

Research Article

**Primary School Teacher Candidates' Experiences Regarding Problem-Based Stem Applications<sup>1,2</sup>**

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**Abstract**

In this study, it was aimed to reveal how primary school teacher candidates who were educated in the primary school teaching program experienced the problem-based STEM application performed in Science and Technology Teaching (STT) I and which skills they employed in the process. The research was carried out with a case study, one of the qualitative research approaches. Easily accessible sampling method was used to identify participants. In this context, 41 primary school teacher candidates who were studying in their third year in the classroom teaching program at the education faculty of a university and taking the STT I course participated. The research data were collected through semi-structured interviews and observations. Descriptive analysis technique was used to analyze the data in the study. The interviews and the data obtained from the recorded videos about the STEM activity that the primary school teacher candidates conducted within the scope of the STT I course, "The Studies of Primary School Teacher Candidates in the STEM Implementation Process", "The Skills and Affective Characteristics of Primary School Candidates Employed in the STEM Implementation Process", "Primary School Candidates' Opinions on the STEM Implementation Process" under the themes in the form of findings. As a result of the research, it was seen that the teacher candidates both followed the engineering design steps and used interdisciplinary skills within the scope of an engineering design task presented in a real life context.

**Key words:** *STEM, primary school teacher candidates, case study*

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## Sınıf Öğretmeni Adaylarının Probleme Dayalı STEM Uygulamalarına Yönelik Deneyimleri

### Öz

Bu araştırmada, sınıf öğretmeni adaylarının Fen ve Teknoloji Öğretimi I dersinde gerçekleştirilen probleme dayalı STEM uygulamasını nasıl deneyimledikleri ve süreç içinde hangi becerileri kullandıklarının ortaya koyulması amaçlanmıştır. Araştırma nitel araştırma yaklaşımlarından durum çalışması ile gerçekleştirilmiştir. Bu araştırmada nitel çalışmalarda sıklıkla kullanılan yöntemlerden kolay ulaşılabilir örnekleme kullanılmıştır. Bu kapsamda bir üniversitenin eğitim fakültesinde sınıf öğretmenliği programında üçüncü sınıfta öğrenim gören ve Fen ve Teknoloji öğretimi dersini alan 41 sınıf öğretmeni adayı katılmıştır. Araştırmanın verileri, yarı yapılandırılmış görüşme ve gözlem yolu ile toplanmıştır. Araştırmada verilerin çözümlenmesinde betimsel analiz tekniği kullanılmıştır. Sınıf öğretmeni adaylarının Fen ve Teknoloji Öğretimi I dersi kapsamında yaptıkları STEM etkinliği ile ilgili gerçekleştirilen görüşmeler ve kaydedilen videolardan ulaşılan veriler, “*Sınıf Öğretmeni Adaylarının STEM Uygulama Sürecinde Yaptıkları Çalışmalar*”, “*STEM Uygulama Sürecinde Sınıf Öğretmeni Adaylarının Kullandıkları Beceriler ve Duyuşsal Özellikler*”, “*STEM Uygulama Sürecine İlişkin Sınıf Öğretmeni Adaylarının Görüşleri*” temaları altında bulgular biçiminde sunulmuştur. Araştırma sonucunda, öğretmen adaylarının gerçek yaşam bağlamında sunulan bir mühendislik tasarım görevi kapsamında gerek mühendislik tasarım basamaklarını takip ettiklerini gerekse de disiplinler arası becerileri kullandıkları görülmüştür.

**Anahtar Sözcük:** *STEM, sınıf öğretmeni adayı, durum çalışması*

## Introduction

One of the most effective reforms carried out to meet the expectations of the 21<sup>st</sup> century societies is the inclusion of STEM education in curricula at all levels. Disciplines such as science, mathematics, and social studies are included in primary school curricula. It is possible to say that students can acquire the skills required by the information society by integrating different disciplines such as engineering and technology into their curriculum. In this way, students use the knowledge and skills of different disciplines together to solve the problems they encounter in life. Integration of different disciplines with education enables students to perceive how different disciplines relate to each other in real life and to make what has been learnt more meaningful. Interdisciplinary approaches positively affect students' conceptual learning, interests and motivations. Interdisciplinary approaches positively affect students' conceptual learning, interests and motivation.

Among the educational reforms based on the idea of integrating disciplines, the most recent one is STEM Education movement. STEM consists of the abbreviation of the initials of the words science, technology, engineering and mathematics. This approach, which is based on the integration of science, mathematics, technology and engineering with education, basically requires the integration of engineering into K-12 classes (Guzey, Harwell, Moreno, Peralta, & Moore, 2017). On the other hand, the fact that engineering design practices are new for most educators is one of the factors which make it difficult to apply engineering and STEM effectively to the classroom (Guzey et al., 2017).

Within the scope of STEM education reform, it is emphasized that all students studying at K-12 level have experience in research and finding solutions to problems encountered in the real world and that these experiences start as early as possible (National Science Board [NSB], 2010). Therefore, it is important for teachers and prospective teachers, especially at primary school level, to have professional development opportunities for STEM-oriented teaching (MacFarlane, 2016). Although STEM education approach is a current global reform, its future, especially in primary schools, is limited by teachers' capacity to be successful in this new paradigm (Avery & Reeve, 2013).

It is argued that the inclusion of engineering design experiences in STEM curricula may improve and contextualize young students' understanding of various engineering roles in

society, thereby helping to improve achievement, motivation, and problem solving (Brophy et al. 2008; English & King, 2015; Stohlmann et al. 2012). Primary school classrooms provide a powerful environment to lay the foundations for STEM practice and learning. Therefore, it is inevitable to investigate how teachers can be better supported when conceptualizing integrated STEM education and incorporating engineering-based STEM experiences into primary school classrooms. The lack of teachers who are competent to apply the STEM approach in their classrooms is further compounded by the fact that many teachers are not trained to promote interest and success in science and mathematics (Jeffrey, McCollough, & Moore, 2015). This situation is much more pronounced for primary school teachers who have received general education rather than specialization in a specific field (Adams et al., 2014). Future teachers who have not developed a STEM identity may enter the field of education with anxiety, insecurity and negative attitudes towards STEM subjects (Adams et al., 2014). This may affect the teacher's choice to teach these subjects, his attitudes about STEM subjects, or determine how he will teach in the future (Adams et al., 2014; Jeffrey et al., 2015). Therefore, primary school teachers' acquisition of the necessary competencies with rich and applied experiences in STEM education in the pre-service period will ensure that this educational approach can be applied in classrooms.

21st century skills include skills such as creativity, critical thinking, collaborative working, problem solving, initiative, self-management, and leadership. These skills are included in the curriculum of different countries (Anagün, Atalay, Kılıç, & Yaşar, 2016). In Turkey, although it is not explicitly called 21st century skills, the listed skills above exist in national curriculum. For example, the skills such as observing, measuring, classifying, recording data, testing hypotheses, using data and creating models, analytical thinking, decision making, creative thinking, entrepreneurship, communication, teamwork, innovative thinking are included under the titles of scientific process skills, life skills, and engineering design skills in the Science Curriculum (Ministry of National Education [MoNE], 2018). These skills overlap with those included in the 21st century skills. Therefore, primary school teachers knowing and performing STEM activities in their Science instruction can help students acquire 21st century skills.

It was recommended by the National Science Board (2010) that all K-12 students get the opportunities to explore real-world discoveries. At secondary level, achieving this seems more natural and feasible than at the primary level. For this reason, it is emphasized that primary school teachers' having pre-service and in-service professional development opportunities plays a key role in the success of STEM approach in learning environments (MacFarlane, 2016).

Moore et al. (2014) argued within the STEM framework that they developed at the primary school level that STEM-oriented teaching processes should be presented in an interesting real-life context where students can learn from failure and gain problem-solving skills. The most fundamental point in the STEM curriculum in order to present the real-life context to students in an interdisciplinary way in our age is engineering design. Engineering design in the STEM approach gives students the opportunity to integrate disciplines in a variety of contexts (Moore et al., 2014). The engineering process will enable students to engage with real world contexts and problems specific to engineering (Estapa & Tank, 2017). However, the integration of engineering design emerges as a challenge, especially for primary school teachers. This difficulty results from the fact that primary school teachers are often unprepared or have limited content knowledge about STEM and the engineering process (Banilower et al., 2013; Estapa & Tank, 2017).

This study aims to reveal how primary school teacher candidates studying in the primary school teaching program experienced the problem-based STEM implementation performed in the Science and Technology Teaching I course and which skills they employed in the process. In this context, it is aimed that students find a solution to a socioscientific issue determined in the STEM activity through engineering design processes, thus enabling the realization of experiences in the context of real life.

### **Method**

This study, which was conducted to determine what the experiences of primary school teacher candidates during the STEM activity process presented in the context of real life in Science and Technology Teaching I course, was carried out with a case study, which is one of the qualitative research approaches. In a case study, the case may be an activity, an event or a problem. A case is a series of events which reflect the time when a problem or activities occur. Case studies cover in-depth examinations of events, phenomena, people, groups or institutions defined as the case. Case studies are used to investigate a current phenomenon in a real-life context and to determine the patterns between the case and the context in depth in cases where clear lines cannot be determined between the case and the context (Yin, 2014). In this study, STEM practice in Science and Technology Teaching I is a case. As it included an-depth examination of how this practice was carried out and what the opinions of primary school teacher candidates were regarding the subject, a study design was adopted in the study.

## **Participants**

In qualitative research, sampling affects the quality of the study and the findings. Therefore, in qualitative research, sampling is created to provide rich and detailed information (Baş & Akturan, 2017, p.225). Convenience sampling, which is one of the sampling methods used in qualitative studies, was used in this study. The basic understanding in this sampling method is to determine the participants with sufficient richness and content from the population that is close to hand (Yıldırım & Şimşek, 2011). In this study, the study group was selected in accordance with the fact that the participants were primary teacher candidates who did not have previous experience with STEM education. In this context, 41 primary school teacher candidates, who were studying in their third grade in primary school teaching program at the education faculty of a university and taking Science and Technology teaching course participated. 36 of primary school teacher candidates participating in the study are female and 5 are male. The age range of primary school teacher candidates participating in the study is between the ages of 20 and 22.

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## **The Practice Process**

The research process consists of a four-week practice within the scope of Science and Technology Teaching I course. In the first week, the STEM implementation was introduced to primary school teacher candidates, and primary school teacher candidates were informed about the plan to be followed in the process. Then, they were divided into six groups. Within the scope of STEM, the duty of the groups was to build nests in order to protect pelican eggs from negative situations. Primary school teacher candidates carried out a design process by first drawing the nests they designed on paper. The groups came together during the class to design their nests, provided the necessary materials for their nests and formed their nests. In the final week, the groups presented their nests to other friends and researchers. The researchers evaluated the nests built by the groups within the framework of criteria such as maximum suitable conditions, naturalness of the materials used in nesting, cost and durability.

## Data Collection Tools

In this study, which aims to reveal how STEM implementation is carried out in Science and Technology Teaching I course in primary school teaching program and what the experiences of primary school teacher candidates regarding STEM implementation are, the data were collected through semi-structured interviews and observations. Observation is a method used to describe the behavior occurring in any environment or institution in detail (Yıldırım & Şimşek, 2011). The primary purposes of the data obtained through observation are to describe the observed event, the activities which took place in the event, the people participating in these activities and what was observed from the perspective of the observees (Patton, 2002/2014). In this study, primary school teacher candidates used observation to describe how the STEM activity they performed within the scope of Science and Technology Teaching I course was realized. In this process, the camera was positioned in the classroom in order for primary school teacher candidates to get used to the camera in the first week of the practice, and no video recording was done. Also, the first week observation process was not included in the analysis. Then, during the implementation, observations were made with a video camera. Every week, Science and Technology Teaching I course was devoted to STEM activities during the implementation. In this process, primary school teacher candidates came together with their groups and worked to solve the problem given to them within the scope of STEM.

At the end of the practices, semi-structured interviews were conducted with a total of twelve primary school teacher candidates, consisting of two volunteers from each group 8 of primary school teacher candidates participating in the interview are female students and 4 are male. An interview is defined as a mutual and interactive communication process based on asking and answering questions, conducted for a predetermined and serious purpose (Stewart & Cash, 1985; cited in Yıldırım & Şimşek, 2011). In this study, among interview types, semi-structured interview was used to reveal the experiences and opinions of primary school teacher candidates about the STEM activity. Within the scope of the study, firstly the literature was scanned and a semi-structured interview form including interview questions was prepared. During the development phase of the semi-structured interview form, expert opinions (a faculty member in the department of primary school teaching, a faculty member with STEM training and a primary school teacher candidate) were obtained, thereby making the interview form suitable for research purposes. In order to determine the functionality of the questions in the semi-

structured interview form, a pre-interview was made with a primary school teacher candidate. Pre-test interviews were excluded from the scope of the research.

### Data Analysis

Descriptive analysis technique was used to analyze the data in the study. The data obtained in descriptive analysis are summarized and interpreted according to previously determined themes. Direct quotations are used to reflect the views of the interviewed or observed individuals in a striking way (Yıldırım & Şimşek, 2011). In order to answer the first research question, “primary school teacher candidates’ practices in STEM processes, the stages of planning, designing, testing, developing and presenting STEM's implementation process were determined as the themes. The data about the second research question, “the skills and affective characteristics employed by primary school teacher candidates”, was analyzed based on the skills under the heading "field-specific skills " and “the values” in the Science curriculum.

### Validity and Reliability

Some precautions were taken by the researchers to ensure the validity and reliability of this study. The measures taken are shown in Table 1 below.

Table 1.

*Tools used to ensure validity and reliability in the study*

Validity	Internal Validity	Taking expert opinion
		Participant confirmation
		Direct quote
		Long-term interaction
		Supporting with images
		Preliminary interview
	External Validity	Explanation of the data collection tool and process
		Explanation of the data analysis process
		Explaining the characteristics of the participants
		Description of the participants' practice process
		Purposeful sampling

Reliability	Internal Reliability	Prevention of data loss by using a voice recorder and a camera
		Presentation of the findings without comment
	External Reliability	Checking the consistency within the data
		Check list

In order to ensure the reliability and validity of the study, the opinions of the experts for the semi-structured interview form in the study were taken before the implementation, a pre-interview was made to understand whether the interview questions were understandable and this interview was not included in the study. In addition, interviews were held in the meeting room at the times and dates determined by primary school teacher candidates. During the interview, primary school teacher candidates were asked to confirm the answers of the participants regarding each question by repeating them. The data obtained through interviews and observations were transferred to the computer and themes were formed. A checklist was created under the formed themes by writing down the skills employed by primary school teacher candidates, the activities they performed during the STEM implementation stages (planning, designing, testing, developing and presenting) through the videos and audio recording watched independently by each researcher. Then, the researchers came together and compared the checklists, watched the videos again if there was a conflict, the audio recording transcripts were examined and a consensus was reached. To prevent loss of data, audio recordings and video cameras were used.

## Results

The data obtained from the interviews conducted by primary school teacher candidates within the scope of the Science and Technology Teaching I course and the recorded videos are given as results under the themes of *"The Studies of Primary school teacher candidates in the STEM Implementation Process"*, *"The Skills and Affective Characteristics Primary school teacher candidates Employed in the STEM Implementation Process"*, *"Primary school teacher candidates' Views on the STEM Implementation Process"*.

## Findings Regarding the Practices of Primary school teacher candidates in the STEM Implementation Process

Table 2 shows the practices of primary school teacher candidates at the stages of the STEM implementation process.

Table 2.

### *Practices of primary school teacher candidates in the STEM implementation process*

Stages of the STEM Implementation Process.	Actions performed by primary school teacher candidates
Planning	Identifying the problem
	Drafting / Drawing
	Research
	Deciding (size, materials to be used)
Designing	Considering the criteria
	Sourcing the materials
	Making it three-dimensional
Testing	Testing
	Recognizing the mistakes
Development and Presentation	Making changes (of the material used, of size)
	Giving a Presentation

At the beginning of the practice process, primary school teacher candidates were divided into groups to carry out their work after they were informed about STEM practices. Afterwards, the research problem was shared with primary school teacher candidates. The research problem is to build a nest in accordance with certain criteria (strength, natural materials and natural appearance, protection- preservation of temperature, protection from rain, etc., ability to carry optimum (ideal) number of eggs, cost- easy to find, cheap material) in order to protect pelican eggs from adverse conditions.

The groups drew the draft plans by doing research for the research problem before the design process. They aimed to have knowledge about the subject by reaching the information about

how real pelican nests look like along with general information about pelicans. S1, one of primary school teacher candidates, described this research process as follows:

*We got to know the problem first. Then we developed a hypothesis as required. We did a lot of research on the internet. How should the pelicans' nest be? How many eggs do pelicans make a year? After getting the answers to the questions, we reached a decision about our nest. First of all, we made our draft plan by considering the criteria suggested by our teacher, such as being aesthetical and being economical. After preparing our plan, we talked as a group about how it should be during the project phase. We wrote down the materials depending on the research we did on the internet. S1*

Primary school teacher candidates stated that they determined the problem in the planning stage of STEM practices, prepared a draft, did research and decided on subjects such as size and materials to be used. Therefore, it can be stated that design groups formed their plans before starting the design stage in STEM practices and realized their designs within the framework of this plan. As quoted below, it was seen that the participants made a joint decision by planning how to realize their designs in line with the criteria and limitations in this process:

*It should have been natural, I objected to a few of my friends because it lost some of its naturalness. They especially told to use thread. They told us to use cotton. I wanted a little more naturalness there. That's why we completely used trees. We used ivy and tree branches which could be bent and twisted and wrapped it without using any thread or anything, without disturbing its naturalness. S1*

During the design stage, it was observed that primary school teacher candidates provided the materials and made their nests by taking the criteria into account. This is reflected in the in-group conversations as follows:

*S12: Our lid is here.*

*S13: Then let's create cavities suitable for the volume of the egg. Let's cut it twice and then we close the lid.*

*S14: Let's add different features to the outside. Whether it is for heat insulation or other features, we will make an image with leaves or something. Thus, when hatched, the chick will feel at home.*

*S11: A cozy home (Group 2, Video recording, 15.03 p., 14.10).*

In another example dialogue, one of the groups preferred to use materials such as straw and broom in order to add an environmentally friendly feature to their designs:

*S22: Let's make it in the form of a basket.*

*S24: Let's combine them in this way now.*

*S25: Considering that it is a little wider*

*S26: Let's expand it.*

*S22: We will surround the edges with brooms.*

*S29: If we could find straw, we would make it from straw, but since we cannot find straw, we will make it from broom (Group 4, Video recording, 23.12 p., 14.10).*

Although the same research problem and criteria were given to each group during the design process, it was observed that there were differences in the materials used by the groups. Among these materials, it was observed that there were natural materials such as leaves and bushes as well as artificial materials such as foam and styrofoam. Primary school teacher candidates strongly used the design criteria in justifying the materials they used. For example, they stated that they used artificial materials such as plastic and styrofoam to design a more sheltered and sturdy nest, while they expressed that they used materials such as leaves and shrubs to meet the environmentally friendly criteria.

In the testing stage of the nest designed by Group 1, when the nest built by the group members fell to the ground, all of the eggs in the nest were broken. Although the group members stated that they considered all the criteria, the eggs in the nest were broken during the test phase. The nest built by the members of Group 1 before and after testing is shown in Figure 1:



Figure 1. *Test stage of the nest designed by the members of group 1*

As seen in Figure 1, natural materials were used in the nest designed by Group 1. However, when the nest fell to the ground, it was scattered and the eggs were broken. Group 2 members, on the other hand, designed their nests with artificial materials without considering the naturalness criteria and stated that they aimed to make the nest strong and long-lasting. Even so, the eggs in the nest cracked during the test phase despite the efforts of the group members. After the test phase, while the group members were justifying their decisions, they stated that using natural materials would cause the nests to be less durable and short-lived, and therefore they did not make their choices accordingly.

The test phase of the nest made by the members of Group 2 is as follows:

*S8: How high should I throw it?*

*A: Over your height*

*S11: Go, throw it*

*A: Yes, but what's the problem here?*

*S8: One has cracked*

*S9: All three of them have cracked, Madam.*

*A: What condition did you not meet here?*

*S8: This gap actually closes like this*

*A: No. We are talking about the material inside.*

*S11: What's it? What?*

*A: We said natural material*

*S8: But Madam it will rot, natural materials will have a short life span.*

*S13: Biodegradable materials might be used.*

*S8: Okay, but it won't last long, it will be used for one year or two years. (Group 2, Video recording, 18.23 p., 28.10)*

The nest built by the members of Group 2 before and after testing is shown in Figure 2:



Figure 2. Test stage of the nest designed by the members of group 2

As seen in Figure 2, group 2 members used sponge and styrofoam box in the nest they designed to protect the pelican eggs. Eggs in the nest made of artificial materials cracked during the test phase.

The eggs in the nest made by the members of group 4 did not fall to the ground and did not break or crack in the first attempt during the test phase. However, group members stated that the nest was not protected. Group members tested their nest again. In the second attempt, the eggs came out of the nest and were broken. Group 4 members also stated that they would raise the nest a little more. Therefore, they realized their mistakes by stating that they would raise the nest a little more in order to make the nest they built more sturdy and protected. This group used natural materials in the nest they designed. However, the eggs in the nest were broken during the test phase. This is seen in the video recording as follows:

*S24: Go, throw*

*S22: Yes. One, two, three*

*The researcher: Not broken.*

*S25: It is not broken Madam. It is natural.*

*S27: These are the most natural materials, but it will be broken, yes, why is it not broken?*

*Ö29: Madam, hmm. We don't have enough of these. We'll go up a little higher, we'll add layers Madam*

*A: Have you boiled the eggs?*

*S27: No Madam, let's try again*

*S26: We've just bought it*

*S22: Madam, it was not broken after all. Moreover it does not have a natural sponge*

*S29: We'll make duplex Madam.*

*A: OK, do it. Let's throw it again.*

*S27: No, Madam. We did it already.*

The researcher: Okay, let's try it again. Now we will not give any points. Or yes, just throw it up. *Up up, go.*

*S23: Oh, it is broken Madam.*

*S24: It has cracked Madam, it has*

*S26: The rest inside is not broken.*

*A: But look, it doesn't stay inside, it goes out.*

*S29: We'll raise the edges.*

The researcher: *Well, OK raise them (Group 4, Video recording, 12.23 p., 28. 10).*

Pre-post versions of the nest made by the members of Group 4 during the test phase are shown in Figure 3.



Figure 3. Test Stage of the Nest Designed by the Members of Group 4

The groups tested the nests they designed during the testing stage by throwing them from a certain height. The purpose of testing the nests was to reveal the strength, safety and stability of the nests designed by the groups. During the testing stage, the nests designed by some groups were observed to be unsound and to disperse when thrown from a height, while the nests designed by some other groups were found to be sound when they fell to the ground. As it was the testing stage, the groups tested the nests they designed. In addition, the groups realized their mistakes about why the sturdy nests were not sound. Later, the groups developed their nests and presented their final versions in the classroom.

During the development and presentation stages, groups which designed the nests that either disintegrated during the testing stage or whose eggs were broken in their nests developed their nests. At this stage of development, the groups either made adjustments in the nests they designed or designed a nest better suited to the criteria. At this stage, the groups redesigned their nests by using more natural materials or changed the basic characteristics (e.g. height) of their previous nests. In the presentation stage, they retested the nests they organized or redesigned in the classroom. Other teacher candidates in the classroom evaluated the groups according to the criteria and made comments on the designs. For example, the nest designed by the members of Group 2 was made up of artificial materials and the eggs in the nest cracked during the testing stage. In the development and presentation stage, the members of Group 2 designed a different nest, presented it in the classroom and tested it again, thereby testing the nest's strength and protection. This is reflected in the video recording as follows:

*The researcher: Are you the ones who made sponge last week?*

*S12: Yes Madam.*

The researcher: *Hah, look where you've come from this week, it meets the criteria.*

*S10: Madam, the eggs are normally visible but when thrown, they came on top.*

The researcher: *OK*

*S8: Madam, we focused entirely on pine trees.*

*S1: There were two or three broken pine trees, we took them and wrapped them there, there was such a thing.*

The researcher: *Then you made this nest out of sponge. How do you keep the heat?*

*S13: The heat? It is very stuffy in there, I mean there are three very large pine tree things in it, three large pine branches, that is, a very large pine branch. Umm, there was one branch left, wasn't there?*

*S29: It also smells pine.*

*S10: Exactly, its body.*

*S11: There's that big branch, its body, we used all of them except those big branches.*

*I mean, it was completely stuffy, there was nothing left to take from the pine tree, I think we put thin leaves on it lastly.*

*S27: What did you throw?*

*S11: Thin leaves and such...*

*S14: We threw the last remaining pine leaves on it.*

*S9: For the image, we also sewed them on those edges, here it is made entirely of pine for more shelter.*

*The researcher: Well done, thanks for your efforts (Group 2, Video recording, 02.39 p., 4.11).*

As understood from the conversations of the group 2 members with the researcher and other classmates in the development and presentation stage, the group members designed the nest

made of natural materials in the development stage instead of the nest made of artificial materials in the testing stage. In the presentation stage, they presented the redesigned nest to the researchers and their classmates. They told their friends how they built the nest and what the materials they used in their new designs were. Group 2 members used natural materials in the nest they designed as they indicated. In addition, when they tested the nest again in the presentation, the nest did not scatter and the eggs did not break. The researchers and other primary school teacher candidates generally gave positive comments about the new nest. Figure 4 shows the nest designed by the members of group 2 in the testing stage and the newly designed nest in the development and presentation stages.



Figure 4. *Pre-post versions of the nest designed by the members of group 2*

As seen in Figure 4, group 2 members tested the nest made of artificial materials during the testing stage. However, the eggs in the nest were broken during the testing stage. During the development stage, group members designed a new home. They presented the newly-designed nest at the presentation stage. It was observed that the re-designed nest by the members of Group 2 was more protected and sturdy than the previous nest. During the testing stage, the nest designed by the members of the Group 1 was dispersed and the eggs in the nest were broken. During the development and presentation stage, group members tested the nest they redesigned and presented it to their classmates. During the presentation, they also emphasized the low cost of their nest. This is reflected in the video recording as follows:

*S1: Madam, our cost is very low.*

*S2: Madam, we spent one lira*

*S5: We only spent one lira*

*The researcher: OK, now tell me. Are there eggs in it?*

*S7: Yes, Madam.*

*The researcher: How many eggs were broken last week?*

*S3: Two were broken because they fell from the edge.*

*Th researcher: Now let's throw them (The student throws two nests) (Group 1, Video recording, 02.52 p., 4. 11).*

During the development and presentation stage, the members of group 1 made the previously dispersed nest more sturdy and its surroundings higher. Therefore, when hrown again, the rearranged nest did not disperse and the eggs did not break. One of the group members, S1, shared this process with her classmates and the researchers during the presentation stage as in the following:

*S1: Later in that class, we learned about pelicans, how many eggs they have, how they live in the environment, then we talked about the design of artificial pelican nests, we drew a plan, in mathematical modeling, our design here was completely made of natural materials, well... as it is seen, it kept really well and we believe that the actual egg temperature will remain constant. We spent a budget of one lira. Madam, I live in the village, I brought wool etc, I brought hay etc. Let's talk about the materials Madam, cones, straw, wool, cotton, a small amount of bird feathers, Madam, pieces of wood, tree branches, ivy  
Researcher: You haven't plucked the birds, have you?  
S1: No, Madam, we picked up those which fell (Group 1, Video recording, 05.27 p., 4.11).*

As understood from the conversations of S1 with the researcher, the members of group 1 made changes on their previous nests. The group members reinforced the nest by making it higher and used natural materials. Pre-post versions of the nest of the nest designed by the members of Group 1 are shown in Figure 5.



Figure 5. Pre-post versions of the nest designed by the members of group 1

As seen in Figure 5, the nest designed by the members of Group 1 was dispersed during the test stage and its eggs were broken. In the development and delivery stage, the group members made the nest higher and more sturdy, which made the nest sheltered. In the last stage, when the nest was thrown from a height, the eggs in the nest were not broken. In the development and presentation stage, Group 6 designed a nest by taking different criteria from the other groups into consideration. They shared the nest they designed with their classmates during the

development and presentation stage. The nest designed by the members of Group 6 is shown in Figure 6.



Figure 6. *The nest designed by the members of group 6*

As seen in Figure 6, the members of group 6 designed their nests using natural materials such as melon and orange peels, unlike the other groups. They used the melon as the nest and placed the eggs inside the melon. They added a parachute to the nest. This parachute allows the nest to land without any damage if it falls from a high place. During the development and delivery stage, although the group members threw their nests from the fourth floor, the nest landed firmly on the ground thanks to the parachute.

During the development and presentation stages, the groups presented the final versions of the nests they designed to their other friends and the researchers in the classroom. At this stage, some groups redesigned the nests that fell apart or whose eggs were broken during the testing stage. Some groups did not redesign their nests but only changed the height. A few groups made no changes to their nests which did not fall apart or whose eggs did not break during the testing stage. During the presentation stage, they only explained how they designed their nests and tested them.

Primary school teacher candidates generally followed the design stages in the practice process. These stages are planning, design, testing, development and presentation. In groups, primary school teacher candidates planned and designed their nests, and tested them to check the strength and protection of the nests. In the development and presentation stages, they either redesigned or changed the shape of the nests which were dispersed or the eggs of which were broken during the testing stage.

### Findings Regarding the Skills and Affective Characteristics Employed by Primary School Teacher Candidates in the STEM Practices Process

Findings regarding the skills and affective characteristics employed by primary school teacher candidates in the STEM practices process are given in Table 3.

Table 3.

*Skills and affective characteristics employed by primary school teacher candidates in the STEM practices process*

Skills and Affective Characteristics	Behaviors-Actions-Applications
Scientific process skills	Conducting research
	Using the data and building models
	Changing and controlling the variables
Life Skills	Communication and Teamwork
	Decision Making
	Creativity
Affective Outcomes	Responsibility    Fulfilling the given task
	Doing job-share
	Value                Valuing the Technology-Society-Environment relationship

As seen in Table 3, it was revealed that primary school teacher candidates used their scientific process and life skills at the stages of planning, designing, testing, developing and presenting during the STEM practices process. It may also be suggested that affective characteristics such as responsibility and value are revealed. During the practice process, primary school teacher candidates used their skills of conducting research, using the data and building models, changing and controlling the variables within the scope of scientific process skills. Primary school teacher candidates generally preferred to conduct research at the beginning of the process. These studies focused on the general characteristics and breeding behaviors of pelicans. For example, a primary school teacher candidate S34 expressed this as follows:

*We did research about pelicans. For example, I had never seen a pelican. Some of my friends had not, either. We researched them first. We did research on them. For example, I did not know how many eggs they laid a year. Some of us said that they would lay 6, some of us said 1. I learned that they actually laid 2 or 3 eggs. We investigated how their nests were, what the physical size of a pelican was, how their nests should be, in what places they lived. It needed to be natural when moving on to the construction stage. We investigated such things as "how is natural material, what does a pelican use?" S34*

Primary school teacher candidates stated that they did research on the research problem given to them before the planning stage of the design. It may be stated that the purpose of the research was to find the answers to such questions as "what are the features of a pelican nest? how many eggs should there be in a pelican nest?".

Primary school teacher candidates also stated that they used appropriate materials to build the nest according to the criteria given to them. It may be suggested that by perceiving the ideal nest criteria they obtained through research as data, they used different materials and formed models to make nests in accordance with the criteria. Thus, it can be said that primary school teacher candidates employed their skills of using data and creating models within the scope of scientific process skills in STEM practices. This is revealed in the following statements of the teacher candidate, S39:

*"For example, it had to be natural. That's why we made it from natural materials. It would be different if we used unnatural artificial materials. For example, what we used was artificial, we put cotton in between just because the wool was not adequate. It needed to be low in cost. The natural materials we used were those we could find on land in winter. This also had an impact. For example, it was natural but not common, which was also important. Then sturdiness was also important. For example, when a bird builds its nest, it does not fall easily despite the wind. What we constructed had to have a certain weight so that it would not fall. But it didn't have to be too heavy. These affected a lot. We did it by taking these risks." S39*

It may be said that primary school teacher candidates employed their ability to change and control the variables within the scope of scientific process skills in the design process. For example, S7, one of the primary school teacher candidates stated that they tested the nest they built as a group in the testing stage and that they developed the nest as higher in size because they saw that the egg in the nest fell to the ground, and therefore the eggs in the nest did not fall off during the presentation stage and expressed his ideas as in the following:

*... Then we bought eggs in the testing stage. We put the eggs inside. There was no problem in the basket, in the nest when we threw it onto the ground. But the egg jumped and fell to the ground. The edges were supposed to be a little higher. Then we said "let's add layers." We did it again, which our teacher had already suggested. We added layers again. We tested the eggs again in the presentation stage after that. Nothing happened this time. In the presentation, everyone said that it was beautiful.*  
S7

As understood from the words of primary school teacher candidates, it was seen that they learned about pelicans and pelican nests during the planning stage, they chose their materials and designed their nests by taking the criteria given into account during the design stage, and they threw their nests from a certain height to test the sturdiness of their nests and whether they protected their eggs during the testing stage. In addition, the groups whose nests were not sturdy during the testing stage or whose eggs were broken in the nest changed the size of the nests. Therefore, it can be inferred that primary school teacher candidates employed their skills of conducting research, using the data and creating models, changing and controlling the variables within the scope of scientific process skills while they were planning, designing, testing, developing and presenting their nests.

Primary school teacher candidates stated that they employed life skills as well as scientific process skills. One of these life skills was decision-making. For example, the teacher candidate, S18 expressed his opinions as follows and stated that they decided how many eggs there should be in the nest and the materials to be used in the nest before designing the nest.

*We looked at the pelican's characteristics, the number of its eggs, the size of its egg, and examined their natural nests. Thus, we decided to use straws. Since we found the optimum number of eggs between 1 and 6, we decided to make space for 6 eggs. Later, we decided on styrofoam to keep its temperature well, of course, styrofoam is not natural, but it keeps its temperature constant.* S18

In addition to decision making skills, it was observed that the participants used their skills of collaboration and teamwork. For example, the teacher candidate S20 expressed his opinion as follows and stated that they divided the tasks in group work, took the opinions of the group members while designing the nest and that they built the nest together.

*We shared the work load. We went together to pick up the branches. We took the branches we found outside and brought them to our house. Then we chopped that big pine branch into pieces together. We laid the table cloth on the floor. Then we put them together around that table cloth. Then we tested ideas for bringing the ends*

*together. It didn't work, we took it to pieces. We did it again. We did it completely with my group friends. S20*

During the practice process, the group members shared the work load in group work and fulfilled the task assigned to them. S8, one of primary school teacher candidates, said, *"In this process, as we worked in cooperation with our friends, we took the responsibilities to work by sharing the workload."* S38 said *"We shared the work load while bringing the materials. For example, I live in a district of Eskişehir. Because it is easier for me to reach natural materials, I brought sheep wool and straw. Our friends who stayed in the dormitory brought wood pieces and leaves. Then, while we were working on the presentation, we shared the work load, too. We also shared the work during the production stage. We shared the tasks according to what everyone could do and whatever they were confident in according to their abilities"* and stated that they shared the work load in group work and fulfilled the task assigned to them. It may be suggested that group members took responsibility and worked in harmony with each other.

In addition, although all groups were given the same research problem and criteria, the pelican nests designed and built by each group appeared to be different. Figure 7 shows the photographs of pelican nests built by the groups.



Figure 7. Pelican nest samples made by the group members

As seen in the photos, although the criteria for the pelican nest were the same, different designs were made by the group members. Therefore, it is possible to deduce that primary school teacher candidates employed their creativity skills. The results from the reportings of primary school teacher candidates appear to show that these teachers recognized the contribution of science studies and of the relationship among technology, society, environment and daily life. They also made judgments about how important this relationship was for them. For example, the teacher candidate S1 revealed how important it was to take action on behalf of the society and the environment with the following statements

*First of all, when we did this practice, I really liked doing something for the society and contributing to the nature myself, I really did. We left that nest to nature with our friends. We placed it on a tree somewhere nearby in order for an animal to come and use it. To give an example, this emphasized that we should be individuals who are really beneficial to the society. S1*

The pre- service teacher S22 also emphasized how valuable it was to find a solution to an environmental problem and the importance of their experience in revealing the relationship between science-technology-society-environment.

*Now, we always cover it in our classes. Combining science with other social fields, especially in the field of science-technology-society-environment. For example, the lecture is normally delivered. There you teach this, you equip the student with knowledge by giving the exact definitions and descriptions of the concepts such as electrical circuit etc. but the student does not know. It just lives for that class. But I realized something. We did something like this. We created a solution by reflecting a problem in nature to our lesson. I think this is a good thing. In terms of improving ourselves, when I studied that part in science-technology-society-environment, it mentioned that teachers were inadequate in this regard, while teaching children. But we had an experience with that. Science-technology-society-environment, we can pick a problem in nature for children and bring it into our classes. We can teach it in connection with science. This is a beautiful thing. S22*

## **Results and Discussion**

Within the scope of this case study, it was aimed to reveal how primary school teacher candidates experienced the STEM practices in Science and Technology Teaching I course and the skills which they employed in this process. Within the scope of the study, the data were obtained through semi-structured interviews and observations based on video recordings. The data obtained from the interviews and the recorded videos about the STEM activity which primary school teacher candidates conducted within the scope of Science and Technology Teaching I course, are presented in the form of findings under the themes "*The experiences of primary school teacher candidates in the STEM practices process*" and "*The skills and affective characteristics employed by primary school teacher candidates in the STEM practices process*". The data obtained within the scope of the research showed that primary school teacher candidates both followed the engineering design steps and used interdisciplinary skills within the scope of an engineering design task presented in a real-life context. Moore et al. (2014) emphasized the importance of engineering design processes offered to students in the STEM

education approach, and Estapa and Tank (2017) stressed the importance of real-life context specific to engineering in acquiring knowledge and skills. The data obtained within the scope of this study also showed that primary school teacher candidates displayed interdisciplinary skills such as scientific process skills and life skills such as creativity and teamwork in the process. Therefore, it was seen that the STEM activity, structured around a socioscientific issue presented to teacher candidates, gave them an opportunity to demonstrate the skills and competencies which they aim for their students to acquire.

It is suggested that the activities carried out in pre-service and in-service teacher training should be in a structure in which students can experience, their learning outcomes are clearly defined, and teachers participate actively in the learner role (Guskey & Sook Yun, 2009). In addition, it is underlined that these practices should be carefully adapted to certain content, process and context elements (Guskey & Sook Yun, 2009). The process structured within the scope of this study was arranged in a way which was appropriate for the classroom level of primary school teacher candidates, which determined the learning outcomes, and in which primary school teacher candidates played an active role as the learner. Primary school teacher candidates demonstrated the behaviors and skills that students are expected to acquire in the process. Therefore, primary school teacher candidates demonstrated the behaviors and skills which students were expected to acquire in the process.

Since STEM is included in secondary school science curriculum and classroom practices, but not at the same level at primary school level, the teachers may not be sufficiently familiar especially at primary school level. Hence, teaching practices for STEM education should give participants time to try new practices, get feedback about their teaching, and reflect on these new practices (National Staff Development Council, 2001). Research shows that professional development focusing on science content and how children learn is important in changing teaching practices (Cohen & Hill, 1998; Fennema et al., 1996). Accordingly, the fact that the practice process carried out within the scope of the research was content-oriented and practice-oriented made it possible for primary school teacher candidates to exhibit the behaviours required by STEM in general and by engineering design steps in particular. The findings of the study regarding the participants' practices in the STEM-based instruction showed that primary school teacher candidates followed the engineering design steps and revealed the key behaviors aimed to be displayed in these steps. In addition, primary school

teacher candidates not only followed the engineering design steps, but also had the opportunity to notice and exhibit the behaviours they were expected to show within these steps.

One of the strongest criticisms STEM education-oriented teaching processes receive is that concepts such as values, morality and ethics, which have an important place in science education, stay in the background (Zeidler, Herman, Clough, Olson, Kahn, & Newton, 2016). A similar criticism is that the acquisition of basic scientific knowledge and skills is ignored due to the effort to include different disciplines (Karahan, 2018). When the findings obtained through the study were examined, it was seen that primary school teacher candidates gained basic scientific skills such as scientific process skills and certain values especially through the relationship between the human and the environment. Therefore, it is suggested that the STEM practices should be presented in the context of real life and structured in line with learning outcomes as the reason for this.

Considering the results of the study, suggestions have emerged for both teachers and teacher educators. The inclusion of standart-based and skill-oriented activities in pre-service and in-service teacher education has a critical importance for prospective teachers to gain the necessary competencies. Therefore, activities that participants can implement directly in their classrooms and put themselves in the role of learners should be considered in the process of designing pre-service and in-service professional development programs. In addition, it is important for the practitioners from all grade levels to follow the STEM teaching processes that are developed based on real life problems in order to help students acquire critical skills.

#### **Statements of ethics and conflict of interest**

"I, as the Corresponding Author, declare and undertake that in the study titled as "*Primary School Teacher Candidates' Experiences Regarding Problem-Based STEM Applications*", scientific, ethical and citation rules were followed; Turkish Online Journal of Qualitative Inquiry Journal Editorial Board has no responsibility for all ethical violations to be encountered, that all responsibility belongs to the author/s and that this study has not been sent to any other academic publication platform for evaluation. "

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