GEFAD / GUJGEF 37(2): 649-684 (2017)

The Opinions of Prospective Science Teachers Regarding STEM Education: The Engineering Design Based Science Education*

Fen Bilgisi Öğretmen Adaylarının STEM Eğitimine İlişkin Görüşleri: Mühendislik Tasarım Temelli Fen Eğitimi

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Makalenin Geliş Tarihi: 11.10.2016 ***Yayına Kabul Tarihi: 10.04.2017***

ABSTRACT

The purpose of this study is to reveal the opinions of prospective science teachers regarding the engineering design based science education (EDBSE). Being conducted with 42 prospective 3rd grade science teachers by using the action research design, the study lasted for 5 weeks. At the end of the process, the teachers were asked to write their negative or positive views about process, suggestions, and their opinions regarding whether they will use it or not in the future. The qualitative data that were collected via the participant opinions form were analyzed with the content analysis. Prospective science teachers generally expressed positive opinions regarding the EDBSE and they stated that they would like to apply it in their classes in the future. On the other hand, the negative opinions or suggestions of prospective teachers regarding these practices were determined as having difficulties with time planning and management, classroom management, preparation of activities and designing of a convenient problem.

Keywords: *Action Research, Engineering Design Based Science Education, STEM Education, Teacher Education.*

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* This study is part of the first author's doctoral thesis and the preliminary version of this study was presented in II nd International Eurasian Educational Research Congress in Ankara-Turkey in 2015 and published in the abstract book of conference.

ÖZ

Bu çalışmanın amacı, fen bilgisi öğretmen adaylarının mühendislik tasarım temelli fen eğitimine ilişkin görüşlerini ortaya çıkarmaktır. Eylem araştırması olarak yürütülen bu çalışma 42 üçüncü sınıf fen bilgisi öğretmen adayı ile 5 hafta boyunca yürütülmüştür. Uygulamanın sonunda öğretmen adaylarından sürece yönelik olumlu-olumsuz görüşlerini, uygulama konusunda önerilerini ve gelecekte öğretmenlik yaşantılarında kullanıp kullanmamaya yönelik görüşlerini yazmaları istenmiştir. Katılımcı görüş formu ile toplanan veriler nitel veri analiz yöntemlerinden içerik analizi ile incelenmiştir. Öğretmen adayları genellikle mühendislik tasarım temelli fen eğitimine yönelik olumlu görüş sunarak gelecekte öğretmen olduklarında derslerinde uygulamayı istediklerini ifade etmişlerdir. Bununla birlikte olumlu görüşlerle birlikte olumsuz görüş bildiren öğretmen adayları sürecin iyileştirmesine yönelik öneriler sunmuşlardır.

Anahtar Sözcükler: *Eylem Araştırması, Mühendislik Tasarım Temelli Fen Eğitimi, STEM Eğitimi, Öğretmen Eğitimi.*

INTRODUCTION

In this century, the increase in forming and spreading the knowledge is highly remarkable. Thus, there are changes and developments in almost every area. These changes and developments are socially and economically important for societies (National Assessment Governing Board [NAGB], 2010). Societies that are aware of this condition make various attempts for keeping pace with this change. A number of reports that have been published (National Academy of Engineering [NAE] & National Research Council [NRC], 2009, p. 49-50; NRC, 2012; Next Generations Science Standards [NGGS], 2013) emphasize that societies will need individuals that would keep pace with changes, contribute to the necessities of the time, think creatively, have the skill of innovation and possess more than one disciplines (Bozkurt, 2014). Modern countries have started to revise the educational policies in order to raise such individuals as expected. They have placed the STEM education; based on the integration of the disciplines of STEM at all educational levels right, in the center of educational reforms (National Academy of Engineering [NAE], 2010). STEM education has become an inseparable part of the learning programs of the 21st century (Honey, Pearson & Schweingruber, 2014; NAE & NRC, 2009; NRC, 2014). The transformation from science education to STEM education primarily started in the United States and it continues in a number of European countries and the studies increase in an accelerated way. Besides, the fact that science literacy forms the onset and the basis of the educational reforms of the STEM education is also remarkable (Shaughnessy 2013).

Examining the effect of all these studies on the scale of Turkey; the reports that are published by TÜBİTAK (2004) and TÜSİAD (2014), which are at the center of scientific developments, issue a call for “increasing the interest in STEM areas and emphasize the necessity for raising individuals that are skillful in these areas. Examining the studies in the field of education, on the other hand; they are observed to be resonated as FeTeMM (Fen, Teknoloji, Mühendislik ve Matematik Eğitimi -in Turkish) education; however, the practice mainly remains academic or at the level of science centers, which are out-of-school learning environments. Studies and projects are sustained in order to start the practice. Besides, in the Science Curriculum, revised in 2013, it has emphasized that the integration of STEM should be provided in the learning environment (Ministry of National Education [MNE], 2013). MNE also involved engineering discipline to science curriculum (MNE, 2017).

The aim of STEM education is to provide relevant, focused, meaningful and appropriate learning that provides the holistic approach and integrating disciplines (Smith & Karr-Kidwell, 2000). To do this, STEM connects science with other disciplines by establishing a relationship between a unit or course content and a real-life problem in education. There are some concerns about STEM education in terms of both researchers and curriculum in the literature (NAE, 2010). These concerns primarily involve the lack of a single focus in the STEM education and need the integration of four disciplines (Atkinson, & Mayo 2010; Barrett, Moran, & Woods, 2014; Berland, 2014; NRC, 2014; Taskforce Report, STEM, 2014). According to the Next Generation Science Standards (National Academies Press [NAP], 2013), this integration is mainly interdisciplinary.

A number of approaches have been proposed to achieve the integration of disciplines in STEM education (Bybee, 2000; Dugger, 2010; Sanders, 2009). One of these approaches is the integration of engineering discipline into science education (Dugger, 2010; Pratt, 2012). In addition to this, even though the literature involves studies regarding the development of students' understanding about the important role of engineering in shaping the society and how the disciplines of science and mathematics are contextualized for developing the students' success, motivation and problem-solving skills (Cunningham, & Lachapelle 2014; Diaz, & King 2007; English & King, 2015; Holmes, Rulfs, & Orr, 2007; Moore et al., 2014a; Stohlmann, Moore, & Roehring, 2012; Zawojewski, Defes-Dux, & Bowman, 2008); it does not sufficiently emphasize how to integrate engineering for students to learn (Hudson, English, & Dawes, 2014; Miaoulis, 2014). Engineering integration into science education has been proposed to use engineering design processes (Daugherty, 2012; Roth, 2001; Strong, 2013; Wendell, 2008). In addition, in the related literature, "Design Based Science Education" has been proposed as one of the approaches to provide this integration and expressed as engineering design based science education (EDBS) (Householder & Hailey, 2012; Wendell, 2008). Even though it is the contribution of engineering is explicitly addressed in STEM curriculum for elementary schools, teachers do not have experiences regarding the integration of engineering (English, & King, 2015). This study is believed to make a contribution to filling this gap in literature concerning the practices of integration of engineering into science education.

The balanced integration of inquiry based learning and EDBSE is important for achieving the goals of science curriculums. EDBSE is an educational approach that involves the integration of STEM disciplines, which handle the inquiry and engineering design together in order to enable students to acquire the targeted behaviors and aim to generate solutions for engineering design problems that form the real-life context within the scope of the process of engineering design (Householder, & Hailey, 2012; Wendell, 2008). Practices of EDBSE not only increase the success of students in science lessons, but also enable them to acquire skills, develop positive attitudes, and have an increased interest and motivation regarding the lesson and the discipline of engineering (Roth, 2001; Tal, Krajcik, & Bluemenfeld, 2006; Ercan & Şahin, 2015).

Teachers have the main responsibility in implementing STEM approaches therefore the necessity of teacher education needs to be realized. In order to transfer engineering applications to science classes, teachers should have competencies, such as design and development processes together with scientific research process, use of various materials in class, associate course content with real life, and combine laboratory experiments with engineering design process (NRC, 2012). Teacher candidates need to experience this process before they can use the engineering process as a teaching method. Thus, it is important to take the views of teachers who experience the engineering design about integrating EDBSE to science classes (Apedoe, Reynold, Ellefson, & Schunn 2008; Bozkurt, 2014; Capobianco, 2011; Capobianco, 2013; Cuijck Keulen, & Jochems, 2009; Felix, 2010; Hacıoğlu, Yamak & Kavak, 2016).

In light of the information stated above, this study is important for several perspectives:

- EDBSE activities prepared and implemented by researchers, will be improved based on the feedback from prospective science teachers.
- This study will provide an example for the use of EDBSE approach in the teacher education programs.
- It will make a contribution to the development of STEM activities and interdisciplinary curriculum.
- Based on all these perspectives, the feedbacks from prospective science teachers included in the process of EDBSE will be taken into consideration in future studies.

Thus, we prepared and applied an activity program for prospective science teachers regarding the approach of engineering design based science education.

The purpose of this study is to reveal the opinions of prospective science teachers regarding the EDBSE. In the study, answers were sought for the following questions:

1. What are the prospective science teachers' positive opinions about EDBSE practices?
2. What are the prospective science teachers' negative opinions about EDBSE practices?
3. What are the prospective science teachers' suggestions about EDBSE practices?
4. What are the prospective science teachers' opinions about the use of EDBSE teaching experience in the future?

METHODS

Research Design

This study is an action research that was conducted in the fall term of the school year of 2014-2015. Action research is a process using research technics that enable participants to examine the educational practices in a careful and systematic way (Ferrance, 2000). According to Mills (2007), action researches generally focus on collecting systematic information about the distinctive teaching methods of teachers, managers, counselors and other relevant people, and how the students learn. Action researches have various types. One of them is the practice/cooperation/discussion based action research (Van de Berg, 2001). In this type of action research, which constitutes the focus of our study, researchers and practitioner come together and determine the problems in the practice, the factors causing these problems, and generate solutions (Yıldırım & Şimşek, 2008: p. 296). This study is conducted based on the cycles of action research (consist of two consecutive cycles) (McKernnan, 1996; as cited in Hopkins, 2014, p. 63) and includes the first cycle. This action research enabled us to discuss about the positive and negative conditions in every stage of the study and improve the study. This study also enabled the prospective teachers to gain experience in their own field and in EDBSE.

Participants

The participants of the study consist of 42 prospective science teachers (27 female, 15 male) at a state university in the north east of Turkey. They voluntarily participated to this study. They took basic science courses (physics, chemistry, biology and laboratory practices), science teaching methods course, and science-technology curriculum and planning course. The participants were purposefully selected for this study because they were in fift semester in the faculty and had no experience in STEM education, but enrolled in Science Teaching Laboratory Practice course during this study.

P**reparing and Applying the EDBSE Activities**

The study process was planned by using the stages of the action research (Mamlok-Naaman, Nayon, Carmeli & Hofstein, 2003). Being planned as 10 hours, this process was completed in 5 weeks. In the process of planning, we primarily reviewed the relevant literature and determined the activities that could be applied in Science Teaching Laboratory Practice-I course. In this stage, we also received feedbacks from the experts studying on STEM education and EDBSE and reorganized the activities.

The activities are designed according to EDBSE. However, in the literature have been proposed many approach to EDBSE (Wendell, Connolly, Wright, Jarvin, Rogers, Barnett et al., 2010): Design-Based Modeling (Penner, Giles, Lehrer, & Schauble, 1997; Penner et al., 1998), Engineering for Children (Roth, 1996, 1997, 2001), Engineering Competitions (Sadler, Coyle, & Schwartz, 200), Project-Based Science (Krajcik & Blumenfeld, 2006; Tal, Krajcik, & Blumenfeld, 2006), Learning by Design (Kolodner et al., 2003; Kolodner, 2006). The activities in this study based on instructional pattern for our Science through LEGO™ Engineering units, compared to a simplified model of the engineering design process (Figure 1).

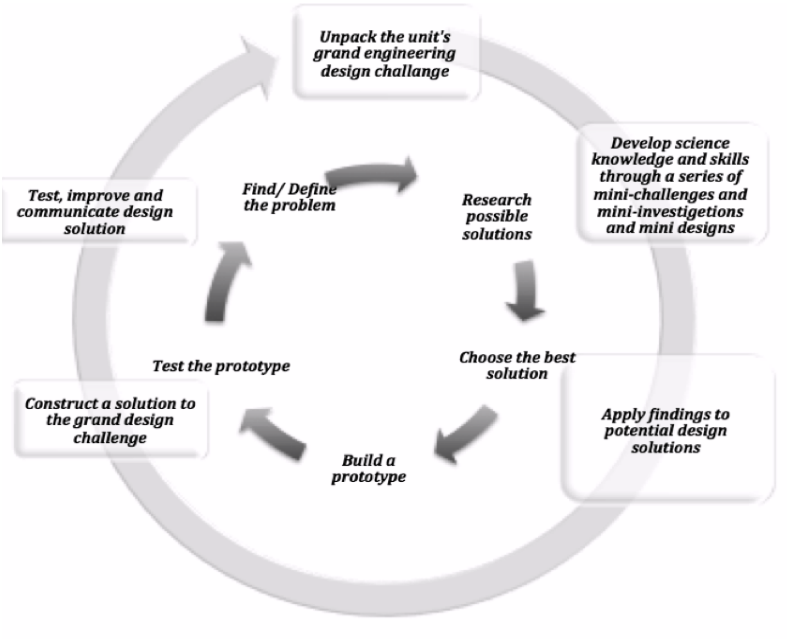

Figure 1. Engineering Design Based Science Curriculum Unit Phases (Wendell, et al. 2010).

In the figure 1 consist of two cycles. The outer cycle is about how the unit and explains "How are the unit/lessons to be processed during 6-8 lesson?" (Wendell, et al., 2010). The first lesson starts with the grand engineering design challenge and the big science question for the unit. Students encourage to discuss what they already know that will help them complete the challenge and answer the question and what they still need to learn. In the next six to eight lessons of each unit - "research possible solutions" step of engineering design process”-, students carry out “mini design challenges” and “mini science investigations” to learn the knowledge and skills that will enable success on the grand design challenge. Along mini investigations and mini design, students construct and test physical artifacts, and teachers guide students in reflecting on how their findings will inform the step of “choosing the best solution.” In the last two to three lessons, students build, test, and improve their solution to the grand design challenge, and then present.

The inner cycle is related to the engineering design process with five stages for elemantary students. However, as this 5-stage approach was predicted to possibly remain simple for prospective teachers, some adjustments were made (Bozkurt, 2014). These adjustments were made by using the following 9-stage process, which was developed by Hynes, et al. (2011) (Figure 2).

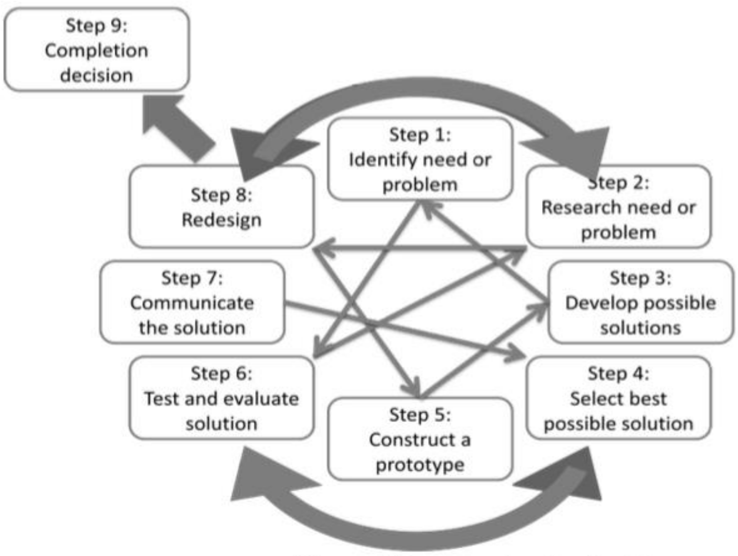

Figure 2. Engineering Design Process (Hynes, et al. 2011, p. 9).

The process in Figure 2 explains “How do engineers design?” and the process should require the students to identify the problem, determine the need, do research, plan, brainstorm, test, evaluate and communicate (Hynes, et al. 2011). Hynes, et al. (2011) explain this stage in detail as below:

In the step 1, identify problems; students are exposed to real life problems. They should identify the necessary constraints and specifications of real world engineering problems that are open-ended with many possible solutions, and provide solutions.

In the step 2, **research the need or problem,** students need knowledge and skills to solve engineering challenge or problem, so they should do theoretical research before developing a solution. Because of the research conducted by students, they will be redefining and clarifying the problem.

In the step 3, **develop possible solution(s),** student should do brainstorming in groups actively and provide multiple ideas for problem solving requiring planning and teamwork and specify their ideas via words, drawings, and prototypes. So, they understand tradeoffs.

In the step4**, choose the best possible solution(s);** students should choose the best possible solution(s) through optimization and using their knowledge of math and science and make decision for solution that allows to overcome to problem as much as possible.

In the step5, **construct a prototype;** students should construct a model of their solution.

In the step 6: **test and evaluate the solution(s)** they learn from failures as they iterate on their solution. They test the construct based on the constraints and requirements of the problem.

In the step7: **communicate the solution(s);** students should share their ideas and findings with others for feedback, explain their design process by using their acquired knowledge and skills to convince other group friends or exchange ideas about why their design failed.

In the step8: **redesign;** students should review the process and debate on how to improve the prototype.

In the step9: **completion (leaves the cycle);** students should believe they have sufficiently optimized their product based on the selected constraints and make a decision for their design (Hynes, et al., 2011).

Engineering design process, which is explained in detail above, has the qualifications for engineering, science and mathematics integration (Felix, 2010; NAE & NRC, 2009). Hynes et al. (2011) emphasized that engineering design process is an iterative process and requires rotation to a certain step. On the contrary, it is a set path or stepwise approach.

In this study, the activity was structured based on the EDBSE model, that Bozkurt (2014) recommended for pre-services science teachers, in Figure 3, where the design processes of Wendell et al. (2010) and Hynes et al. (2011) are combined.

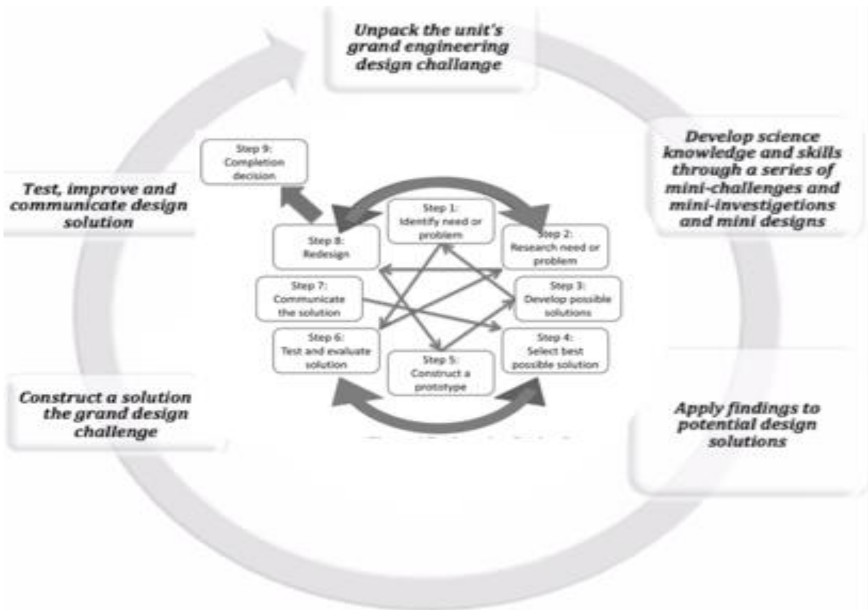

Figure 3. EDBSE structured by engineering design process (Bozkurt, 2014; Wendell, et al., 2010; Hynes et al., 2011).

The first stage of EDBSE activities that are used in our study is to expose the students to a context, which could be the design problem. In this stage, the students are expected to define the problem. After defining the problem, we get two different thoughts about how to realize the education. According to Kolodner, et al. (2003), the focus of this process is the development of a design by the cooperation of students. While developing the design, inquiry based activities are also performed. According to Wendell (2008), on the other hand, there should be a balance between the design and inquiry in this process. In our study, the practices were prepared based on the second opinion.

For this study, activity plan (in Figure 4) “Clothes straighteners design”, that consist of grand challenge and three mini investigations and two mini designs, are planned and implemented by researchers. Mini investigations and designs are aimed to ensure that prospective teachers have the necessary knowledge and skills to carry out the grand challenge design task.

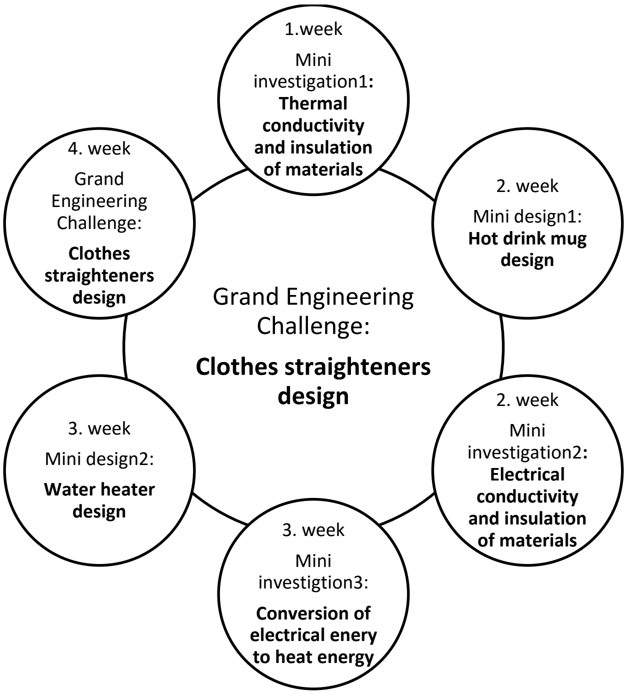

Figure 4. Grand design challenge and related mini investigations and mini designs.

Before the implementation, we discussed and questioned whether or not the prospective teachers had a pre-experience about EDBSE in the classroom environment. As a result of informal observations, it was determined that none of the prospective teachers had an experience about this subject. And then they were informed about the integration of engineering design process into science education for two courses hours/ one week. The participants were also allowed to form their own study groups of 4 or 5 by paying attention to having similar rates of boys and girls in each group. The students worked in 9 groups.

Implementation

Activities were conducted in the fall semester of 2015-2016 at the Science Teaching Laboratory Practice course that is four hours in a week (two-hour theoretical and two-hour practice). These activities allow the use and execution of materials and open-ended experiments. The activities were implemented in the two-hour practical part. So, the activities were applied for 4 weeks/8 hours. The first week was performed by defining the great design problem, determining the criteria and limitations, presenting the possible solution suggestions and determining the best solution suggestion. The second week was performed by applying the first mini investigation and the first mini design. The third week was performed by applying the second mini investigation the second mini design and the third mini investigation. The fourth week was performed by creating and testing a prototype for the great design, as well as being involved in the processes of communication and redesign.

For the successful implementation of the engineering design process, there are three factors: students are engineers; teachers need to listen to their students; and classroom environments need to change properly to enable learning through the engineering design process (Hynes et al., 2011). Activities were conducted through activity booklets. The grand engineering challenge is explained in detail in order to understand how it works during the task:

Activity "Clothes straighteners" starts with a grand engineering challenge problem. Indeed, the first stage of the engineering design process is to identify the problem and is designed to accomplish this stage.

> *Nil's skirt was wrinkled when she went to her grandmother's village. But, her grandmother did not have any tool to solve the problem. Therefore, Nil considered to design a product that is small and light, and it costs maximum 20 Turkish Liras.*

The prospective teachers are asked to solve Nil's problem. The guidelines for implementing the engineering design process are presented in the activity booklet.

In the first week, prospective teachers conducted the stage of identify and define problems; research the need or problem, develop possible solution(s) and choose the best possible solution(s) of engineering design process to solve grand design challenge. Meanwhile, prospective teachers were encouraged to conduct research via computer and reference books in the class. They were free to go to the library if necessary. They noted the information that they had obtained in the course of their research and discussed with their group of friends. In the light of the research, they developed a grand design problem-oriented possible solution. Then, they evaluated each possible solution(s) in the context of problem-related criteria and limitations, and they determined the best possible solution.

Over the second and third weeks, mini investigation (inquiry based, open ended experiment) and mini design were conducted before constructing a prototype. Engineering design process was carried out throughout each mini design. For example, of mini design, hot drink mug design and its implementation can be examined in the study of Hacıoğlu et al. (2016).

In the fourth week, the prospective teachers evaluated the best possible solution and conducted the stages of constructing a prototype, present the solution(s) and completion. At this stage, all materials necessary for the design of prospective teachers were prepared by the researchers in the class environment. If the material is not available in the classroom environment, these materials were provided. Particular attention has been paid to the use of waste materials. In addition, they were encouraged to conduct in-group scientific discussions.

Research Instruments and Procedures

The data of the study were collected via the feedback forms that were written by prospective teachers at the end of the practices aimed at the process of EDBSE. In the feedback form, the prospective teachers were asked "*What is your opinion about EDBSE? You can expresse positive and negative opinions, suggestions and opinion about the use of EDBSE teaching experience in the future.".* Also, unstructured form was used to not limit their opinion. They expressed their opinions regarding the process, their suggestions for improving the process and using it in their future professional life. Even though the process of practice was conducted with 44 prospective teachers, the data were collected from 42 prospective teachers as two of them did not express their opinions and then the data were analyzed.

Data Analysis

At the end of the practices, the prospective teachers were asked to write down their positive and negative opinions regarding the process, as well as their suggestions about the practice and whether or not they would use it in their future teaching life. In the study, we followed the stages of qualitative data analysis and performed a content analysis: the data were primarily coded with open coding (Strauss & Corbin, 1990). And then a common code category (theme) and sub-categories were determined for the codes regarding the same title or subject (LeCompte & Preissle, 1993). The convenience of the code, category and sub-categories that were formed separately by two researchers and all codes and categories were compared. And inter-rater reliability of 95,6% was reached by using Miles and Huberman (1994, p. 64)'s formula;

> [*Reliability=Number of Agreements/Total number of Agreements and Disagreements*].

But, the process also continued until the agreement was reached. Thus, a reliable data analysis was provided. In order to provide the validity of the results in the study, we tried to explain the process of categorization, which comprised the data analysis process, in detail. The categories were approached under the titles of positive and negative opinions regarding the practice process, opinions regarding the improvement of the process and opinions regarding the future practice. And it quoted prospective science teachers' opinions.

RESULTS

In this part of the study, the opinions of prospective teachers were collected and presented under four main categories. These categories respectively included positive opinions regarding the EDBSE process, negative opinions regarding the EDBSE process, suggestions for improving the process and opinions regarding the practice of EDBSE activities in the future. Besides, each category was presented and explained in tables displaying the sub-categories, codes, resources and frequencies (F). The frequency (f) values in these tables signify the frequency of repeating the relevant code.

Table 1 shows the positive opinions of prospective teachers regarding the practice process of EDBSE.

Table 1. Findings regarding the category of positive opinions of prospective teachers concerning the EDBSE process

Sub-categories	Codes	f	PCT code
Acquiring skills (f=45) (25PCT)	Creative thinking skill	13	4, 5, 6, 7, 10, 11, 19, 20, 26, 27, 32, 35, 42
	Thinking skil ls	6	1, 7, 9, 33, 37, 41
	Problem solving skill	5	2, 6, 11, 20, 35
	Psychomotor skill	4	7, 9, 11, 41
	Inquiry skill	3	2, 24, 42
	Scientific process skill	2	37, 42
	Analytical thinking skill	2	11, 19
	Critical thinking skill	2	10, 11
	Skill of working in groups	2	11, 19
	Communication skill	2	3, 17
	Decision-making skill	2	11, 19
	Skill of living	1	36
	Integrated thinking skill	1	11
Teaching methods (f=4, 4PCT)	Different teaching method	2	3, 39
	Interdisciplinary teaching	2	2, 15
Learning (f=21) (14PCT)	Active learning	9	3, 10, 14, 16, 18, 22, 24, 30, 31
	Learning by experience	4	3, 14, 21, 22, 24
	Permanent learning	4	3, 14, 22, 40
	Learning by entertainment	4	8, 23, 30, 37

Table 1. Continued.

Sub-categories	Codes	f	PCT code
Affective domain (f=15) (12PCT)	Increasing the motivation	8	1, 21, 22, 25, 28, 34, 35, 38
	Bringing an awareness in problems	2	12,35
	Increasing the attitudes	2	5, 34
	Bringing self-confidence	2	4, 28
	Bringing responsibility	1	22
Process (f=8,8PCT)	Interesting	8	5, 6, 7, 13, 16, 20, 36, 37
Knowledge (f=6) (5PCT)	Daily life problems	4	2, 4, 9, 20
	Applying theoretical knowledge	1	9
	Filling deficient knowledge	1	25
STSE (f=4) (4PCT)	Consciousness of career	2	6, 21
	Science-society relation	2	12, 35
Total (f = 103) (43 PCT)		**PCT=Prospective science teacher*	

Examining Table 1; it is observed that prospective teachers expressed positive opinions regarding EDBSE respectively in the sub-categories of acquiring skills, learning, affective domain, relationship of process, knowledge and Science- Technology- Society-Environment (STSE), and teaching methods. For example; PCT42 expressed her opinions about acquiring creative thinking, inquiry, scientific process, and communication skills during the EDBSE process. She argued;

> *"…Thanks to these activities, our scientific process skills have improved and our creativity has emerged. This process makes us more active. It encouraged us to reach the information by ourselves. As a group, we did research and discussion in order for making our design to solve the problem. At this stage, we actually learned to do research as well…".*

PCT3 stated her opinion on acquiring communication skills thanks to EDBSE process. She explained;

> *"I think our communication skill improved, because we worked as a group…".*

She also emphasized on a learning sub-category, which consists of active learning, learning by experience and permanent learning. She argued;

> "*...I think that the student needs to work actively because we did everything by experiencing during the process. I also think that our knowledge increased permanently because we applied our theoretical knowledge into our designs."*

And she emphasized on another sub-category which is about teaching methods. She expressed;

> *"...I also think that it is a different teaching method....".*

PCT13 expressed his opinions about the sub-category of STSE and affective domain. He explained;

> *"…Such practices increase the learner's motivation for the science learning. I think students are more scientific when they look around at the end of the process…".*

Besides, examining the numbers in the prospective science teacher's code column in the table, it is observed that only PCT 29 is missing. It means that all prospective teachers had expressed a positive opinion (97,6%), except for the PCT29.

Table 2 shows the negative opinions of prospective teachers regarding the practice process of EDBSE.

Table 2. Findings regarding the category of negative opinions of prospective teachers concerning the EDBSE process

Sub-categories	**Code**	**f**	**PCT code**
Limitation (f=10) (10 PCT)	Duration Material supply	8 2	3, 11, 16, 23, 26, 27, 29, 33 4, 41
Self-sufficiency (f=1) (1PCT)	Insufficiency	1	10
Total (f=11) (11 PCT)		*PCT=Prospective science teacher	

Examining Table 2; it is observed that prospective teachers expressed negative opinions regarding the practice process of EDBSE respectively in the sub-categories of limitations and self-sufficiency. Besides, it is observed that 11 (26,2%) prospective teachers expressed their opinions in the category of negative opinions. Comparing this finding with the findings in Table 1, it is observed that only the prospective teacher coded PCT29 expressed negative opinions about time limitation sub-category. He explained:

> *"If our time were not limited, we could finish the lesson more effectively and realize our design."*

Only PCT10 stated her negative opinion about self-sufficiency category and she stated;

> "*…Sometimes I am bored in the process of designing, because I cannot think creatively...".*

Table 3 shows the suggestions of prospective teachers regarding the improvement of the practice process of EDBSE.

Table 3. Findings regarding the category of suggestions of prospective teachers concerning the improvement of the EDBSE process

Sub-categories	Code	f	PCT code
Process (f=6) (5PCT)	Equipment supply	4	9, 17, 23, 38
	Conducting the research outside of the lesson	2	23, 25
Student (f=2) (2PCT)	Willingness	1	1
	Level	1	5t
Activity (f=2) (2PCT)	Selection of problems	1	8
	Forming activities	1	36
Total (f=10) (9PCT)	*PCT=Prospective science teacher		

Examining Table 3; it is observed that only 9 (21,4%) prospective teachers expressed their opinions in the category of suggestions. The suggestions of prospective teachers regarding the improvement of the practice process of EDBSE are in the sub-categories of process, student and activity. For example, PCT23 recommended about the process;

> "*It would have been more efficient if we could reach all the materials, which we imagine and think about them. The time could be shorter if the information was given instead of doing research at the beginning of process."*

Comparing this finding with the findings in Table 1 and Table 2, it is observed that PCT23 also had expressed opinions in all three categories. On the other hand, 5 prospective teachers (PCT1, PCT5, PCT17, PCT25, and PCT36) expressed positive opinions and only presented suggestions. Three prospective teachers presenting their suggestions regarding the improvement of the EDBSE process (PCT5, PCT8, and PCT38) expressed their hesitations in the practice.

Table 4 shows the opinions of prospective teachers regarding whether or not they would apply the EDBSE in their future teaching life.

Table 4. Findings regarding the category of opinions of prospective teachers concerning applying the EDBSE in their future teaching life

Sub-categories	**Code**	**f**	**PCT code**
Hesitation in implementation (f=9)(9PCT)	Equipment/ material supply	3	5, 15, 38
	Insufficiency	3	7, 18, 37
	Problems of educational system	1	8
	Problems of classroom management	1	26
	Difficulty with assessment and evaluation	1	14
Willingness for implementation (f=5) (5PCT)	Students' development	3	1, 4, 12
	Sufficiency	1	6
	Easy Implementation-accessible materials	1	16
Total (f=14) (14 PCT)	**PCT=Prospective science teacher*		

Examining Table 4; it is observed that only 14 (33,3%) prospective teachers expressed their opinions on this subject. The opinions in question were collected under two sub-categories as hesitation in practice and willingness for practice. Comparing this finding with other findings, it is observed that while PCT26 expressed both positive and negative opinions and a hesitation in practice. He expressed;

> "…*I think it is difficult to manage group working and keep each group active. For this reason, I do not know if it can be used in primary or secondary school...".*

PCT4 and PCT16 expressed both positive and negative opinions and willingness for practice. Only PCT1 stated that she/he had willingness while making suggestions regarding the practice and he explained;

> "…*I want to use the design activities in the future to teach our students the science and improve their thinking skills*...".

CONCLUSION AND DISCUSSION

As a result of the study, it was determined that prospective science teachers generally expressed positive and partially negative opinions regarding the EDBSE. All opinions were discussed in the light of literature and were presented in this part.

In their positive opinions of prospective science teachers regarding the process, majority of prospective teachers stated that the practice contributed especially to the increase of high-level thinking skills. Similarly, Marulcu and Sungur (2012) stated that EDBSE would develop the thinking skills of prospective science teacher, which are already developed in scientists.

Majority of prospective teachers agreed that EDBSE would develop the creative thinking skills. This result is related with the nature of the engineering design process. Because individuals are required to present more than one solution suggestions in order to solve the design problems in the engineering design process (Brunsell, 2012; Silk & Schunn, 2008). Individuals are also required to use their creativity while presenting their possible solution suggestions (Brunsell, 2012; Mentzer, 2011; Wendell, et al., 2010).

Prospective teachers expressed the other positive opinions are inquiry and problem-solving skills. According to prospective teachers, EDBSE contributes to the development of these two opinions, which shows a parallelism with literature. According to Fortus, Dershimer, & Krajcik (2004), individuals not only design a product in the engineering design process, but also try to solve a problem. This effort develops their inquiry (scientific inquisition) and problem-solving skills. Similarly, Aslan-Yolcu (2014) stated that the interdisciplinary approach had a positive effect upon the problem-solving skills of students. In the study processes, both scientists and engineers follow similar steps like conducting inquiry, forming mental models and presenting the knowledge they acquire (NAE & NRC, 2009).

In the study, the prospective teachers also stated that their scientific process skills and decision-making skills had developed. This result is thought to be associated with the integration of the engineering design process into the scientific inquiry process. As a result of the study, the prospective teachers also expressed positive opinions regarding the critical thinking skills. In their studies, while Clarke (2010), Sullivan (2008) and Bozkurt (2014) stated that interdisciplinary science and engineering education was effective upon developing the scientific process skills of individuals; Bozkurt (2014), Denson (2011), Jonansen (2011) and Dym, Wood & Scott (2002) stated that it was effective upon the efficient decision-making of individuals, Ure (2012) stated that high school physics students showed an increase in critical thinking skills and in confidence to use them after engineering design process unit over 1 month. At the end of the process, the prospective teachers also stated that EDBSE activities were effective upon increasing the skills of working in groups and communication skills. This result supports the statement of Kolodner, et al. (1998), who suggested that trying to solve the design problems via the approach of learning by design would enable the students to develop their social and communication skills.

A part of prospective teachers stated that the process had/would have a positive effect upon students, in terms of raising an awareness of career and understanding the science-society relation. This result is important in terms of the relations between Science-Technology- Society- Environment in the process. It also shows that the EDBSE practices could meet the expectation of the STEM education to give the career opportunities in various disciplines required by the era in national education reports, which emphasize the necessity of interdisciplinary education. Similarly, Apedoe et al. (2008) stated that the engineering design process increased the interest in engineering career.

In their positive opinions regarding the EDBSE process, the prospective teachers emphasized that it is interesting. This opinion shows a parallelism with the findings in literature. In the study of Çavas, Bulut, Holbrook and Rannikmae (2013) that was conducted with students and in the study of Capobianco (2011) that was conducted with teachers, it was indicated that the EDBSE practices were effective upon being interested in the lesson and increasing the willingness. On the other hand, Capobianco (2013) suggested that teachers had both positive and negative opinions regarding the EDBSE practices. He stated that teachers at elementary schools had found the EDBSE practices complex, which was also observed in our study. Even though a large part of prospective teachers found the process interesting, a group of prospective teachers stated that they had some concerns about applying the process or preparing activities and some hesitations about applying it in the future.

The other positive opinion, was expressed by prospective teachers, is related to affective domain. They thought that EDBSE practices motivated them and positively changed their attitudes toward the lesson. In the context of real life, the literature involves a number of studies on the contribution of engineering design problems to the motivation of individuals and their attitudes toward the STEM disciplines (Bozkurt, 2014; Moore, et al., 2014b; Schunn, 2009; Harkema, Jadrich, & Bruxvort, 2009; Mehalik, Doppelt, Schunn., 2008; Sadler, Coyle, & Schwatz, 2000).

Prospective teachers think that the process of EDBSE provides knowledge, skills, attitudes and values, which is important in terms of bringing these skills in their students by taking this process to the future educational environments. This result is associated with the intertwined processes of scientific inquiry and design within the process of EDBSE, which was suggested by Wendell, et al. (2010) and was conducted via mini investigation and challenge or design that were taken into consideration in the process of practice.

Negative opinions of prospective teachers, although not as many as positive ones, are among the results of this study. These negative opinions are: Difficulties with time planning and management, classroom management, preparation of activities and designing of a convenient problem. Negative opinions are thought to be important in terms of guiding the future implementers. It is observed that prospective teachers center upon limitations concerning their negative opinions regarding the process. They expressed the negative condition as the limitation of time especially during the implementation of their designs in the process of practice and the absence of all materials while transforming their designs into prototypes in the classroom and they made relevant suggestions. Similarly, as a result of the EDBSE practices that were conducted by Bozkurt

Altan (2016) with prospective science teachers, it was determined that prospective teachers had suggested to involve all materials regarding the design tasks in laboratories in order to developed the process.

While majority of prospective teachers stated that they would consider applying the EDBSE activities while teaching; those expressing negative opinions regarding the difficulty of preparing activities stated that they were hesitant about practices. Regarding applying the process, a part of prospective teachers stated that they had a tendency to apply it as they found themselves sufficient for that. Another part of prospective teachers, on the other hand, stated that they had some hesitations about the practices as they had some concerns about the education system of the country, provision of required materials, possibility of remaining incapable in classroom management, evaluation of students at the end of the process and their self-sufficiency regarding the practice. Similarly, as a result of the study that was conducted by Sungur-Gül and Marulcu (2014) who applied the approach of engineering design to prospective science teachers via Legos, it was determined that prospective teachers had not found themselves sufficient for using the process in their teaching experience yet; however, they could present activity suggestions. In his study, Arafah (2011) also stated that even though teachers had a tendency to integrate the technology and engineering discipline into science education, they did not feel sufficient. Capobianco (2011) and Capobianco (2013) determined that teachers who had been trained via the approach of engineering design were enthusiastic about applying the process in the classroom. In his study where he applied the EDBSE approach to prospective science teachers, Bozkurt, et al. (2016) stated that even though the prospective teachers had felt insufficient about applying the process within the first 6 weeks of the process, they had started feeling sufficient at the end of the 13th week. Besides, as a result of this study, a part of prospective teachers actually expressed positive opinions regarding the process as applying EDBSE in their teaching experience made a contribution to the student development. The fact that prospective teachers expressed opinions in the sub-category of feeling sufficient about using the EDBSE in their classes reveals the importance of teachers' education in terms of learning and applying modern-new education methods and technics.

RECOMMENDATIONS

According to the findings and results acquired from the study, the following suggestions were made:

EDBSE could be used by teachers and researchers for their different science subjects, concepts, contexts and units in order to integrate the process of engineering design into science education. However, when this integration made, should consider the negative opinions and suggestions of prospective teachers expressed in this study. For instance, in order to avoid the concerns of prospective teachers about the course duration, the process should be well planned and prepared plan B.

In order to actuate the design process regarding the concerns of teachers that would manage the process about the classroom management and remain close to goals, it is required to gather individuals that would work in cooperation while forming the student groups. It is also required to pay attention to gender equality in groups. Besides, teachers should keep their students away from competition and be determined to manage the process.

Teachers that would use the engineering design process in science education may receive support from experts in terms of preparing activities, other concerned and hesitated topics. Thus, it can provide cooperate between teacher and university. It is also suggested to should be selected problems close to students' environment and domain, while forming the design problem, which constitutes the beginning of the process.

While preparing EDBSE program, the program developers could consider both positive and negative opinions of prospective teachers regarding this process in the study. These programs will provide the development of a number of skills in individuals that would constitute the society in the transition from childhood to professional life.

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GENİŞ ÖZET

Hızlı gelişim ve değişiminin gerçekleştiği 21. yüzyılda ülkeler gelişebilmek için ve bu gelişmelere ayak uydurabilecek bireyler yetiştirmek için eğitim politikalarında çeşitli girişimlere yer vermişlerdir. Yayınlalan raporlarda (NAE & NRC, 2009, s. 49-50; NRC, 2012; NGGS, 2013) disiplinler arası eğitime vurgu yapmışlar ve fen, teknoloji, mühendislik ve matematik (STEM) eğitiminin entegrasyonuna odaklanmışlardır. Fakat yapılan çalışmalar ve program hazırlıkları incelendiğinde STEM eğitim yaklaşımında mühendisliğin katkıları açıkça ifade edilmesine rağmen, mühendisliğin fen eğitimine entegrasyonuna yönelik deneyimler eksik kalmıştır.Alanyazında bunu gerçekleştirebilmek için mühendislik tasarım temelli fen eğitimi önerilmiştir.Ülkemizde yapılan çalışmalar incelendiğinde ise eğitim programları revizyon çalışmalarında STEM eğitiminin önemine vurgu yapılmasına ve hazırlanan fen bilimleri eğitim programında STEM eğitimine yer verileceği ile ilgili girişimler olmasına rağmen, hâlihazırdaki uygulamaların daha çok akademik düzeyde ya da okul dışı öğrenme ortamları olan bilim merkezleri düzeyinde kaldığı da dikkat çekmektedir. Mühendislik tasarım temelli fen eğitimi yaklaşımının örnek etkinlikler ile öğretmen adaylarına tanıtılması ve uygulanması şeklinde yürütülen bu çalışma onların uygulamaya yönelik fikirleri alınarak STEM eğitimi alanlarında yapılan uygulamaların iyileştirilmesi, gelecekte yapılacak çalışmalara örnek teşkil ederek çok disiplinli ders programlarının geliştirilmesi ve uygulamaların arttırılması ve bu alanda öğretmen yetiştirmeye katkı sağlaması açısından önemlidir. Bu çalışmanın amacı fen bilgisi öğretmen adaylarının mühendislik tasarım temelli fen eğitimine yönelik görüşlerini ortaya koymaktır.

Bu çalışma 44 fen bilgisi (üçüncü sınıf) öğretmen adayı ile yürütülmüş bir eylem araştırmasıdır. Araştırma süreci 5 haftalık, 10 saat olarak planlanmıştır. STEM eğitimi ve MTTFE üzerine çalışan uzman görüşleri alınarak, mühendislik tasarım sürecinin işlendiği MTTFE etkinlik planları hazırlanmıştır. Uygulama öncesi öğretmen adaylarına MTTFE süreci ve uygulamaya yönelik bilgiler verilmiştir. Uygulama süresince etkinlik planları yürütülmüştür. Uygulamanın sonunda öğretmen adaylarından sürece yönelik olumlu- olumsuz görüşlerini, uygulama konusunda önerilerini ve gelecekte öğretmenlik yaşantılarında kullanıp kullanmamaya yönelik gürüşlerini yazmaları istenmiştir ve 42 öğretmen adayından görüş alınmıştır. Veriler nitel veri analiz yöntemlerinden içerik analizi ile incelenmiştir. Yapılan araştırmada sonuçların geçerliğini sağlamak amacıyla ise veri analiz sürecini oluşturan kategorileştirme süreci detaylıca açıklanmaya çalışılmıştır.

Fen bilgisi öğretmen adayları genellikle mühendislik tasarım destekli fen eğitimine yönelik olumlu görüş sunarak gelecekte öğretmen olduklarında derslerinde uygulamayı istediklerini ifade etmişlerdir. Sürecin olumlu yönlerine ilişkin olarak araştırma sorgulamaya dayalı olduğu için süreçte uzun süre düşünmeleri gerektiğini, uygulamaların öğrenci merkezli olması, yaparak yaşayarak öğrenmeyi sağladığı, problem çözme, yaratıcı düşünme, eleştirel düşünme ve bilimsel süreç becerilerini geliştirmelerini sağladığı, grupla çalışmayı gerektirdiği için iletişim becerilerini geliştirdiği, salt bilgi değil probleme yönelik bilgi edinmeyi ve yaşamın farklı alanlarını da düşünmeye ittiği yönünde olumlu görüşler ileri sürmüşlerdir. Öğretmen adaylarının bu uygulamalara yönelik olumsuz düşünceleri veya önerileri ise, zaman planlanmasının ve yönetiminin zor olması, sınıf yönetiminin zor olması ve öğretmen açısından etkinlik hazırlamanın ve uygun problem tasarlamanın zor olması olarak tespit edilmiştir. Bununla birlikte öğretmen adaylarının birçoğu MTTFE etkinliklerini öğretmen olduklarında uygulamayı düşündüklerini belirtirken, etkinlik hazırlanmasının zor olması yönünde olumsuz görüş bildirenlerin ise uygulamada kararsız oldukları yönünde görüş bildirmişlerdir. Süreci uygulamaya yönelik olarak öğretmen adaylarının bir kısmı uygulama konusunda kendilerini yeterli buldukları için uygulamaya eğilimli olduğunu ifade ederken, öğretmen adaylarının diğer kısmı uygulama konusunda ülkenin eğitim sistemi, gerekli malzeme ve materyallerin temini, özellikle de sınıf yönetimi, sürecin sonunda öğrencinin değerlendirilmesi ve uygulamaya yönelik öz-yeterlilikleri konusunda kaygıları olduğu için uygulama konusunda tereddüt yaşadıklarını ifade etmişlerdir. Bu sonuçlarlar mevcut çalışmaları desteklemekle beraber, STEM eğitiminde fen eğitimine mühendisliğin entegrasyonunu sağlayacak mühendislik tasarım temelli fen eğitimi etkinliklerinin gerçekleştirildiği bu çalışmanın olumlu ve geliştirici dönütlerinin, bu konuda çalışma yapacak araştırmacılara, öğretmenlere ve program geliştiricilere yol gösterici olacağı düşünülmektedir.