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Pre-Service Science Teachers Views on STEM Materials and STEM Competition in Instructional Technologies and Material Development Course

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Abstract: This qualitative study was designed to introduce STEM (Science, Technology, Engineering, Mathematics) activities to pre-service science teachers and identify their views about STEM materials. In this context, a competition was organized with 42 pre-service science teachers (13 male- 29 female) who took Instructional Technologies and Material Development course in Elementary Science Education Department in Siirt University. The competition consisted of 5 categories: balloon powered car, mousetrap car, water rocket, spaghetti bridge 1 (durability) and spaghetti bridge 2 (visuality). Structured interview form developed by researchers was used as data collection instrument. The results were analyzed with the conventional content analysis. Results indicated that participants (especially females) are more willing to use STEM materials in their future teaching life. Participants mostly believe that STEM materials facilitate learning, enhance retention and increase self-confidence. However, there are also pre-service science teachers who believe that preparation of STEM materials is difficult, takes too much time and not appropriate to students' levels.

Keywords: *Pre-service science teachers, science demonstrations, science education, STEM education, STEM materials.*

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Introduction

STEM acronym simply refers to the four distinct fields that we know as science, technology, engineering, and mathematics. STEM education is an attempt to bring these fields together for a century. Moreover, STEM education should not be separated from the disciplines of social studies, arts, and humanities (Sanders, 2009). Students' interest and learning in STEM disciplines is critical to the long-lasting economic health of the countries. In other saying, the countries that have more qualified STEM professionals are globally more competitive (Lennon, Moriarty, & Zivkovic, 2014).

For the competition among the countries, reforms on technology education developed. Currently, while educational reforms on technology education have focused on technological design, the science education has focused on inquiry. Besides, inquiry based teaching rarely occurs in technology education, while technological design hardly occurs in science classrooms(Sanders, 2009).

The Essence of STEM Education

STEM applications are basically project-based learning that allows learners to explore real-world problems and challenges. For instance, designing a water rocket is a project-based learning that gives a chance to present engineering, physics, and problem solving methods in a way that students enjoy and understand. STEM challenges in schools allow students to use the principles that professional engineers use. Additionally, STEM materials let them to plan, design, and sometimes struggle to figure it all out. Students learn complex scientific concepts while being completely engaged in STEM challenges. Besides, they learn how to collaborate with their peers to solve problems and accomplish goals (Nesbitt, 2013).

Students become more excited and confident by using technology and engineering in combination with math and science (and even the arts) in STEM projects which make school subjects meaningful or pertinent. Besides, projects

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conducted under the STEM education can stimulate learners to gain a deeper understanding of the topics and inspire them to do quality work. Moreover, it enables students to bridge the classroom learning with everyday life and the external world (Forrester, 2013).By incorporating technology and engineering with math and science in STEM education, students gain opportunities to engage with topics that have meaning to trigger their ability to solve real-life problems (Barbato, 2013).

Literature review indicates that an integrative STEM education is seen as a remedy (1) to remain viable and competitive in the global economy (Akgunduz, 2016), (2) to increase achievement in STEM subjects(Han, Capraro, & Capraro, 2014; Jensen & Sjaastad, 2013), (3) to raise student interest and learning in STEM subjects(Nugent, Barker, Grandgenett, & Adamchuk, 2010), (4) to increase graduation rates and reduce dropout rates (Havice, 2013) and (5) to maintain scientific innovation (Rincon & George-Jackson, 2014). That is why; a grooving body of research in this arena has been conducted over the last two decades.

Nevertheless, the research has not influenced the policy makers and the curriculum developers as intended. Different countries have different educational systems which prevent STEM subject integration. For instance, in Turkey students and related teachers are in a race to pass high stake exams both at the end of middle school and high school required to have a better education in the next level. Accordingly, these conditions prevent teachers from integrating STEM related topics into their teaching.

Moreover, integration of STEM subjects require qualified teachers who are educated in all subjects effectively. However, teachers do not step up toward using STEM integration approaches in their classrooms because they are in need of guidelines or models regarding how to teach STEM integrated approaches (Wang, Moore, Roehrig, & Park, 2011).

Fast-changing education landscape of school systems happening around the world requires specialized STEM teacher preparation programs (Teo & Ke, 2014). One of the reasons why teachers confront challenges in a schools is the fact that they have not been trained to teach STEM or gifted students. At present in Turkey, teacher education programs are designed neither at universities to prepare pre-service teachers nor in in-service training courses specifically to teach only in specialized STEM schools.

Even though specialized STEM (science, technology, engineering and mathematics) schools have appeared elsewhere in the world, for example in the US and Singapore, they have not yet been considered in Turkey.

Integration of STEM into School Curricula

There are four possible ways to teach STEM in K–12 schools. One is to teach each of the four STEM disciplines in separate. In other words, teaching each discipline individually, as an independent subject with little or no integration with others. Another solution is to handle each of the four STEM disciplines with more importance going to one or two of the four. A third way is to incorporate one of the STEM subject into the others. A more complete solution is to defragment all four subject matters into each other and teach them as integrated disciplines. More research needs to be done as to which way or approach works better (Dugger, 2013).

Researchers need to establish which STEM applications are more effective and applicable. In this respect, with suggested STEM applications which infuse all four STEM subject matters, this study will have contributions to the literature regarding STEM education.

Science and mathematics have dominance in curricula of many countries. However, it is expected that future curricula will include both technology and engineering in their structures. Dependently, in-service teacher education programs will train teachers with related qualifications. Thus, curriculum developers cannot distinctly develop their own curriculum. An integrative and disconnected curriculum that requires cross-discipline collaboration should be explored and implemented alternative to traditional curricula.

STEM Applications

Action based and hands-on-activity learning is core to integrative STEM education (Havice, 2013). STEM applications in the classrooms promote the natural curiosity of students who learn best by doing and give the opportunity to teachers to integrate multiple subjects into singular tasks. Integrative STEM training is grounded on the principles of constructivism and the results of the developments in the cognitive science(Sanders, 2009). STEM challenges that combination of the design process with math and science is offering amazing environments for students to learn and innovate as well as to create and solve real life problems (Forrester, 2013). Experiential learning has continually been an essential part of STEM education, and hands-on activities which enable to tactile interactions with objects often contribute to students' learning in STEM disciplines (Lennon et al., 2014). STEM applications in the classrooms are intrinsically student-centered (Bransford, Brown, & Cocking, 2000), and when used with groups of students, they deliver a remarkably strong environment for the social collaboration, which is so crucial to the learning process.

STEM Studies

Han et al., (2014), in their study that took over three years, indicated that when project based learning was integrated into STEM education in schools, low performing students benefited much more than students with high and middle performance. Successful results were gathered when STEM challenges were introduced to at-risk students (Havice, 2103). STEM learning experience positively associates with students' interest in pursuing STEM disciplines in higher education (Chachashvili-Bolotin, Milner-Bolotin, & Lissitsa, 2016). STEM-related summer camps offer a chance for students to become more intensely involved in STEM activities (Nugent et al., 2010). Students participated in STEM engineering applications outperformed in the areas of conceptual knowledge, higher-order thinking skills, and the design project activity (Fan & Yu, 2015).

STEM Education in Turkey

Students in Turkey have usually had a poor performance in the programs for International Student Assessment. Students' mathematics and science achievements are below average compared to participating countries. Some recruitment efforts have been developed and implemented in order to improve students' achievements in international exams, however; none resulted as expected. For example, the curricula of all subjects have been reformed twice over the last decade, and schools have been equipped with interactive whiteboards (Balta & Duran, 2015). However, engineering and technology topics have not been integrated into the science and math curricula (Balta, Yerdelen-Damar & Carberry, in press). Besides, STEM applications have not been employed during teacher preparation in universities and in in-service teacher programs. On the other hand, some efforts can be seen as STEM project competitions. For example, Scientific and Technological Research Council of Turkey is now funding the schools which wish to conduct STEM exhibitions (TUBITAK, 2016). However, these efforts are not enough considering the students' population in Turkey (approximately 18 million students in K-12 schools). Moreover, in the last decade there has been an increase in the number of science centers in Turkey positive effects of which expected in the future.

In Turkey, successful students' (particularly those in the top thousand in the high stake national exam) interest in STEM fields decreased between the years 2000-2014. Besides, more male than female students were placed in engineering departments of universities among STEM fields (Akgunduz, 2016). One reason why students do not choose STEM fields is the insufficient regulation of the guidance offices in schools which can provide students a wide range of career information about all the available careers so that they can be able to explore widely before making their choices (Cavas, Cakiroglu, Cavas, & Ertepinar, 2011).

Science education research in Turkey on STEM interests, attitudes, and choices is trying to increase, but the efforts are not convincing. For instance, when compared to USA, researches related to STEM education in Turkey are rather limited (Akgunduz, 2016).

Limitations

This study is limited with:

1. Instructional Technologies and Material Development course content and participated students in Elementary Science Education Program of 2016 spring semester in Siirt University.

2. Data collection tool, and used materials; balloon powered car, mousetrap car, water rocket and spaghetti bridges.

Methodology

STEM Activities

A main question in this study was how the views of participants in a university were influenced using several STEM challenges. In this context, a competition was organized with pre-service science teachers who took Instructional Technologies and Material Development course at Elementary Science Education Department of Siirt University, Turkey. This competition contained 5 categories: balloon powered car, mousetrap car, water rocket, spaghetti bridge 1 (durability) and spaghetti bridge 2 (visuality). Figure 1 shows examples of materials from each category developed by participants.

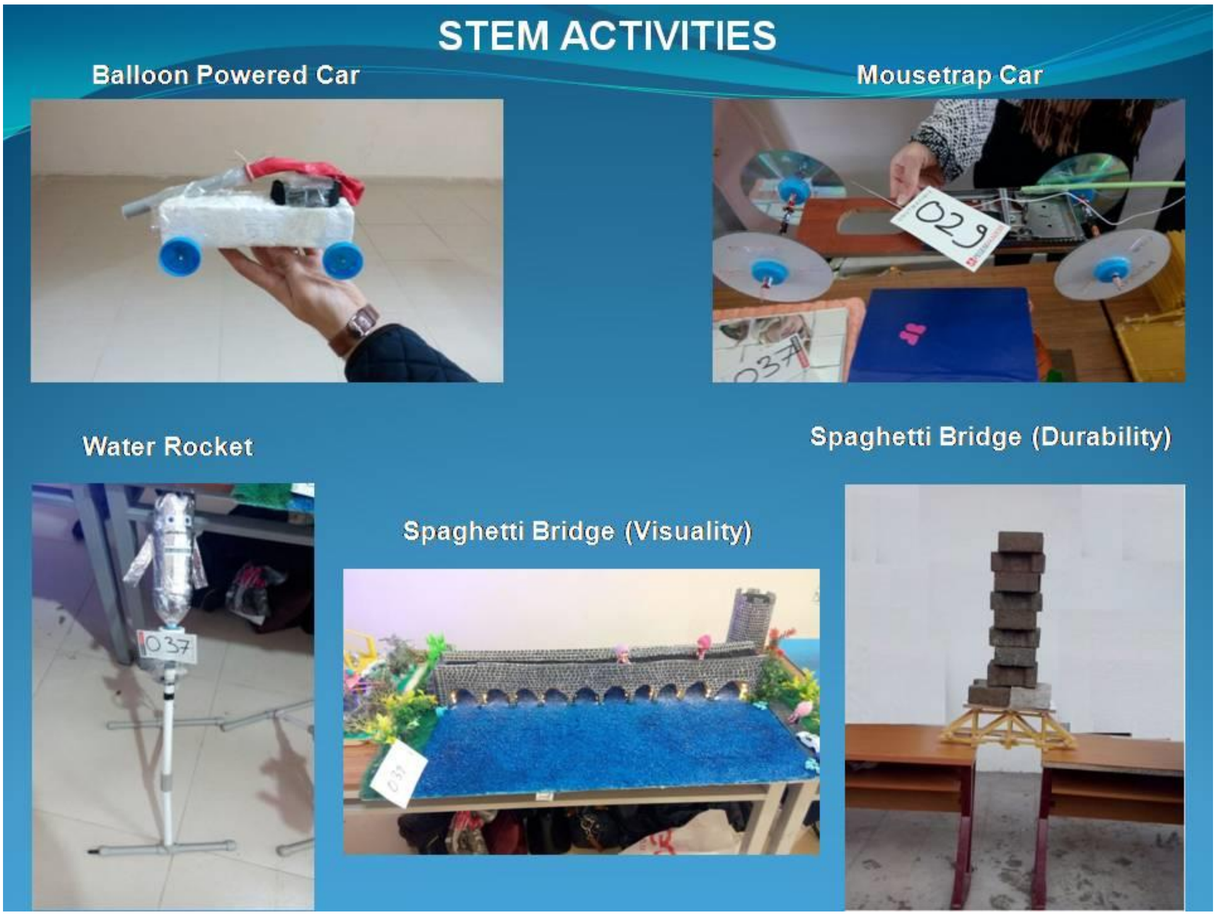

Figure 1. Examples of STEM Materials designed by participants

Balloon Powered Car

A balloon powered car is moving forward by air escaping from a balloon, and these cars can be easily built with materials you already have around your house (Finio, 2015).The objective of the competition was to design and build an original balloon powered car that can travel as far as possible.

The rules are: (1) The car has to work only by the air escaping from the balloon(s).(2) The car must have at least three wheels. (3) The car should not fly. (4)Participants can use at most three balloons. (5)Any type of the balloons can be selected. The balloons can only be filled with air. (6)They have to use hand-made cars. Besides; any type, any size and any shape of materials can be used in building the car. (7)They can use the wheels of ready toy cars if they prefer. (8)The participation is individual.

Mousetrap Car

Mousetrap cars are small mobile cars powered by an ordinary mousetrap to travel and aim to teach conservation of energy, torque, friction and mechanical energy (Klahr, Triona& Williams, 2006).The objective of the competition was to design and build an original mousetrap car that can travel as far as possible.

The rules are:(1)The car has to work only with the potential energy stored in a string of mousetrap.(2)Participants may use combination of mousetraps. (3)If they want they can use ready cars by adapting a mousetrap (car toys, models, etc). (4)Any type, any size and any shape of materials can be used. (5)The participation is individual.

Water Rocket

Water rockets are usually made with empty bottle by adding water and pressurizing it with air for launching and these rockets are used in schools to help students understand the principles of aeronautics (Mazza, 2015).The objective of the competition was to design and build a water rocket and throw it as high as possible.

The rules are: (1)The water rocket must work with air pressure. (2)The same pomp will be used by all participants to pressurize the rocket. (3)Participants will build and use their own launcher. (4) Each launcher should have a valve. (5) Any type, any size and any shape of materials can be used. (6) The participation is individual.

Spaghetti Bridge 1 (Durability)

Spaghetti Bridge is a good example to motivate students in the fields of physics, mathematics and engineering. Students must think of minimum and maximum span, height, width and position of load point (Gonzalez, Morsch&Masuero, 2005).The objective of the competition was to design and build a spaghetti bridge to carry maximum load.

The rules are: (1) The bridge must be built just using spaghetti and glue or silicon. The title of spaghetti is not important. (2) The bridge must be at least 40 cm length, 5 cm wide and 5 cm height. (3) The weight of the bridge must be between 750 g and 1000 g.

Spaghetti Bridge 2 (Visuality)

Similar to spaghetti bridge in the previous competition, in this case pre-service science teachers compete due to the visuality of spaghetti bridges. The objective of the competition is to design and build a spaghetti bridge that is most visual. The weight and length limitation is not used for this category. During the competition, pre-service science teacher exhibit their spaghetti bridges. Visitors voted each bridge and the bridge which got thegreatest point was selected as the winner.

After the competitions, pre-service science teacher answered open-ended questions. This research was conducted to address the following research questions:

1. What are the pre-service science teachers' views about STEM materials? Is there an effect of gender on pre-service science teachers' views?
2. What are the pre-service science teachers' views about STEM competition? Is there an effect of gender on pre-service science teachers' views?

Design

A qualitative research study was conducted to identify pre-service science teachers' views about STEM materials and the competition designed by these STEM materials. Qualitative research is useful for describing the perspectives of a participant group toward events, beliefs or practices (Gay & Airasian, 2000).

Participants

The study was carried out at Siirt University located in Siirt city of Turkey. The data was collected from 42 pre-service science teachers (13 male- 29 female) in their fifth semester of the program in the department of elementary science education. The pre-service teachers enrolled in Instructional Technologies and Material Development course participated in the study during 2016 spring semester. The objectives of this course are to introduce properties of some instructional technologies, to give information about the role and the use of these technologies in science and developing 2- and 3- dimensional teaching materials (Aran, Derman &Yagci, 2016).

Data Collection Procedure

Structured interview form developed by researchers was used during data collection process. The interview form includes two main open-ended questions These are:

1. You have prepared a 3-dimensional material for one of the projects of Instructional Technologies and Material Development course. Do you think you will use these materials in your future teaching life?

Yes	No

   a. If yes, what are the positive sides of these materials in science education?
   b. If not, what are the negative sides of these materials in science education?

2. You have participated in an exhibition/competition with these materials at the end of the course. Do you want to organize these kinds of activities in your future teaching life?

Yes	No

   a. If yes, what are the positive sides of these activities?
   b. If no, what are the negative sides of these activities?

Data Analysis

The conventional content analysis was used to analyze the answers of pre-service science teachers. In this analysis, coding categories are derived directly from the text data (Hsieh & Sahnnon, 2005). Texts were read word by word to derive codes to capture key thoughts or concepts. Response frequencies and percentages were calculated for each category. Some participants gave more than one answer for the same questions, so some tables contain greater number of responses than the number of participants.

Results

The first question was related to whether pre-service science teachers think to use STEM materials in their future teaching life. Of the 42 participants 35 supplied answers as "yes" and 7 replied as "no". This shows that most of the students want to use these materials and think positive about STEM materials. Students' answers related to this question are represented in Table 1.

Table 1. Pre-service science teachers' answers to the first question

		Female	%	Male	%
Do you think you can use these materials in your future teaching life?	Yes	25	86	10	77
	No	4	14	3	23
	Total	29		13	

Chi Square=.557; df=1 ; *p*=.455

Table 2. Codes for positive and negative perceptions about STEM materials

Positive Sides	f	%	Negative Sides	f	%
Facilitates learning	14	12	Too much time	4	21
Enhance retention	10	8	Not appropriate to students' level	3	16
Self-confidence	8	7	Difficult to prepare	3	16
Handicraft	8	7	Difficult to understand	3	16
Concretization	5	4	Not connected to science	2	10
Different ideas	5	4	Not appropriate for crowded classes	1	5
Imagination	4	3			
Visual	4	3			
Funny	4	3			

Note. f represents the number of repetition of each code

According to Table 1, 86% of females and 77% of males think that they can use STEM materials in their future teaching life, while 14% of females and 23% of males think they cannot use them. In other words, females and males mostly believe these STEM materials are useful. Chi-square test is not significant, so there is no significant difference between males and females views about the use of STEM materials in their future life.

The pre-service teachers who think to use these materials in their future life, created 113 codes about positive sides of these materials for science education and those who do not think to use them, created 19 codes about negative sides. The mostly used codes are given in Table 2 with their percentages.

According to Table 2, pre-service science teachers mostly think that STEM materials facilitate learning, enhance retention and increase self-confidence. Small number of students think negatively about STEM materials and believe that the preparation of STEM materials take too much time, and are not appropriate to students' levels and are difficult to prepare and understand.

Some examples of responses related to the first question as follows:

- "I can prepare a water rocket to show projectile motion; balloon car to explain potential and kinetic energy, mousetrap car to show how an object can start to move (Positive - Facilitates learning- Participant 19)."
- "By using the visual dimension of these materials, the knowledge can stay longer in students' mind (Positive - Enhance Retention - Participant 9)."
- "These materials can increase curiosity of students towards science. This curiosity might enable students to become future inventors(Positive- Self-confidence - Participant 24)."
- "Preparing these materials need too much time and effort (Negative- Too much time -Participant 36)."
- "These materials may be helpful for science lesson, but I think that they are not appropriate for students'ages. We made these materials at the university level and faced with a lot of challenges. I believe that the students may not

make a connection between materials and the subject (Negative – not appropriate to students' level - Participant 12). "

As a result of the first question, we may conclude that pre-service science teachers mainly think positive about STEM materials. They mostly agree that these materials facilitate learning, enhance retention, increase self-confidence levels of students, develop their psycho-motor skills, and give a chance to see their friends' ideas. The pre-service science teachers who think negative about these materials mostly agree that preparing these materials take too much time, they are not appropriate for students' levels are difficult to prepare and difficult to understand.

The second question was related to whether pre-service science teachers wanted to organize competition with STEM materials in their future teaching life. 40of them answered "yes" and 2 answered "no". This shows that most of the participant teacherswant to organize these kinds of activities. Participants' answers to this question are represented in Table 3.

Table 3. Pre-service Science Teachers' Answers to Second Question

		Female	%	Male	%
Do you want to organize these kinds of activities in your future teaching life?	Yes	28	97	12	92
	No	1	3	1	8
	Total	29		13	

Chi Square=.356; df=1 ; p=.550

According to Table 3, 97% of females and 92% of males are willing to organize a competition by using STEM materials in their future teaching life while 3% of females and 8% of males think they cannot make such an organization. Chi-square test is not significant so there is no significant difference between males and females. As a result, both females and males are mostly willing to organize exhibitions/competitions in their schools in the future.

The pre-service teachers who think of organizing these activities in their future life, created 137 codes about positive sides of them and those, who do not think of using, created just 4 codes about negative sides. Most used codes are given in Table 4 with their percentages. Negative codes are not represented in Table 4.

According to Table 4, pre-service science teachers mostly think that activities designed by STEM materials increase socialization and self-confidence levels of students. Similarly, they think that these kinds of activities are funny and motivate students towards lesson. For negative sides, just 4 codes were created; competing, difficult, much time and effort.

Table 4. Codes for positive sides of activities designed with STEM materials

	f	%
Socialization	20	15
Self Confidence	14	10
Funny	14	10
Motivation	8	6
Facilitate Learning	6	4
Retention	6	4
Responsibility	5	4

Note. f represents the number of repetition of each code

Participants' responses about the activities designed with STEM materials are listed below:

- "We saw the evidence of a saying "two head is better than one head" (Positive – Socialization -Participant 5).
- "Prejudices towards some people can be eliminated. I find how amiable the girl I found irritating before was" (Positive – Socialization -Participant 41)."
- Students' self-confidence is raised when teachers and friends like and appreciate course materials prepared by the student (Positive – Self-confidence -Participant 31).
- "Students can say that "when I want, I can do" (Positive – Self-confidence -Participant 28)."
- "These kinds of activities should not include competitions absolutely because when students participate in such a competition, they may face psychological problems and fear of being in the shadow of their friends. (Negative–Infighting–Participant 8)"
- "I think that organizing these activities takes too much time and effort (Negative– Too much time –Participant 7)."

As a result of the second question, we may conclude that pre-service science teachers mostly think of the positive sides of activities designed by STEM materials. They mostly agree that these activities increase socialization among students and other people around them, increase self confidence levels and motivation. They are funny activities, facilitate learning and enhance retention. The pre-service science teachers who think negative sides of activities believe that these activities take too much time and effort, additionally they create a competing environment which may result in psychological problems on participants.

Discussion and Implications

The purpose of this study was to reveal pre-service science teachers' views on STEM activities. This research also enabled an exploration of pre-service science teachers' views on STEM exhibitions/competitions. Initially, STEM activities were prepared by students, then students presented their talents through competitions and finally an interview form was applied to collect data.

Findings indicate that preparing STEM activities and having competitions with these activities have affected participants' views of STEM applications. Accordingly, this study has prompted the positive views of pre-service science teachers. Positive social experiences with STEM activities have indicated that teacher candidates will use STEM applications in their classrooms in the future and conduct similar competitions. Moreover, teachers' views did not significantly differ across gender.

By preparing the STEM activities, teacher candidates became acquainted with the functions of different apparatuses, and they allowed them to acquire practical skills and hands-on-activity experiences. Therefore, the activities helped pre-service teachers to become familiar with STEM applications which accordingly increased their interest on conduction of these activities.

Among OECD countries Turkey is one of the growing countries. Since developed countries, for instance USA, are giving a special importance to STEM education (Rincon & George-Jackson, 2014), Turkey has to imitate these countries for its future. Students' STEM related carrier choices are decreasing in Turkey (Akgunduz, 2016). Use of these activities in their teaching by teachers can affect students' decisions (Anderson-Rowland, Banks, Zerby& Chain, 2005).

Even though the engineering-related objectives are very rare in Turkish high school curriculum in STEM fields, sooner or later, this condition will change because STEM education is a remedy to remain viable and competitive in the global economy (Akgunduz, 2016). Before the curriculum renew, teachers should be prepared previously for STEM activities and activities done by students in this study are expected to be examples for STEM applications.

This study implies that when teachers are educated for STEM applications, they gain self confidence in conducting similar activities in their classes. We strongly suggest the in-service teacher training programs to include STEM activities. Teachers' use of STEM activities in schools may raise the possibility of a choice of STEM (Lyons & Quinn, 2010). As the research base in STEM education grows and improve, through the views and practices of pre-service science teachers, our study will help to design effective teacher professional development programs or in-service training programs.

STEM activities, in this study, were conducted with pre-service science teachers during their education in university. Since teachers in traditional teaching did not prompt students' attention to STEM subjects (Sahin, 2009), the familiarity of teachers with STEM applications at early years might encourage them to design STEM activities and competitions.

The excess of positive factors identified through qualitative analysis of students' responses in this study is a sufficient evidence to conduct STEM activities in schools. In Turkey, the STEM education took place at middle school level in "science and technology" lesson between 2004 and 2013. Currently, it is integrated to "life science" lesson at middle school. However, there is no STEM education at high school level and students usually decide about their carrier at high school. Thus, based on teachers' views in this study, we suggest the STEM education must address not only the middle school, but the high school as well.

This study contributes to a developing knowledge base of the views about STEM education held by pre-service science teachers. By presenting teachers' views we aim to contribute to the wide-scale efforts currently in place to expand and improve STEM education. As a consequence, responses received from students with interview forms indicated that the STEM activities and competitions played important roles in improving pre-service teachers' views toward STEM.

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