers who will develop students' 21st-century skills (Partnership for 21st-century skills, 2009). Preparing efficient STEM teachers experienced in STEM instructional approaches is also main need to success this vision (Lynch et al., 2014; Outlier Research & Evaluation, 2014). The results of a preliminary study have also shown the need for effective pre-service STEM preparation programs in preparing quality STEM teachers (Bartels et al., 2019; Bell, 2016; English, 2017; Shernoff et al., 2017).

The critical question is "How do teacher education programs prepare teachers for STEM teaching?" The reality is that teacher education in many countries is focused on discipline-based content and pedagogy courses which mainly provide mathematics and science disciplines, provide insufficient knowledge and experience in STEM (Epstein & Miller, 2011; Bartels et al. 2019). Consequently, science and mathematics teachers who try to implement STEM education in their courses will be experts only in their fields (Lederman & Lederman, 2013), and therefore they will focus on learning objectives specific to their subject areas (English, 2015; Williams, 2011).

A serious preparation process is required for teachers who are practitioners of the STEM curriculum. American National Science and Technology Council-NSTC (2013) has suggested pre-service education and continuous professional development to increase STEM education from pre-school to higher education. Hence, in-service and especially pre-service teachers who are new in the field must be equipped with the abilities to integrate

STEM into their education programs. Since, pre-service teachers have an important role in managing the trajectory of STEM education as future educational leaders (Atkinson & Mayo, 2010; Bybee, 2013). Consequently, STEM curriculums are needed in K-12 education and there is a lack of experienced STEM teachers to design and implement STEM lessons. Preservice teacher preparation programs are important for developing an understanding of STEM knowledge, integrated STEM, and pedagogical practices that support STEM integration (Radloff & Guzey, 2016; Shernoff et al., 2017). Therefore, it is urgently necessary to provide pre-service teachers professional development about STEM education. This study aims to design a STEM course for pre-service teachers and examine its effectiveness.

STEM Education in Pre-Service Teacher Education

STEM education is more progressive, student-centered, and experimental than traditional teacher-centered education approaches. STEM education encourages the teacher to create a learning environment based on the constructivist approach that students learn by doing and living (Fioriello, 2010). Therefore, it is extremely important how teachers successfully implement STEM education (Vescio et. al., 2008). In addition, teachers need to be educated about STEM and the content of the pre-service and continuing education should focus on the structure and functioning of STEM and its integration. This will raise awareness among in-service and pre-service teachers and to promote STEM education (Buyruk & Korkmaz, 2016; Ministry of Education, 2016).

The qualities of a competent and effective teacher in STEM education have been mentioned in many studies. For instance, Lee and Nason (2012) suggested that pre-service teacher education programs should ensure both disciplinary and interdisciplinary STEM knowledge as well as situational theoretical knowledge to form the basis of STEM education training, the development of positive attitudes and orientation towards STEM. In addition, teaching methods courses that prepare future STEM teachers should include advanced pedagogy lessons that are compatible with how scientists do science (National Research Council [NRC], 2012). In order to include engineering practices in science courses, teachers should have competencies such as designing scientific research processes, using various materials in the classroom, determining course content and linking it with real life situations, and combining engineering design and laboratory experiments (NRC, 2012). Furthermore, Williams (2011) reported that teachers' competencies should be defined according to the STEM education needs. Turk, Kalaycı, and Yamak (2018) conducted needs analysis for the curricular design of STEM education for pre-service science teachers.

The results of the research showed that STEM teachers should have features such as creative thinking, ability to use technology, cooperation, being open to learning and having knowledge in their content, being expert in their STEM disciplines, and following developments in education. It was also underlined that they should have the knowledge and skills to prepare and apply lesson plans suitable for STEM education. It was also stated that teachers should have sub-themes of integrated teaching knowledge such as educational technologies, content knowledge, other STEM disciplines, and interdisciplinary science. In sum, pre-service teachers should be equipped with necessary knowledge, skills, and beliefs to implement STEM education.

Related Studies about STEM Education in Pre-Service Teacher Education

Previously, there have been several studies examining STEM education in pre-service teacher education (e.g Aydeniz & Bilican, 2018; Karışan et. al., 2019; Lin & Williams, 2016). However, to the best of our knowledge, there were few studies that suggested and defined the efficiency of the STEM program, model, course, etc. for pre-service science teacher education. For example, Pimthong and Williams (2021) developed a STEM methods course at three phases as preparation, planning, and evaluation and revision for pre-service teachers. Thus, the researchers investigated the pre-service teachers' development of STEM understanding and pedagogical knowledge. The study was conducted with only seven pre-service teachers in the implementation phase and many of them were in science education. Similarly, Ryu, Mentzer, Knobloch (2019) also developed a STEM education methods course for secondary pre-service teachers in STEM disciplines utilizing principles and techniques of grounded theory and examined pre-service teachers' practices and experiences of STEM integration. Data were collected to investigate the methods course students' practices and experiences of STEM integration. According to the findings, students accomplishedly improved the STEM integration lessons and instructed them. Bartels, Rupe, and Lederman (2019) designed a STEM unit to bridge elementary pre-service math and science methods courses through the modeling of integrated STEM lessons and explored the pre-service elementary teachers' understandings of STEM and their ability to plan integrated STEM lessons.

Eckman, Williams, and Silver-Thorn (2016) evaluated the effectiveness of the pre-service STEM teacher education model which incorporates science or mathematics content with pedagogical content knowledge, and defined its impact on pre-service teachers' understanding of STEM content and teaching skills. These studies provide general insights into the effects of a STEM methods course, a STEM teacher education model, or a STEM unit on pre-service teachers' STEM understanding, their pedagogical knowledge, their pedagogical content knowledge, and their experiences of STEM integration.

Considering the gap in the literature, this study aims to be the basis for current and future studies on pre-service teacher preparation by using a STEM course design developed in three phases with the Educational Design Research (EDR) method. EDR is a systematic but flexible methodology that seeks to improve educational practice through iterative analysis, design, development, and implementation, which is based on collaboration between researchers and participants in real-world settings, leading to contextually sensitive design principles and theories (Wang & Hannafin, 2005). Accordingly, activities focused on product design were conducted in the course of "Instructional Technology and Material Development". The course includes both technology as a discipline and the design of teaching materials, while providing the opportunity to integrate science and mathematics into this course we developed. Accordingly, the following research questions were formulated:

1. How can a course that aims to improve pre-service science teachers' knowledge and skills related to STEM education be designed, developed and evaluated?
2. How effective was the STEM course design in increasing pre-service science teachers' knowledge and skills in STEM education?

Method

This study was conducted in three phases according to the Educational Design Research (EDR) method: preliminary research, development or prototyping, and assessment as mentioned by Plomp and Nieveen (2013). EDR method was used to design and evaluate a course to improve the pre-service science teachers' knowledge and skills about STEM education. As seen in Figure 1, the main outputs of the EDR are mentioned as follows: Design principles were determined as the STEM education knowledge and skills that pre-service science teachers should acquire. The curriculum products of the study are STEM course design which was developed to increase the knowledge and skills of pre-service science teachers about STEM education. Another output is professional development as training of the pre-service science teachers in the study and ensuring their active participation through cooperation.

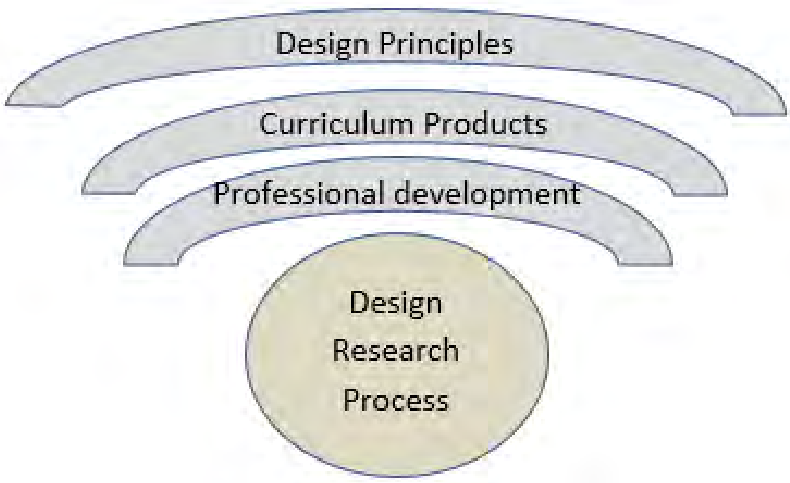

Figure 1. The three main outputs of design research. (McKenney et. al., 2006)

The Three Phases of the EDR

The schematic representation of the STEM course design development processes was shown in Figure 2. The research was designed to consist of three phases in accordance with the EDR.

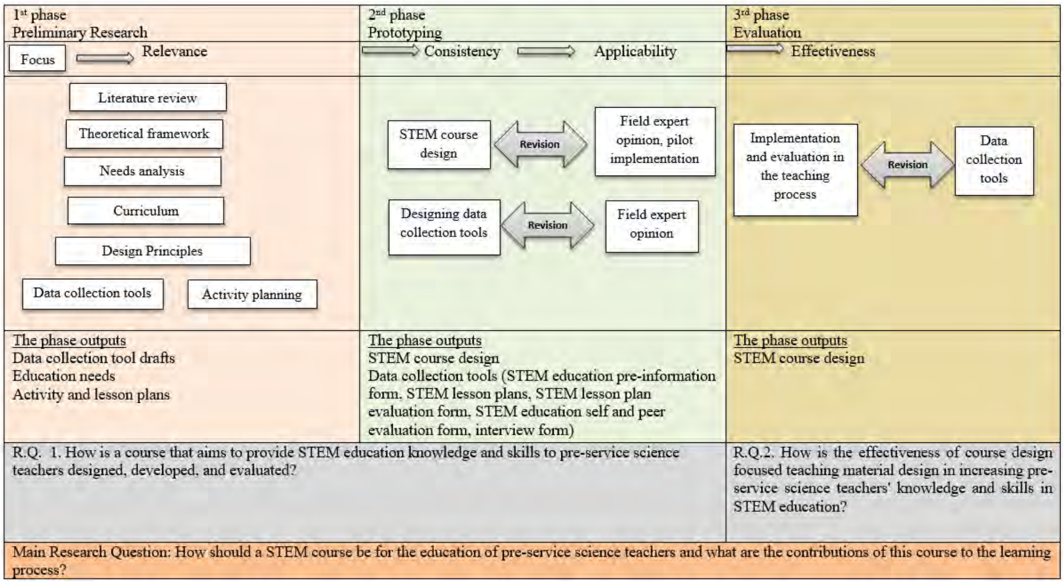

Figure 2. Schematic representation of the STEM course design development process

1. *Preliminary Research Phase*

In this phase, needs analysis was conducted to create a detailed scientific framework required to ensure the STEM professional development of pre-service science teachers. All contents specified in the STEM education needs analysis form were stated to be necessary by the experts. However, robotics-coding was not stated to be necessary at the first stage. In addition, it is thought that pedagogical content knowledge and teaching profession competencies should be included. Similarly, the pre-service teacher education literature supported the opinions of experts (Sanders, 2009; Eckman et. al., 2016; Hacıoğlu, et. al., 2016; Pimthong & Williams 2018). When the curriculum as “Science Trainings” and the “Science” is also examined, it can be said that they do not fully include STEM education and they take into account science, engineering, and entrepreneurship practices.

Thus, several activities have been designed to increase the knowledge and skills of pre-service teachers regarding STEM education. The activities were prepared according to the transdisciplinary model expressed by Vasquez et al. (2013). Science concepts were associated with mathematical thinking and data collection, engineering was used as a context and activities were engineering centered. The ending engineering product and materials used were associated with the technology discipline. Six activities were designed according to hands on-minds on method with simple materials and the participants were asked to design a 21st century house as a common theme. In this way, "Prototype 1-STEM Course Design" was created.

2. *Prototyping Phase*

The prototyping phase of the research reflects the process of developing STEM course design through formative assessments as a result of collaboration between pre-service teachers, experts, and researchers. In the sub-phases of the prototyping phase shown in Figure 3, the necessary arrangements (seen in the Pilot study and Expert Opinions) were made and thus, the consistency and applicability of the STEM course design were determined.

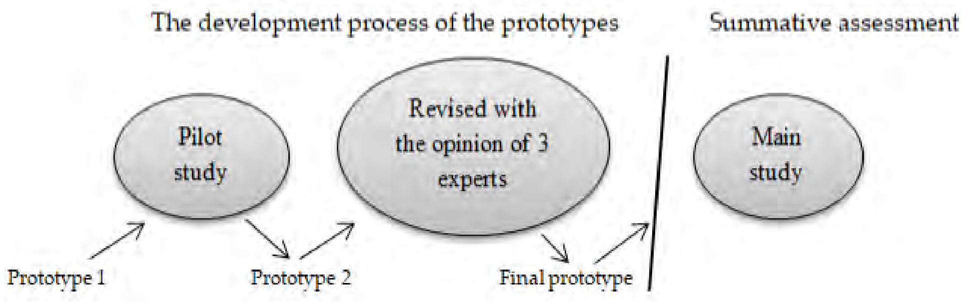

Figure 3. Prototyping phases of STEM course development

2.1. Pilot Study

Prototype 1 which was developed in the preliminary research phase was evaluated in the Special Teaching Methods-I course. The participants of the study were 20 pre-service 3rd year science teachers who participated voluntarily in the spring semester of 2017-2018 in Turkey. Prototype 1 was revised by taking into account the researcher's experience and observations in the pre-service teachers' trainings performed every week and the reflections written by the pre-service teachers. In this initial phase, theoretical framework of STEM education in the STEM course design was revised by enriching with teaching methods and techniques without reducing its content. In addition, instant (online applications such as Kahoot, plickers) and alternative assessment methods (examine-prepare PISA questions) were included in STEM course design. As a result, the course design was reviewed in terms of understandability, applicability, and suitability.

2.2. Expert Opinions

The opinions of the three experts (two from science education, one from curriculum and instruction) were received in terms of suitability and applicability of the STEM course design for pre-service science teachers, and the suitability of STEM activity-lesson plans. According to expert opinions, the theoretical parts in the 1-4th weeks of Prototype 2 was not changed and consequently, structured STEM lesson plans prepared according to the 5E instructional model, problem and project-based learning methods were planned to be examined and discussed by the pre-service science teachers between 5-7th weeks. These methods were preferred because they are among the models and methods frequently used in STEM education (e.g. Han, Capraro & Capraro, 2014; Yıldırım & Selvi, 2017). Moreover, problem/project-based strategies provide a deeper and more relevant learning experience in the process of solving real-world problems with open-ended and multiple solutions (Vasquez, Sneider & Comer, 2013). In the 8th and 9th weeks, the pre-service teachers actively participated in determining outcomes, selecting materials, designing products, and preparing lesson plans according to the 5E instructional model and problem-based learning method. Between the 10-14th weeks, pre-service teachers designed a STEM activity as the final task, prepared a lesson plan according to the project-based learning method in STEM, and presented them. The researcher and other pre-service teachers gave feedback to the presenter group. Thus, the final prototype was created by making the necessary improvements suggested by the experts in the STEM course design.

3. Evaluation Phase

In this phase, to determine the effectiveness of the STEM course developed in this cyclical process, it was applied in the course titled "Instructional Technologies and Material Design" to 21 volunteer pre-service science teachers (3rd year) in the fall semester of the 2018/2019 academic year. The whole study group consisted of female students who have not received any STEM education.

Data Collection Instruments

STEM Education Needs Analysis Form

STEM education needs analysis form was developed to determine the knowledge and skills that pre-service teachers should have about STEM education. In the process of developing the form, national (Turkish Ministry of Education [TMoNE], 2016) and international research reports (e.g. National Academy of Engineering [NAE] & NRC, 2014) about STEM education in pre-service teacher education (Stohlmann et. al., 2012; Teo & Ke, 2014) and science curriculum were taken into consideration. Two experts in STEM studies and an expert from curriculum and instruction were consulted to establish the content validity of the items. After expert opinions, the final version consisted of 15 items answered as 3-point Likert type (disagree, undecided and, agree). An example of which is: *"There are educational needs for the application of the project-based learning method in the STEM education." After the form was prepared, it was sent to five experts from STEM education and the opinions of pre-service science teachers regarding STEM education needs were defined.*

STEM Education Pre-Information Form

STEM education pre-information form was developed to determine the current knowledge and skills of pre-service teachers regarding STEM education. In this form, the subject was "Connecting Light Bulbs" which is included in the science curriculum was topic chosen and three different scenarios included the teaching performances of teachers according these different methods (1st scenario: STEM education approach, 2nd scenario: Prediction-Observation-Explanation (POE) method, 3rd scenario: Experimentation technique based on demonstration). In this form, pre-service teachers were asked to evaluate three different scenarios comparatively and to fill in the table containing the unit outcomes by associating the outcomes with the scenarios.

STEM Lesson Plan and STEM Lesson Plan Evaluation Form

Firstly, the STEM lesson plans in the literature (Walton & Caruthers, 2016; Konuk, 2014) were examined. The STEM lesson plan evaluation form was developed in line with the STEM lesson plan. Two experts from both science and STEM education were consulted to finalize the STEM lesson plan and the STEM Lesson Plan Evaluation Form. The STEM Lesson Plan Evaluation Form consists of three parts: Pre-lesson (Preparation and Planning), Course Process (using 5E Instructional Model) and Course Outcome (Design Evaluation). The pre-lesson section consists of 8 items that aim to measure the knowledge and skills of pre-service teachers regarding the preparation and planning process for the STEM education course. The course process consists of 5 items that aim to measure the knowledge and skills of pre-service teachers to use the stages of the 5E teaching model in the STEM lesson plan. The lesson result consists of 1 item that aim to measure the knowledge and skills of pre-service teachers to design a product as a result of STEM activity. Summarily, 14 items and a 3-point Likert type form was constructed. In addition, a column was supplied to write the justification for the score obtained for each item. The minimum score to be given from the STEM lesson plan evaluation form is 0, the maximum score is 42.

STEM Education Self and Peer Evaluation Form

In the self-evaluation form, pre-service teachers were asked to evaluate whether STEM activity and lesson plans were effective and they were asked where to change if they had to re-present the STEM activity in their future practices.

In the peer evaluation form, pre-service teachers were asked to find out the components of STEM education presented by their peers and they were asked to indicate the faults or deficiencies of their peers' presentations in terms of teaching-learning process, if any. They were asked to evaluate the differences of the lesson from an ordinary science lesson. Finally, they were also asked to evaluate the effectiveness of STEM lesson plans presented by their peers in real classroom environment.

The Interview Form

Interviews were carried out with the 21 pre-service science teachers to determine pre-service teachers' STEM education knowledge and skills and the effectiveness of STEM course design. To achieve this aim, the literature was examined during the preparation of the semi-structured interview form (e.g. Blackley, et. al., 2017; Pimthong & Williams 2018). The semi-structured interview form was reviewed by two STEM education experts. As a result, each pre-service science teacher was asked 8 questions in the interview form such as "What were the difficulties you encounter while planning STEM education (STEM activity and lesson plan)? What kind of solutions did you develop for the situations you had difficulties while planning STEM education?" Interviews were conducted by the first researcher and completed in an average of 18 minutes with each participant individually.

Data Analysis

Descriptive and content analysis techniques were used together in analyzing the qualitative data. Interview forms were analyzed after being transcribed. The written responses of the pre-service teachers to the STEM education needs analysis form, STEM education pre-information form, self and peer evaluation form were added to the data pool electronically and analyzed using two data analysis techniques.

Moreover, the data from the STEM lesson plan evaluation rubric were analyzed by calculating arithmetic averages (X_{ort}). The group interval coefficient suggested by Kan (2009) was used to make the arithmetic means obtained from the STEM lesson plans meaningful. Thus, group intervals are determined between 2.26-3.00 as very good, between 1.51-2.25 as good, between 1.50-0.76 as acceptable, and between 0.75-0.00 as initial level.

Validity and Reliability

To provide validity of the research, data collection method and tools were diversified in the research. The research method, data collection and analysis stages, and the findings are presented in a detailed way. The opinions of two experts from STEM education were obtained in all phases of the data collection.

In the descriptive analysis of the data, themes were created by examining the research questions, the STEM course design developed within the scope of the research, the theoretical framework of STEM in teacher education and the findings of STEM-focused studies in teacher education. Themes and codes that emerged in the descriptive analysis were examined in more depth and unnoticed concepts and themes were discovered through content analysis. To provide reliability of the research, the researcher checked the codings by reading the data set at different times. In the second coding, the codes expressed in long sentences were shortened and several new categories were added. Direct quotations were presented in the results part. The opinion of an expert from STEM education regarding the codes, categories and themes were obtained. In addition, the STEM lesson plans of the participants were examined and scored by the researcher and another expert according to the STEM lesson plan evaluation form. The data obtained within the scope of the research were collected and documented systematically. The schematic representation of the STEM course design development process is as shown in figure 3 below.

Findings

STEM Education Course Design

Firstly, the nine main knowledge and skills, which were explained in-depth in the discussion part, have been determined in the educational design research cycles. The content of the STEM course has been planned according to the nine items. Then, activities for a group who did not take the STEM education were prepared and applied according to the hands on-minds on method with simple tools and equipment at the beginning level. In this study, activities were designed according to the transdisciplinary approach that enables pre-service teachers to find solutions to real-life problems. In determining the activities, the contexts used in the PISA questions and the contexts (e.g. Health, Energy Efficiency) explained by Bybee (2010) within the scope of the 2006 PISA framework were examined. Considering the outcomes of the science curriculum, activities have been developed as in the following Table 1.

Table 1. Disciplines and models related to STEM activities

Context of the activity (STEM integration model)	Name of the activity	Science	Technology	Engineering	Mathematics
Designing a 21-st century house (Trans-disciplinary)	Earthquake-proof house	✓	✓	✓	✓
	Electricity generation by wind power	✓	✓	✓	✓
	Sound-proof house	✓	✓	✓	✓
Designing a vehicle (Trans-disciplinary)	Two-Stage Rocket Design	✓	✓	✓	✓
	Designing a tool to reduce the impact of air or water resistance	✓	✓	✓	✓

Pre-service teachers were asked to design a 21-st century house and vehicle design by conducting various activities such as earthquake proof house, wind power electricity generation, sound-proof house design; two-stage rocket design and vehicle design to reduce the effect of air and water resistance, respectively. To exemplify 21-st century house, the activity was associated with the 5th grade subject of destructive natural event in the science curriculum as shown in Table 2 below. In addition, a shaking table with a system consisting of a spring and motor was created by the researcher to test the groups' designs.

Table 2. STEM disciplines with which earthquake proof house design is associated

STEM disciplines	Earthquake Proof House
Science (S)	Destructive natural events and ways of protection
Technology (T)	Designed earthquake-proof house, using necessary materials, using shake table
Engineering (E)	Engineering design process, knowledge and skills related to the field of engineering related to the activity, design thinking
Mathematics (M)	Length and time measurement, area calculation

The Effectiveness of STEM Course

In order to determine the knowledge and skills of pre-service science teachers in STEM education, STEM education pre-information form was applied to the pre-service science teachers and their level of knowledge and skills were explained. In the form, the pre-service science teachers were asked to match the subject of "Connecting Light Bulbs" included in the science curriculum with three different scenarios included the teaching performances of teachers according to different methods. The reason for choosing this subject area is that it includes an experimental process. According to the result of STEM education pre-information form, the pre-service science teachers have difficulty to match the subject with different teaching methods, which showed that pre-service teachers had low level of STEM awareness. The pre-service teachers did not only have an explanation to interpret scenario 1, but also, they did not use the main characteristics of STEM education correctly. Their explanations did not go beyond repeating the scenario in general and making evaluations accordingly. To illustrate these results, the pre-service teachers said that calculations were made for design, but they did not state that it was an interdisciplinary practice or a STEM-oriented education. Moreover, the pre-service teachers used the expression of "design", mentioned in the scenario, but they did not explain the engineering design in their answers. Therefore, it can be said that pre-service teachers had superficial knowledge about STEM education at the beginning. An example of the responses of the pre-service teachers is as follow:

> *PST16… "The difference from other scenarios is that it does not arouse curiosity in students and there was no measurement and evaluation in the teaching process. I think it is not efficient to ask students directly design after the concepts are given to the students."*

When the STEM course design was implemented, significant improvements were made in the knowledge and skills of pre-service teachers about STEM education. At the end of the term, the lesson plans prepared by the pre-service teachers according to STEM activities and project-based learning method in STEM were evaluated according to the STEM lesson plan evaluation form. Sample projects from the training are shown in the figure 4. The results regarding the evaluation of STEM lesson plan were presented in Table 3.

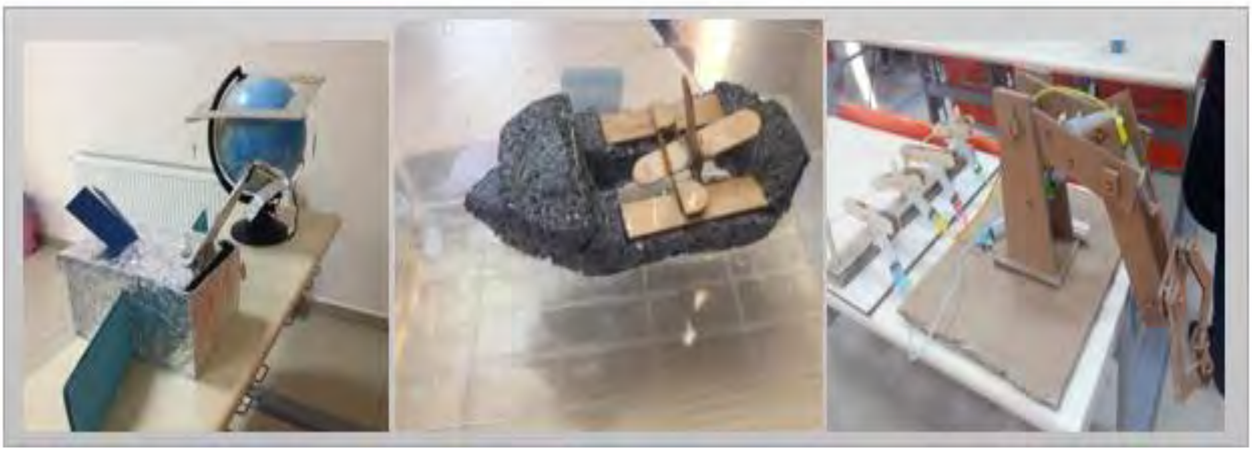

Figure 4. Examples of project designs

Table 3. Findings obtained from the STEM lesson plan evaluation form (Number of groups (n) =7)

Phases		Item	Proficiency level
Pre-lesson (Preparation and planning)	1	the knowledge and skill of the pre-service teacher to determine the gains in STEM disciplines	Very good
	2	the knowledge and skill of the pre-service teachers to determine the appropriate period for the gains	Good
	3	the knowledge and skill of the pre-service teacher to use 21-st century skills divided into 4 groups within the framework of P-21 in STEM activities within the recommended period	Good
	4	the knowledge and skills of pre-service teachers to prepare STEM activities.	Very good
	5	the knowledge and skill of the pre-service teacher to use the Engineering Design Process stages while creating the product	Very good
	6	the knowledge and skill of the pre-service teacher to prepare an introductory paragraph (scenario) containing a real-life problem.	Very good
	7	the knowledge and skill of the pre-service teacher about limitations (time, budget, materials to be used) regarding the real-life problem.	Very good
	8	the pre-service teachers' knowledge and skill about the professions related to STEM disciplines and special to a problem situation.	Very good
Course Process (Using 5E Instructional Model)	9	"Engage" phase of the 5E instructional model: preparing stimulants (brainstorming with questions and answers, cartoons, videos, etc.) to evaluate the preliminary information and to arouse curiosity	Very good
	10	"Explore" phase of the 5E instructional model: preparing activities such as hands on-minds on activities, educational software, access to information from print resources, online and other experts, class discussions to reveal students' existing knowledge, skills, and misconceptions (if any)	Very good
	11	"Explain" phase of the 5E instructional model: preparing the concepts and definitions related to the outcomes of the science course to complete the STEM project.	Very good
	12	"Elaborate" phase of the 5E instructional model: preparing the content that reflects the gains of other STEM disciplines (Technology, Engineering, and Mathematics) related to STEM activity.	Good
	13	“Evaluation” phase of the 5E instructional model: using a measurement-evaluation approach for STEM education.	Very good
Course outcome (Design evaluation)	14	The knowledge and skill of the pre-service teacher to create an original and durable product that provides solutions to real-life problems.	Good

As a result, i.) it was observed that the pre-service teachers had a very good level of knowledge and skill from the pre-lesson (preparation and planning) phase according to the STEM education approach. ii) pre-service teachers for using the 5E teaching model in the course process reached a very good level of knowledge and skill. iii) Pre-service teachers have good knowledge and skills about creating products at the end of the course. The findings obtained from the lesson plan evaluation rubric were also supported by the findings obtained from peer evaluation, self-evaluation, and interview forms. The similarities and differences in terms of themes and codes in peer evaluation, self-evaluation, and interview forms are presented in Table 4.

Firstly, the codes that emerged after the STEM activity and lesson plan of the presenting group were evaluated by pre-service teachers in terms of components of STEM education were given in Table 4. PT18 from the participants stated their views on the first theme as “*There is a project produced based on design and project, environmental and health literacy, entrepreneurship and self-management, productivity.*" in the form. In the interview form, pre-service teachers were asked to indicate similar or different aspects of the STEM education approach from other learning, teaching approaches, methods, and techniques to learn more about their knowledge and skills about STEM education.

Table 4. Comparative data of self and peer-assessment, and interview

Theme	Code	Theme	Code	
1.STEM education components included in the STEM activity and lesson plan	Peer assessment	2.Similar or different aspects of the STEM education approach from other learning-teaching approaches, methods, and techniques	Interview	
	Including the integration of STEM disciplines		Similar	Different
	Including 21-st century skills		Determining the gains	Interdisciplinary
	Including a real-life problem		Creating a design	Technology oriented
	Including Evaluation-PISA questions		Creative thinking Cooperative learning	Including interaction within the group
	Product design		5E teaching model, Attracting attention, Brainstorming	Including designing process
			Summative assessment, Measurement - evaluation with concept maps	Project-based teaching-Including engagement activities-Using scientific process skills actively-Focusing thinking-Instructor guidance-Asking questions-
			Using techniques such as fishbone, station	Including explore and elaborate phases-Learning by doing-Implementation
3.Whether STEM activity and lesson plans are effective and their reasons	Peer-evaluation	4.Ineffective aspects of STEM activity and lesson plans-Changes in their ineffective performance	Self-assessment	Changes
	Suitability of the contents in the lesson plan (5E)		There are no some disciplines (e.g. engineering or technology)	Using tinkercad and 3D paint
	Including STEM disciplines		No determining the gains correctly	Associating the gains with the activity and the problem
	Including product design		PISA question needs to be developed	Setting the class level correctly, improving preparation scoring key
	Focusing 21-st century skills		Failure to prepare projects following the STEM education	Focusing on design, designing durable, useful and functional
	Fun-engaging		Teacher effectiveness in the "explain" phase	Reforming
	Providing design-oriented thinking-Providing collaboration-Including scientific process skills-Including engineering skills			

Theme	Code
5. Missing/wrong aspects in the STEM activity and lesson plans	Peer assessment There is no mathematics discipline in STEM activities. There is no technology discipline in STEM activities. Shortcomings in the content of the course Not suitable for STEM education approach

Theme	Code
6. What can a lesson planned for STEM education bring to students?	Interview
	21-st century skills Hand skills Design thinking skill Scientific process skills Research-inquiry skills Increasing students' motivation on and interest in the course-Professional career knowledge-STEM literacy-Increasing interest in STEM disciplines

Note. The codes in Table 4 were listed according to the frequency and the codes with the same frequency were shown side by side with the "-" symbol.

While pre-service teachers talked about similar aspects of STEM education, they mostly stated different aspects. For example, *"The feature that distinguishes STEM from others is that students are more active…In STEM, the teacher shows the students a certain way and encourages them to think. It provides an environment where students are active. In a normal science lesson, only science is taught ... we don't associate it with other disciplines. In STEM, other disciplines - technology, engineering, mathematics - are also effective in design"* (PT5). The active learning environment that caused PT5 to have these thoughts is presented in the Figure 5.

Figure 5. An example from the project presentation of the pre-service teachers

Moreover, pre-service teachers evaluated whether the STEM activity and lesson plans of the presenter group were effective in terms of teachers and students and its reasons in the peer evaluation form. All of the pre-service teachers stated that it was effective but needed some minor adjustments. PT1 explained this situation as *"*STEM activity *was very suitable for the life problem. There were different and effective activities. PISA questions were adequate to measure and consistent with the project. Providing feedback with other assessment methods was enough to improve the students. It contained all outcomes in STEM disciplines. It was related to 21-st century skills. It improves students' scientific process skills*". Eight pre-service teachers' views on the ineffective aspects of STEM activity and lesson plans that were prepared as a group were coded as shown in Table 5 (Self-assessment form). PT18 expressed as *"The outcomes are not suitable for the project ... The PISA question was not suitable for the grade level."* and PT5 expressed her views as *"It does not include mathematics discipline."* The pre-service teachers, who evaluated ineffective aspects of their presentations explained how they would make changes in their future practices or had the opportunity to represent it again. For example, PT11 stated that *"I used to prepare the STEM activity and lesson plan in the same way. I would just improve explore phase and improve the PISA question… "* (PT11).

Figure 6. Two-stage rocket designs of pre-service teachers

Pre-service teachers were asked to state missing/wrong aspects in the STEM lesson plan and activities of the presenter group. Few pre-service teachers stated missing or wrong aspects. For example, PT11 explained as *"I* *could not see anything related to mathematics. The technology part is missing. There were science and engineering disciplines." in the peer assessment form.* Figure 6 illustrates that the technology discipline is not effectively involved in the STEM project.

The pre-service teachers were asked to express their thoughts about the benefits of STEM education to their future students. PT13 expressed her thoughts as *"Students will be able to use their knowledge in their daily life. They will be able to design a vehicle. Entrepreneurship... While walking on the road, the student will constantly think about a problem. The student will think about solutions. His ability to interpret will improve. I think this a very effective activity. This activity helps to improve science literacy and mathematic literacy.*

Conclusion and Discussion

This study proposed a STEM course design for pre-service science teachers and explored its effectiveness in increasing pre-service teachers' knowledge and skills in STEM education. The course design was developed in line with the feedback from the experts, the researchers and pre-service science teachers. Therefore, STEM course design reflects pre-service science teachers' needs (knowledge and skills) about STEM education. The knowledge and skills pre-service science teachers need to have about STEM education have been determined in the educational design research cycles as follows. In the research, pre-service teachers acquired the theoretical aspect of STEM. Similarly, Sanders (2009) emphasized that the foundations of STEM education should be in the content of teacher education. In the study, pre-service teachers learned the main characteristics of STEM disciplines. The STEM course design in this study supported the idea of STEM which was applied to encourage people to address authentic problems that cannot be solved with a single discipline, but require using the integration of the knowledge and processes of different STEM disciplines (Bybee, 2013; Nadelson & Seifert, 2017; Urban & Falvo, 2016). Moreover, effectiveness of teachers' teaching STEM disciplines depends on their competencies in these areas (Eckman et. al., 2016). The results of some studies also showed that pre-service teachers need the education to ensure the integration of STEM disciplines (Hacıoğlu et. al., 2016; Pimthong & Williams 2018). Pre-service teachers gained knowledge and skills about associating STEM lessons with 21-st century skills. In the literature, it is stated that teachers should equip their students with 21-st century skills and they should experience in these skills (Akpınar, 2014; Çakmak, 2015; Işık & Saygılı, 2015). Pre-service teachers used current science curriculum to plan a lesson according to STEM education. Considering that pre-service teachers will become the implementers of the programs in the future, they should know how to benefit from the program according to STEM education. In addition, pre-service teachers should know about the program to determine the outcomes of the science discipline that are suitable for STEM education. In the study, pre-service teachers examined STEM activities carried out in the context of Turkey and other countries. It should be ensured that pre-service teachers should see STEM activities in our country and other countries to gain different perspectives. Pre-service teachers gained knowledge and skills about measurement-evaluation methods and techniques in STEM education. According to the STEM education approach, a course can be evaluated with formative, summative and instant measurement-evaluation. NRC (2014) reported that measurement and evaluation in STEM education is that tests multidimensional and diverse learning outcomes and requires using various tools, methods and techniques spread throughout the process. In this process, technology-oriented applications (kahoot, plickers etc.), rubrics for design evaluation, etc. can be used. PISA questions also should be used to evaluate with context-oriented questions in STEM education. Pre-service teachers used different teaching methods and techniques (e.g. 5E teaching model, problem/project based learning methods) in STEM education. It is also emphasized in the literature, a teacher should apply effective teaching method and techniques for the successful learning process for students in STEM subjects (Lichtenberger & George-Jackson, 2013). Pre-service teachers studied in collaboration with their peers. It was discussed that interdisciplinary cooperation will be achieved by studying together with teachers from different fields in their professional lives. Pre-service teachers prepared a lesson plan according to STEM education and implementing it. In parallel with this study, Türk, Kalaycı, and Yamak (2018) concluded that teachers should have the knowledge and skills to prepare and implement a lesson plan suitable for STEM education in the study. It was stated that successful integration of STEM disciplines depends on whether teachers develop an understanding of the subject and conceptualize interdisciplinary connections (Pang & Good, 2000). As revealed in the study of Türk, Kalaycı, and Yamak (2018), this study also allows pre-service science teachers opportunity to develop thinking skills, to use technology effectively, to study interdisciplinary, to become effective in identifying and solving daily life problems, and to become STEM literate within the framework of identified nine knowledge and skills.

In parallel with the nine knowledge and skills, activities were prepared and applied according to the hands on-minds on method with simple tools and equipment at the beginning level. Hence, students learn concepts specific to different disciplines such as science and mathematics during the product design process in a lesson planned according to the hands-on method (Zubrowski, 2002; Featonby, 2010; Thompson & Mathieson, 2001). It also improves students' social skills and thinking skills (Verma et. al., 2011). In addition, STEM knowledge of students is improved and their orientation towards STEM careers is provided (Knezek et al., 2013; Knezek et al., 2014). Moreover, it has been determined that hands on-minds method with simple equipment is mostly used in STEM activities for pre-service teacher education in implementation studies (Authors, 2020). Additionally, activities were designed according to the transdisciplinary approach that enables pre-service teachers to find solutions to real-life problems. Thus, 21st century skills, knowledge and attitudes towards real-world training and problem-solving strategies were combined. In the real-life-oriented education process, students can also discover engineering knowledge and skills. In the literature, teachers had problems in studies related to the engineering dimension and difficulties in the engineering process. This is due to the fact they did not receive any training in their university education process (Blackley & Howello (2015).

The effectiveness of the STEM course design in acquiring the knowledge and skills of pre-service teachers was also investigated. Firstly, it has been determined that pre-service science teachers had low STEM awareness. Indeed, their explanations generally didn't go beyond repeating the scenario concepts in the teaching process and making superficial evaluations. For example, the term "design" is mentioned in the scenario. But the pre-service teachers did not mention the engineering design process and cycle in any way by using this term exactly in their answers. This finding was consistent with many previous studies (Pimthong & Williams, 2018, 2020, 2021; Hacıoğlu et. al., 2016). For example, Hacıoğlu, Yamak, and Kavak (2016) determined that pre-service teachers explained STEM as science, technology, engineering, and mathematics, but they did not have any idea about the nature of integration, they could not explain how the four disciplines can be integrated. These findings are important in determining the effectiveness of STEM course design on pre-service science teachers' development of STEM education knowledge and skills.

In the STEM course, the knowledge and skills of pre-service science teachers about STEM education were expressed under three headings in lesson plans. According to the STEM education, it was observed that the pre-service teachers had a very good level of knowledge and skills at the pre-lesson (preparation and planning) phase, a very good level of knowledge and skill at the phase of using the 5E teaching model during the lesson, and a good level of knowledge and skill at the phase of creating products at the end of the course. All pre-service science teachers were encouraged to prepare and evaluate STEM lessons and activities. Thus, pre-service teachers were guided to understand the importance of preparing an environment for their students to apply knowledge and skills to solve complex and multidimensional issues or problems as stated in the literature (Bybee, 2013; Radloff & Guzey, 2017; Vasquez et al., 2013).

Limitations and Recommendations

As stated in the previous sections, the effectiveness of STEM course design in pre-service science teacher's education was defined. This study's implications were vital in terms of implementing STEM education for pre-service teacher education. Nevertheless, this study is limited in terms of reflecting pre-service teachers' experience in a real classroom setting. It is recommended that future studies should provide collaboration with pre-service teachers, students, and in-service teachers. This study showed that pre-service teachers have problems in integrating knowledge and skills related to technology and engineering disciplines with their real-life problems. Thus, future studies should focus on developing the knowledge and skills of pre-service teachers about engineering and technology discipline and show how to integrate these disciplines into their real-life problems. This study focused only on pre-service science teachers. Therefore, future studies are recommended to be conducted with a mixed group from different departments (e.g. Engineering, Computer Education, and Instructional Technologies) to provide collaboration between different disciplines. In addition, it was found that pre-service teachers could not determine daily life problems for product design and PISA questions. Hence, context information may be enriched by providing awareness of current problems in the world through content education courses such as "Science Teaching Laboratory Trainings" and "Special Teaching Methods".

Scientific Ethics Declaration

The authors declare that the scientific ethical and legal responsibility of this article published in JESEH journal belongs to the authors.

Acknowledgements

This study is produced from the doctoral dissertation of the first author in the advisory of the second author.

References

Atkinson, R. D., & Mayo, M. (2010). *Refueling the U.S. innovation economy: fresh approaches to Science, Technology, Engineering and Mathematics (STEM) education.* Washington, D.C.: Information Technology and Innovation Foundation.

Aydeniz, M., & Bilican, K. (2018). The impact of engagement in STEM activities on primary pre-service teachers' conceptualization of STEM and knowledge of STEM pedagogy. *Journal of Research in STEM Education, 4*(2), 213–234.

Bartels, S. L., Rupe, K. M., & Lederman, J. S. (2019) Shaping Pre-service Teachers' Understandings of STEM: A Collaborative Math and Science Methods Approach. *Journal of Science Teacher Education, 30*(6), 666-680.

Bell, D. (2016). The reality of STEM education, design and technology teachers' perceptions: A phenomenographic study. *International Journal of Technology and Design Education, 26*(1), 61-79.

Blackley, S., & Howell, J. (2015). A STEM narrative: 15 years in the making. *Australian Journal of Teacher Education, 40*(7), 102-112.

Blackley, S., Sheffield, R., Maynard, N., Koul, R., & Walker, R. (2017). Makerspace and reflective practice: Advancing pre-service teachers in STEM education. *Australian Journal of Teacher Education, 42*(3). 21-37.

Bryan, L. A., Moore, T.J., Johnson, C. C., & Roehrig, G. H (2016). Integrated STEM education. In C. C. Johnson, E. E. Peters-Burton, & T. J. Moore (Eds.), *STEM Road Map: A Framework for Integrated STEM Education*. New York: Routledge.

Buyruk, B., & Korkmaz, Ö. (2014). STEM Awareness Scale (SAS): Validity and Reliability Study. *Journal of Turkish Science Education, 13*(2), 61-76.

Bybee, R. W. (2013). The case for STEM education: Challenges and opportunities. Arlington: NSTA Press.

Bybee, R. W. (2010). Advancing STEM education: A 2020 vision. *Technology and Engineering Teacher*, *70*(1), 30– 35.

Eckman, E. W., Williams, M. A., & Silver-Thorn, M. B. (2016). An integrated model for STEM teacher preparation: The value of a teaching cooperative educational experience. *Journal of STEM Teacher Education, 51*(1), 71–82.

English, L. D. (2015). STEM: Challenges and opportunities for mathematics education. In K. Beswick, T. Muir & J. Wells (Eds.), *Proceedings of 39th Psychology of Mathematics Education conference*, Vol. 1(pp. 3-18). Hobart, Australia: PME.

English, L. (2017). Advancing elementary and middle school STEM education. *International Journal of Science and Mathematics Education, 15*(S1), 5-24.

Epstein, D., & Miller, R. T. (2011). Slow off the Mark: elementary school teachers and the crisis in STEM education. *Education Digest: Essential Readings Condensed for Quick Review, 77* (1), 4-10.,

Featonby, D. (2010). Magic physics? *Physics Education. 45*(1), 24–31.

Fioriello, P. (2010). *Understanding the basics of STEM education*. Retrieved from http://drpfconsults.com/understanding-the-basics-of-stem-education/

Hacıoğlu, Y., Yamak, H., & Kavak, N. (2016). Pre-Service science teachers' cognitive structures regarding Science, Technology, Engineering, Mathematics (STEM) and Science Education. *Journal of Turkish Science Education*. *13* [Special Issue], 88-102.

Kan, A. (2009). Statistical operations on measurement results. H. Atılgan (Ed.), *Measurement and evaluation in education*. (pp. 397–456). Ankara: Anı.

Karışan, D., Macalalag, A., & Johnson, J. (2019). The effect of methods course on pre-service teachers' awareness and intentions of teaching science, technology, engineering, and mathematics (STEM) subjects. *International Journal of Research in Education and Science, 5*(1), 22-35.

Knezek, G., Christensen, R., & Tyler-Wood, T. (2014). *Going green! Middle schoolers out to save the world (MSOSW).* National Science Foundation Award 1312168 Annual Report. Retrieved from https://iittl.unt.edu/content/going-green-middle-schoolers-out-save-world

Knezek, G., Christensen, R., Tyler-Wood, T., & Periathiruvadi, S. (2013). Impact of environmental power monitoring activities on middle school student perceptions of STEM. *Science Education International*, *24*(1), 98-123.

Konuk, P. (2014). STEM education: Classroom activities for teachers by student teachers. In M. S. Corlu, (Eds.). *STEM Education Series* (vol. 1). Ankara, Turkey: FeTeMM Eğitimi Çalışma Grubu.

Lederman, N. G., & Lederman, J. G. (2013). Is it STEM or 'S & M' that We Truly Love? *Journal of Science Teacher Education, 24*, 1237–1240.

Lee, K., & Nason, R. A. (2012). *Reforming the preparation of future STEM teachers*. 2nd International STEM in Education Conference (pp. 24-27), Beijing, China.

Lichtenberger, E., & George-Jackson, C. (2013). Predicting high school students' ınterest in majoring in a stem field: ınsight into high school students' post-secondary plans. *Journal of Career and Technical Education, 28* (1), 1-19.

Lin, K. Y., & Williams, P. J. (2016). Taiwanese pre-service teachers' Science, Technology, Engineering, and Mathematics teaching intention. *International Journal of Science and Mathematics Education, 14*, 1021–1036.

Lynch S.J., Peters-Burton E. E., & Ford M. R. (2014). Building STEM opportunities for all. *Educational Leadership, 72*(4), 54–60.

McKenney, S., Nieveen, N., & Van den Akker, J. (2006). Design research from a curriculum perspective. In J. V. D. Akker, K. Gravemeijer, S. McKenney & N. Nieveen (Eds.), *Educational design research* (pp. 67–90). New York: Routledge.

Turkish Ministry of Education (TMoNE) (2016). *STEM education report.* Ankara: Innovation and Educational Technologies General Directorate. http://yegitek.meb.gov.tr/STEM_Egitimi_Raporu.pdf

Nadelson, L. S., & Seifert, A. L. (2017). Integrated STEM defined: Contexts, challenges, and the future. *Journal of Educational Research, 110*(3), 221-223.

National Academy of Engineering (NAE) & National Research Council (NRC) (2014). *STEM integration in K-12 education: status, prospects, and an agenda for research.* Washington, DC: National Academy Press.

National Research Council (NRC) (2012). *A framework for K12 science education: practices, crosscutting concepts, and core ideas.* Washington, DC: The National Academies Press.

National Science and Technology Council (NSTC) (2013). *Federal science, technology, engineering, and mathematics (STEM) education 5-year strategic plan.* Committee on STEM Education National Science and Technology Council, Washington, DC.

NRC. (2014). *Developing assessments for the next generation science standards.* Washington, D.C: National Academies Press.

Outlier Research & Evaluation. (2014). What do STEM schools do? 78 components of inclusive STEM high schools. Retrieved from http://outlier.uchicago.edu/s3/findings/infographic/

Pang, J., & Good, R. (2000). A review of the integration of science and mathematics: Implications for further research. *School Science and Mathematics, 100*(2), 73–82.

Partnership for 21st Century Skills. (2009). P21 framework definitions. Retrieved from http://www.p21.org/documents/P21_Framework_Definitions.pdf

Pimthong, P., & Williams, J. (2018). Pre-service teachers' understanding of STEM education. *Kasetsart Journal of Social Sciences*, 1-7.

Pimthong, P., & Williams, J. (2021). Methods Course for Primary Level STEM Pre-service Teachers: Constructing Integrated STEM Teaching. *EURASIA Journal of Mathematics, Science and Technology Education, 17*(8). 1-14.

Pimthong, P., & Williams, P. J. (2020). Pre-service teachers' understanding of STEM education. *Kasetsart Journal of Social Sciences*, *41*, 289-295.

Plomp, T., & Nieveen, N. (Eds.) (2013). *An introduction to educational design research*. Enschede, the Netherlands: SLO.

Radloff, J., & Guzey, S. (2016). Investigating preservice STEM teacher conceptions of STEM education. *Journal of Science Education and Technology, 25*(5), 759-774.

Radloff, J., & Guzey, S. (2017). Investigating changes in pre-service teachers' conceptions of STEM. *School Science and Mathematics, 117* (3–4), 158–167.

Ryu, M., Mentzer, N., & Knobloch, N. (2019). Pre-service Teachers' Experiences of STEM Integration: Challenges and Implications for Integrated STEM Teacher Preparation. *International Journal of Technology and Design Education, 29*(3), 493-512.

Sanders, M. (2009). STEM, STEM Education, STEM mania. *Technology Teacher, 68*(4), 20-26.

Shernoff, D. J., Sinha, S., Bressler, D. M., & Ginsburg, L. (2017). Assessing teacher education and professional development needs for the implementation of integrated approaches to STEM education. *International Journal of STEM Education, 4*(1), 13.

Stohlmann, M., Moore, T., & Roehrig, G. (2012). Considerations for teaching integrated STEM education. *Journal of Pre-College Engineering*, *2*(1), 28– 34.

Sungur Gül, K. & Taşar, M. F. (2020). A review of researches on STEM in pre-service teacher education. *Elementary Education Online*, *19*(2). 515-539.

Teo, T. W., & Ke, K. J. (2014). Challenges in STEM teaching: implication for pre-service and in-service teacher education program. *Theory Into Practice*, *53*, 18–24
Thompson, G., & Mathieson, D. (2001) The mirror box. *Physics Teacher,* 39(8), 508–509.
Türk, N., Kalaycı, N., & Yamak, H. (2018). New trends in higher education in the globalizing world: STEM in teacher education. *Universal Journal of Educational Research, 6*(6), 1286-1304.
Urban, M. J., & Falvo, D. A. (2016). Preface. In M. J. Urban & D. A. Falvo (Eds.), *Improving K-12 STEM Education Outcomes through Technological Integration* (pp. 498). IGI Global.
Vasquez, J. A., Sneider, C., & Comer, M. (2013). *STEM lesson essentials, grades 3-8: Integrating science, technology, engineering, and mathematics.* Portsmouth, NH: Heinemann.
Verma, A. K., Dickerson, D., & McKinney, S. (2011). Engaging students in STEM careers with project-based learning - Marine Tech Project. *Technology & Engineering Teacher, 71*(1), 25-31.
Vescio, V., Ross, D., & Adams, A. (2008). A review of research on the impact of professional learning communities on teaching practice and student learning. *Teaching and Teacher Education, 24*(1), 80–91.
Walton, J., & Caruthers, J. M. (2016). Sample STEM modul one: Grade 7. C. C. Johnson, E. E. Peters-Burton & T. J. Moore (Eds). *STEM road map: a framework for integration* (pp. 239-309). London: Taylor & Francis
Wang, F., & Hannafin, M.J. (2005). Design-based research and technology-enhanced learning environments. *Educational Technology Research and Development, 53*(4), 5-23.
Williams, J. (2011). STEM education: proceed with caution. *Design and Technology Education, 16*(1), 26-35.
Zubrowski, B. (2002). Integrating science into design technology projects: using a standard model in the design process. *Journal of Technology Education. 13*(2). 48-67.

Author(s) Information

Kibar Sungur-Gul
Nevsehir Hacı Bektaş Veli University
Faculty of Education, Department of Mathematics and Science Education, Nevşehir/Turkey
Contact e-mail: k.sngr89@gmail.com
ORCID iD: 0000-0002-9590-1439

Mehmet Fatih Taşar
Gazi University
Faculty of Education, Department of Mathematics and Science Education, Ankara/Turkey
ORCID iD: 0000-0003-1249-3482