The Effect of STEM Instruction on Attitude, Career Perception and Career Interest in a Problem-based Learning Environment and Student Opinions

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Abstract

Many researchers argue that science, technology, engineering and math (STEM) instruction contribute to the national economy and educators attempt to develop integrated instructional programs. In the current study, the effect of a problem-based STEM activity on students' attitudes, career perceptions and career interests was investigated by using both qualitative and quantitative methods. The participants are 22 students attending a state secondary school in Turkey. Before and after the implementation of the problem-based learning (PBL) activity, the Student Attitudes toward STEM Scale was used to investigate the students' attitudes towards STEM and also the STEM Semantic Survey for Career Interest and STEM Career Interest Scale were applied to investigate their career interests. Following the application, a semi-structured interview form was used to determine students' opinions about problem-based STEM activities. The findings revealed that the students' attitudes towards STEM disciplines, STEM career interests in STEM-related occupations significantly increased. The students' interests particularly in the occupations related to engineering and technology were found to have considerably increased. The students' interview results also support these findings. During their interviews, the students stated that problem-based STEM instruction is effective in their learning and also it helps to develop their skills of the 21st century, makes the class more enjoyable, increases their interest in the profession of engineering and helps them to select their future career. As a result, integration of PBL with STEM positively affects students' attitudes and career perceptions that are in the pursuit of their future career.

Key words: STEM, problem based learning, science education

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Introduction

The 21st century is a technology age and in this age science, technology, engineering and mathematics (STEM) education play an important role in shaping the culture and economic development with a viewpoint of innovativeness, creativity and problem solving (Cooper & Heaverlo, 2013). In America STEM has become a governmental policy (States National Academy of Engineering [NAE], 2010; National Research Council [NRC], 2012). In many European countries, interest in STEM disciplines and STEM instruction has considerably increased (Corlu, Capraro & Capraro, 2014). The Far Eastern countries such as China, Korea and Taiwan have been working to develop the K-12 STEM curriculum, which is designed as "integrative cross-disciplinary approaches within each STEM subjects" (Fan & Ritz, 2014, p.8). Reports issued in Turkey emphasize the importance of reform-based education policies to be developed on the basis of the need for the enhancement of knowledge and skills required to provide better STEM instruction for students and to improve STEM labor (Ministry of National Education of Turkey [MoNE], 2009). Though the research on STEM is in its infancy period in Turkey, some preliminary studies have already yielded positive outcomes. Yamak, Bulut and Dündar (2014) stated that STEM-based activities positively affect the students' scientific process skills and attitudes towards science. Yıldırım and Altun (2015) reported that engineering applications conducted within STEM instruction are effective in enhancing students' achievement. Gülhan and Şahin (2016) stated that STEM activities enhance the fifth grade students' conceptual understanding in the field of science, developed their interest in engineering and their interest in STEM-related occupations.

Owing to the benefits of STEM instruction on the national economy, teachers and educational institutions have been working hard to achieve the desired level of integration between STEM and science education (David & Sharon 2006; Tseng et al., 2013). Dewaters (2006) pointed out that students welcome STEM courses and such courses help students solve their daily problems. These courses and programs help them to gain awareness of meaningful learning by systematically integrating information, concepts and skills. STEM courses and programs can increase students' competences for STEM-related occupations and allow scientific and engineering works to be understood better (Tseng et al., 2013).

In the current study, the secondary school students were given scenarios which contain engineering problems. Students are asked to solve the problem with use of scientific and mathematical methods. Through integrating science, technology, engineering and mathematics into a problem-based learning pedagogy, it is aimed to enhance students' attitudes towards STEM disciplines and to improve students' STEM career interest. To this end, research problems were formed. Do the students' existing attitudes towards STEM disciplines vary significantly after PBL activities? Do the students' career perceptions vary significantly after PBL activities? What are the frequencies related to the students' interest in STEM-related occupations before and after the implementation of PBL activities? What are the students' opinions about the problem-based STEM activities?

Problem based learning (PBL) strategy in STEM instruction

STEM instruction is defined as an educational system creating connections the disciplines which are science, technology, engineering and mathematics and application-oriented approaches (Bybee, 2010). In general terms, STEM education refers to the integration of the STEM disciplines with the content of a problem encountered in daily life to solve the problem. STEM education provides opportunities for students to be able to solve problems, to be innovators, inventors, self-confident, logical thinkers and technologically literate (Morrison, 2006; Stohlman et al., 2011). While integrated STEM education is an attempt to combine these four disciplines with connections established between topics and real-world problems, it does not always have to involve all these four disciplines. Engineering is becoming more widespread in K-12 schools and can offer students the opportunity to solve problems in the fields of mathematics, science and technology while they work through the design process (Stohlman et al., 2011).

The STEM disciplines have shifted from a traditional teaching method to a student-centered teaching, such as problem-based learning (Lattuca et al., 2006). This shift triggers the desire to create an environment for the development of skills such as communication, teamwork, high-level thinking and problem solving that are necessary for future engineers (NAE, 2005). Problem solving, creativity and design are defined as the basic skills in STEM development of students (Baine, 2009). Problem Based Learning, developed and used in medical faculties, has become increasingly popular in K-12 and higher education (Hunt, LockewoodCooke, & Kelley, 2010; Hmelo-Silver, 2004). PBL method also has been successfully used in STEM programs (Davis, Lockwood-Cooke & Hunt, 2011; Hunt, LockewoodCooke, & Kelley, 2010).

PBL is a process in which studies following a learning cycle model for understanding or resolving a problem are carried out. The cycle starts with defining the problem. It goes on with determining the learning topics, working individual or with small group, applying the learning and reformulating the problem. PBL is well suited for engineering and other STEM disciplines because it helps students develop skills and confidence to solve real-life problems they have never encountered before (Bransford, Vye & Bateman, 2002).

It is not possible to talk about a series of fixed and definite steps in the PBL application process. Therefore, researchers have proposed different steps to reflect the characteristic structure of the PBL process (Stepien, Gallagher & Workman, 1993; Hmelo-Silver, 2004; Hung, 2009). In the current study, by drawing on the existing literature, a PBL process integrated with STEM was operated by following the five stages explained below:

1. *Identification of the problem:* The problem is presented in the form of a scenario or an engineering problem is directly presented. By asking appropriate questions to students about the problem statement, they are allowed to gain insights about the problem. Sub-problems are determined. By means of brainstorming, what is already known about the problem and what should be known about it are elicited. Meanwhile, prior knowledge is associated with the new topic.
2. *Collection of the necessary data:* This stage includes conducting research about what should be learned to find a solution to the problem and collection of information and sources.
3. *Research stage:* This is the stage in which students initiate their own learning processes to present (produce) the possible solutions to the problem. This stage serves as a bridge between knowledge and discovery for creative solutions to an engineering problem. It involves active processes such as forming hypotheses for the solution of the problem, planning and conducting experiments to test the hypotheses (determining variables, tools and equipment).
4. *Transferring and designing:* This is the stage in which engineering design is formed with considering the results obtained in the previous stage. It includes producing ideas for a solution to the problem by means of brainstorming, selecting the most ideal idea, schematizing it, determining necessary tools and equipment and conditions, creating and testing the design.
5. *Communication:* It includes the activities of producing ideas to improve the design, developing the design in line with these ideas and retesting. In this stage, groups present their designs in the learning environment and discuss what should be done to improve the design.

Method

In this mixed-approach study, the single-group pretest-posttest experimental design was used. In line with the mixed-approach method, both qualitative and quantitative data were collected in a single study and then they were analyzed (Creswell, 2003). In mixed methods approach, multiple data sources including surveys and interviews are used to establish validity (Lincoln & Guba, 2000). In order to research the quantitative dimensions of the study, before and after the study, Student Attitudes toward STEM Scale, The STEM Semantic Survey for Career Interest, and STEM Career Interest Scale (Table 1) were employed.

Table 1: Single Group Pretest-Posttest Experimental Design

Pre-test	Application	Post-test
Student Attitudes toward STEM Scale The STEM Semantic Survey for Career Interest STEM Career Interest Scale	Problem Based STEM	Student Attitudes toward STEM Scale The STEM Semantic Survey for Career Interest STEM Career Interest Scale **S**TEM Interview Form

In the qualitative dimension of the study, a semi-structured interview form was conducted after students were given the posttest to explore their opinions about the problem-based STEM activities.

The researcher carried out 5 PBL activities within the "Science Applications Course" in a period of three hours per week for 8 weeks. In compliance with the 5th grade science curriculum, the activities were conducted on the topics of force, friction force, heat, light and electricity. Each of the activities which are the friction force, the reflection of light and mirrors and the alarm system lasted two weeks.

The learning objectives and the brief STEM with PBL activities are given in Table 2. Each activity begins with a scenario in which students experience real-life problems (Appendix A: Scenario of Ahmet's village adventure). In the scenario, different engineering fields are mentioned and in this context different engineering branches are introduced. Students apply the 5-step PBL implementation process in order to solve engineering problem. In this process, the students identify the problem, collect the necessary information for solution, and solve the problem by determining the hypothesis and planning the experiment. Taking the results of the experiment into consideration, the students make a design for solving the problem and develop the design by creative ideas (Appendix B: Example of student work).

Sampling

In the study, convenience sampling method; one of the purposive sampling methods, was used (Yıldırım & Şimşek, 2011). In this regard, the study was conducted with the 5th grade students in a state school in the city of Ankara having the suitable laboratory facilities and technological infrastructure and whose classroom sizes are suitable for STEM activities. Of the 22 students participating in the study, 10 are females and 12 are males.

Data Collection Tools and Analysis

In the quantitative part of the study, Student Attitudes toward STEM scale, The STEM Semantic Survey for Career Interest, and STEM Career Interest Scale were used as pretest and posttest.

Student Attitudes toward STEM developed by Faber et al. (2013) and adapted to Turkish by Yıldırım and Selvi (2015) was used. The scale is a five-point Likert scale. This scale containing 37 items has a four-factor structure. The mathematics section of the scale consists of 8 items, the science section consists of 9 items, the engineering and technology section consists of 9 items and the 21st century skills section consists of 11 items. As a result of the adaptation study, it was found that the Turkish version of the scale has a four-factor structure as in the its original form (χ^2/df = 4.72; RMSEA=0.063, SRMR=0.053, CFI=0.96, GFI=0.87). The Cronbach Alpha reliability coefficient for the whole scale was found to be 0.94. For the sub-dimensions of the scale, the reliability coefficients were found to be ranging from 0.86 and 0.89.

The STEM Semantic Survey for Career Interest was developed by Tyler-Wood, Knezek and Christensen (2010) to evaluate students' perceptions about a STEM career. The scale has five item and the items are rated on 7-point Likert type scale. The scale was adapted to Turkish by Yerdelen, Kahraman and Taş (2016). As a result of the adaptation study, Cronbach alpha was found to be .75, indicating sufficient internal consistency of the scores. Five adjective pairs based on a 7-point response scale. Last three items were reverse coded. Students were asked to rate their response on the 7-point likert scale between the related adjective pairs to state the degree of their interest in STEM careers.

Another scale used in the current study is STEM Career Interest Scale. The scale was developed by using the STEM occupations categorized by Milner, Horan and Tracey (2013). This five-item scale is in the form of a four-point Likert scale with answer alternatives ranging from, "It does not interest me at all" (1), "It does not interest me" (2), "It interests me" (3), "It interests me a lot" (4). Each item in the scale represents a different discipline. In order to facilitate interpretation, "It does not interest me at all" and "It does not interest me" options are subsumed under a single heading "not interested" and "It interests me" and "It interests me a lot" options are subsumed under the heading "interested".

The STEM occupations in the scale are;

1. Physics sciences (astronaut, atmosphere and space scientist, biochemists/biophysicists, chemist, ecologist, geologist, physicist)
2. Life sciences (agriculture and food scientist, veterinarian, biologist, microbiologist, pharmacist, nurse, doctor and laboratory technician),
3. Technology (computer and security specialist, software engineer, computer programmer, database specialist, graphic designer),
4. Engineering (space engineer, architect, biomedical engineer, chemistry engineer, computer hardware engineer, electricity engineer, industry engineer, machine engineer),
5. Mathematics (mathematician, accountant, statistician, finance officer)

In the quantitative part of the study, The Wilcoxon signed rank test; one of the nonparametric tests, was used to test whether there was a significant difference in the students' STEM attitudes and career interests before and after the application.

In the qualitative part of the study, in order to elicit the students' opinions about the problem-based STEM activities, "The STEM Interview Form" (Appendix C) was conducted by the researcher after the STEM activities. The form consisted of 6 open ended questions. The data collected through the interview form was subjected to the content analysis. All of the forms were given a number and each form was evaluated at least twice by two independent researchers. One of the researchers is a master student in science education, the other one is a professor whose field of study is STEM and technology based science education. Firstly, all of the data was coded by the researchers according to primary theoretical concept. Secondly, each of the themes was created with the codes representing

Tablo2: Learning objectives and the brief STEM with PBL activities of each lesson

Problem Based STEM Activities	**Learning objectives**	**Science**	**Mathematics**	**Engineering**	**Technology**
Heat-insulated container: *"Ayşe's ice-cream is melting."*	• Realize that science and engineering are closely related. • Realize that the engineering design process consists of steps that can be used to solve problems. • Classify the items in terms of heat conduction. • Determines the criteria for selection of heat insulation materials used in buildings. • Develop alternative heat insulation materials.	Heat, temperature, heat insulation, insulation materials	Calculating temperature change Measuring and recording temperature change with thermometer.	Design and application of heat insulated container (Energy Systems Engineering)	Selection, usability and cost of insulation materials
Alarm system: *"Ahmet's village adventure"*	• Recognize that electrical engineers use their creativity with science and mathematics knowledge to solve their problems. • Show elements of an electric circuit with symbols. • Build the diagram of the electrical circuit which is drawn. • Grasp the schematic diagrams, the "circuit language," and their importance in the electrical engineering. • Explain that the energy can be transformed from one form to another.	Simple electrical circuits, installation of circuits, circuit elements and symbols, circuit diagrams, transformation of electrical energy	Determine the distances between the masses. Identifying the center of gravity.	Designing and implementing warning system with electric circuits (Electrical Engineering)	Selection, usability and cost of materials used in the system to be designed
Reflection of light and mirrors: "Ali's Hide and Seek Game"	• Realize that optical engineers use science and mathematics to solve their problems. • Express the properties of the image in the plane mirror. • Draw the reflections of the light on the smooth and rough surfaces according to observations. • Explain the relation between the light coming from the light reflection, the reflected light and the surface normal.	Reflection in plane, mirror and image	Measuring the angle of reflection of parallel rays in the mirror with an angle meter. Associating with the laws of reflection angles with math subject, angle.	Designing and implementing warning system with electric circuits (Electrical Engineering)	Selection, usability and cost of materials to be used in periscope design,
Force measurement: "Rope pulling game"	• Produce possible solutions for the problem and chooses the appropriate one within the criteria. • Measure the size of the force with a dynamometer and expresses its size.	Force, magnitude of force, dynamometer	Using mathematical operations in force calculation. Recognizing measurement units and using them in mathematical operations.	Designing a tool to measure force (Materials Engineering)	Selection, usability and cost of material to be used in force meter design
Friction force and motion: "Escape ramp"	• Give examples from daily life to friction force. • Develop problem solving, teamwork, communication and creative thinking skills while working with engineering design challenges. • Explore the effect of friction on the motion in various environments. • Produce new ideas for increasing or reducing friction in everyday life.	Motion, friction force and effect of friction force on motion	Data collection, applying related mathematical operations	Designing and implementing a ramp to observe the effect of friction on motion (Road Engineering)	Selection of materials with different friction coefficients, usefulness and cost for problem solving

same dimension of the analysis and also great care was taken to make sure that each theme didn't overlap each other. Thirdly, the reliability of coefficient of the coding process was calculated. The reliability of the data set was calculated by using Miles and Huberman's (1994: 64) formula and found to be 87%. When Miles & Huberman reliability coefficient is over 70%, then it is considered to be reliable for the study (Miles & Huberman, 1994). Finally, the conflicts in categorization were discussed until reaching an agreement. In this way, main themes, sub-themes and codes were determined.

In the current study the identities of the students are kept confidential. The female students are given the code 'K' and the male students are given the code 'E' and they are named as K1, K2, E1, E2 so on. Direct quotations were also made from the responses of the students to the interview questions.

Results

The present study investigated the changes in the students' attitudes toward STEM disciplines and perceptions of STEM careers as a result of a PBL activity. Moreover, the students' opinions about the PBL activity integrated with STEM were also elicited and analyzed.

Wilcoxon signed rank test, one of the nonparametric tests, was conducted to determine whether the students' attitudes towards STEM varied significantly after the implementation since the test scores didn't have normal distribution. As a result of the analysis, it was found that there is a significant difference between the students' STEM attitude scores taken before and after the application (z=2.61, p<,01). When the mean rank and total scores are considered, it is seen that this difference is in favor of the posttest score. Thus, it can be contended that the PBL activity had a significant contribution to the development of the students' attitudes towards STEM. In order to determine whether there are significant differences between the students' mean scores taken from the sub-dimensions of the Student Attitudes toward STEM Scale before and after the application, Wilcoxon signed rank test was conducted for all the sub-dimensions (Table 3).

Table 3: Wilcoxon Signed Rank Test Results concerning the Students' Pretest and Posttest Attitude Scores towards STEM

	Posttest-Pretest	n	Mean Rank	Rank Sum	z	p
General attitude	Negative Rank	4	11.50	46.00	2.61	0.009
	Positive Rank	18	11.50	207.00		
	Equal	0	-	-		
21st century skills	Negative Rank	6	9.17	55.00	2.10	0.035
	Positive Rank	15	11.73	176.00		
	Equal	1	-	-		
Engineering	Negative Rank	5	6.30	31.50	2.92	0.003
	Positive Rank	16	12.47	199.50		
	Equal	1	-	-		
Mathematics	Negative Rank	5	13.80	69.00	0.72	0.472
	Positive Rank	13	7.85	102.00		
	Equal	4	-	-		
Science	Negative Rank	5	9.20	46.00	1.97	0.048
	Positive Rank	14	10.29	144.00		
	Equal	3	-	-		

The data in Table 3 revealed that there are significant differences between the students' pretest and posttest attitude scores for the 21st century skills, engineering and science. When the mean rank and total scores are considered, it is seen that this difference is in favor of the posttest score. However, no significant difference was found between the students' math attitude pretest and posttest scores. Thus, it can be argued that the PBL activity integrated with STEM had positive effects on the attitudes towards the 21st century skills, engineering and science but not on the attitudes towards mathematics.

The Wilcoxon signed rank test results concerning whether the students' career perceptions varied significantly after the application is presented in Table 4. The results of the analysis show that there is a significant difference between the students' pretest and posttest scores taken from the Career Perception test, $z=3.68$, $p<.05$. When the rank mean and sum of the difference scores are taken into consideration, it is seen that this difference is in favor or the posttest score. In light of these results, it can be maintained that the STEM-integrated PBL activity conducted in the current study had a significant effect on the development of the students' career perceptions.

Table 4
Wilcoxon Signed Rank Test Results of the Career Perception Scores

Posttest-Pretest	n	Mean Rank	Rank Sum	z	p
Negative rank	2	6.50	13.00	3.68	0.000
Positive rank	20	12.00	240.00		
Equal	0	-	-		

z scores based on negative ranks

The students' frequency values related to their interest in STEM-related occupations are given in Table 5. The results show that while the ratio of the students stating that they are interested in physics sciences (astronaut, atmosphere and space scientist, biochemist/biophysicist, chemist, ecologist, geologist, physicist) was 45.5% in the pretest, it became 86.4% in the posttest. As a result of the application, interest in physics sciences increased. While the ratio of the students stating that they are interested in life sciences (agriculture and food scientist, veterinarian, biologist, microbiologist, pharmacist, nurse, doctor and laboratory technician) was 68.2% before the application, it dropped to 59.1% after the application. While the ratio of students stating that they are interested in technology (computer and security specialist, software engineer, computer programmer, database specialist, graphic designer) was 45.5% in the pretest, it rose to 90.9% in the posttest. While the ratio of the students stating that they are interested in engineering (space engineer, architect, biomedical engineer, chemistry engineer, computer hardware engineer, electricity engineer, industry engineer, machine engineer) was 40.9% in the pretest, it became 90.9% in the posttest. Finally, while the ratio of students stating that they are interested in mathematics (mathematician, accountant, statistician, finance officer) was 54.5% in the pretest, it became 68.1% in the posttest.

Before the application, the occupations most preferred by the students were life sciences-related occupations (68.2%) such as agriculture and food scientist, veterinarian, biologist, microbiologist, pharmacist, nurse, doctor and laboratory technician. They were followed by mathematics-related occupations such as mathematician, accountant, statistician, finance officer. The ratios of physics sciences-related occupations and technology and engineering-related occupations were very close to each other. As a result of the application of the STEM integrated PBL activity, the occupations the students were most interested in became technology and engineering-related occupations with 90.9% (Table 5). Following the application, students became more interested in careers related to STEM disciplines.

Table 5: Students' Interest Ratios for Occupations relate STEM Careers

Field	Pretest		Posttest	
	Interested	Not interested	Interested	Not interested
Physics sciences	% 45.5	% 54.5	% 86.4	% 13.6
Life sciences	% 68.2	% 31.8	% 59.1	% 40.9
Technology	% 45.5	% 54.5	% 90.9	% 9.1
Engineering	% 40.9	% 59.1	% 90.9	% 9.1
Mathematics	% 54.5	% 45.5	% 68.1	% 31.8

Students' Opinions about the STEM-integrated PBL Activities

The students' opinions about the PBL activities including STEM disciplines were evaluated by means of the content analysis and were gathered under two themes; *Learning effect of STEM education* and *difficulties in STEM education* (Table 6). Sub-themes and codes related to these themes were determined and they were interpreted by making direct quotations from students' statements.

Table 6: Themes and sub-themes related to the students' opinions about the PBL activities combined with STEM disciplines

Main theme	Sub-theme
Learning effect of STEM education	Skill development
	Enhancement of knowledge
	Attitude and motivational orientation
	Innovations
Difficulties in STEM education	Difficulties related to the activity
	Difficulties related skill and knowledge

When the student opinions were evaluated, STEM education carried out through the PBL activities was found to be effective in the areas of knowledge, skills and affective learning. Students' positive opinions in this regard were categorized under the main theme of "*Learning effect of STEM instruction*" in such a way as to create the sub-themes of "*skill development*", "*enhancement of knowledge"*, "*attitude", "motivational orientation*" and "*innovations*" and the codes are given in Table 7.

Table 7: Sub-themes and codes formed under the main theme of learning effect of STEM instruction

Main theme	Sub-theme	Codes	Frequency (f)
Learning effect of STEM education	Skill development	Team work	11
		Problem solving skill	10
		Cooperation skill	9
		Hand skill	8
		Creativity skill	6
		Imagination skill	3
		Thinking skill	2
		Critical thinking skill	1
		Leadership skill	1
	Enhancement of knowledge	More permanent	8
		Enjoyable learning	6

	Effective learning	5
	Reification	5
	Internalization	5
	Learning by doing and experiencing	4
	Relating to the daily life	3
	Instructive	2
	Reinforcement of subjects	2
	Active participation	2
Attitude and motivational orientation	Enjoying activity	19
	Having pleasure	10
	Interest in the course	8
	Investing efforts for an engineering product	7
	Interest in engineering profession	5
	Liking an engineering product	5
Innovations	Creating an engineering product	10
	Designing	9
	Take the role of an engineer	8
	Problem solving	4
	Creating connections among disciplines	2

When the students' responses to the question '*Which skills do you think can be developed through STEM instruction? Please explain how?* were analyzed, many students stated that through STEM education, problem solving, cooperation and creative skills and 21st century skills could be developed. In this connection, some students' opinions are as follows; *'Our helping us by using different skills; that is team work* ' (K9), '*We conducted each experiment via team work. We cooperated to solve the problem'* (E4), '*It might have developed our hand skills, imagination, thinking because throughout the activity we thought, designed and created*' (E2), '*While doing the activities, we disputed but at the end we were able to cooperate to finish the activities. We thought what we would do, our imagination developed; that is, we invented something'* (E12), '*It enhanced problem solving, cooperating skills and our imagination because we found solutions to problems and modeled'* (K3).

All of the students positively responded to the question *'Do you want such activities to be incorporated into your science classes? Why?'* The reasons stated by the students for their wanting such activities were gathered under the theme of "*enhancement of knowledge*". When the students' opinions were evaluated in this regard, it was determined that the students are of the opinion that the activities contribute to retention, reification, effective learning, creating connections with the real life and enjoyable learning; thus, the students' attitudes towards science became more positive. In this connection, some students expressed their opinions as follows; '*I want such activities to be included in science classes because they are fun and teach a lot of information'* (E3), '*Yes, I want because I liked*' (E5), '*Yes, I want because we did nice* *activities; we have never done such activities before'* (E12), '*Yes, I like. I learn better'* (K8), '*Yes, because what I learn in the class becomes more permanent'* (K3).

One of the dimensions emerging under the theme of learning effect of STEM education is "*attitude and motivational orientation"*. The combination of STEM education with PBL seems to have positively affected the students' attitudes and motivational orientation towards science, engineering, technology and design.

All of the students gave positive responses to the question '*Did performing STEM activities increase your interest in the course of natural sciences? Why?* The students stated that they had not done such activities before and they liked the lesson conducted with these activities very much, that the activities enhanced their knowledge and skills and most important of all, they invented something. In this connection, some students expressed their opinions as follows, '*they increased my interest because I had never seen such things before; that is why, I had never heard of something called STEM*' (K9), '*Yes, they increased because It was enjoyable to apply what we had learned in science classes*' (E6), '*Yes, because they develop both our knowledge and skills'* (E3), '*Yes, they increased my interest a lot. We think and do*' (E1), '*Yes, they increased. I revised what I had learned in both math classes and science classes and I invented something with my friends'* (E12), '*Yes, I liked these activities very much*' (K3), '*Yes, they increased my interest, I find thinking interesting*' (K5).

Nearly 95% of the students responded positively to the question '*Are the engineering designs you developed as a result of the* STE*M activities important for you? Why?'* and the other students did not respond. When the students' opinions were evaluated in this regard, it is seen that they invested great effort on their product, they find their products valuable for themselves and like these engineering products. They also stated that as a result of carrying out these activities, they started to be interested in the profession of engineering. In this respect, some students expressed their opinions as follows; '*It is important because we thought a lot about it, we invested great effort on it and even we disputed to decide who would keep it'* (E12), *'Yes, I thought a lot, my friends and I did it and we made a lot of effort'* (K5), '*Yes, because it is useful for us'* (K2), '*Important because I understood what engineering is; it is very important for me*' (K9), '*Yes, important because I might want to be an engineer and designer in the future'* (K3), '*Yes, I might think engineering as a career for me when I become a grown-up*' (K4).

As the students for the first time encountered STEM instruction in the current study, they were asked the most effective aspect of the STEM-integrated PBL activities. When the students' responses to the question '*What is the thing that affected you the most throughout the activities?* were examined, it was found that they are of the opinion that developing an engineering product, designing, taking the role of an engineer and problem solving are effective. These codes are presented under the theme of "innovations" (Table 8). In this regard, some students expressed their opinions as follows; '*What interested me most in the STEM instruction was engineering and inventions'* (E10), '*What interested me most was designing'* (K3), '*What interested me most was to implement projects*' (E6), '*What affected me most was to try to find a solution to the problem and to try to apply the solution we found'* (E12), '*Engineering means designing something*' (K6).

The difficulties experienced by the students while conducting the PBL activities including STEM disciplines were gathered under two categories "*difficulties related to knowledge and skill"* and "*difficulties related to the activity"*.

When the students' responses to the question "In which parts of the activities did you experience difficulties? Please explain with their reasons.*'* were examined, it was found that they largely experienced knowledge and skill-related difficulties. In this connection, though the students stated that they experienced the greatest difficulties in creating an engineering product and in mathematical operations, they also pointed to the difficulties related to lack of knowledge, use of materials, formation of the hypothesis, creative thinking, designing and cooperation.

Some students expressed their opinions about the difficulties experienced in the STEM instruction as follows; '*I had the greatest difficulty in inventions. I had some difficulty because I found them challenging'*(E10), '*I had difficulty in designing, it was difficult to arrange measurements and then stick'* (K5), '*I experienced difficulty in creating an engineering product in the escape ramp activity'* (K8), '*While doing a periscope, I could not find the correct angle for the mirror*' (E6).

Table 8:Sub-themes and codes emerging under the theme of difficulties in STEM education

Main Theme	Sub-theme	Codes	Frequency (f)
Difficulties in STEM education	Difficulties related to the activity	Finding the activity	3
		Long-lasting activity	1
		Lack of equipment	1
	Difficulties related to knowledge and skill	Experiencing difficulties in mathematical operations	7
		Not being able to create an engineering product	7
		Lack of knowledge	6
		Experiencing difficulties in materials use	4
		Not being able to form the hypothesis statement	2
		Lack of creative thinking skill	2
		Experiencing difficulties in creating a design	2
		Not being able to cooperate	1

The students were asked to write about *'the negative aspects of the activities".* Though almost all of the students have positive opinions about the activities, few of them expressed their negative opinions by pointing out that the activities were challenging, lasted long and materials were inadequate and then their opinions about the negativities of the activities were examined. In this regard, some students' opinions are given below; '*The positive side is that we are forced to think and there is no negative side*' (E12), '*Positive sides are that they are enjoyable and instructive; negative sides are that when the materials were inadequate, it wasn't good*' (K3), '*Positive side, they made learning more permanent, negative side, they were too time-consuming*' (E2), '*The negative side is that the activity was difficult'* (K7).

Discussion and conclusions

The present study set out with the aim of enhancing students' attitudes towards STEM and improving students' STEM career interest with PBL activities. Through the results of both questionnaire and interviews, students presented positive attitudes towards STEM disciplines.

This finding concurs with the literature. Rehmat (2015) conducted a study with 4th grade students and concluded that problem-based STEM activities improved the students' attitudes towards STEM. Lou and others (2011) argued that PBL strategies were helpful in enhancing students' attitudes toward STEM learning.

Both the questionnaire and interview findings revealed that the PBL activities positively affected the students' attitudes towards science, one of the STEM disciplines. When the students' interview data were examined, it was found that high majority of the students are of the opinion that the problem-based STEM activities increased their interest in science and that they want such activities to be incorporated into science classes. The students think that these activities enable them to learn more permanently, to reify, to relate to the daily life, to learn by doing and experiencing. Moreover, the students find these activities enjoyable and they enhance their attitudes and motivation towards science while creating products in order to solve the problem. There is a large amount of research reporting that PBL and STEM instruction enhance students' attitudes towards science. Demirel and Dağyar (2016) did a meta-analysis study on the effects of PBL in terms of students' attitudes. They argued that problem-based learning is effective in helping students gain a positive attitude toward science. Yamak, Bulut and Dündar (2014) found that STEM activities enhanced the fifth grade students' attitudes towards science.

The positive change in their attitudes towards knowledge may be due to their use of mathematical and scientific knowledge when designing something and recognizing that the knowledge they possess are useful. Doppelt et al., (2008) stated that STEM education has a potential role in enhancing students' interest in science subjects, learning desire and achievement. Demirel and Arslan-Turan (2010) reported that PBL positively affected the sixth grade students' attitudes towards science. The facts that science education is based on both practice and interpretation, that it is so connected with real life and that it requires cooperation facilitate the problem-based STEM activities. The basic principle of PBL in science education is that students will learn and retain information more effectively when it is presented, discussed, and applied to a real-life format.

The data obtained from the questionnaire and interviews demonstrate that the students have positive attitudes towards engineering. When the students' responses to the question '*What is the thing that affected you most during the activities?*" were examined, it was found that creating an engineering product, designing and taking the role of an engineer are milestone of the applications. These findings support the score increase having occurred in the sub-dimension of engineering in the attitude scale. This result suggested that PBL enhances student attitudes towards engineering. Problem-based learning is a very suitable approach for engineering as it helps students develop skills and confidence in finding solutions to real-life problems because one of the main objectives of engineering is to create flexible engineers who can think, solve problems and engage in life-long learning (Matthew & Hughes, 1994).

Students' attitude scores towards 21st century skills have increased significantly after the study. The students stated that the problem-based STEM activities enhance the 21st century skills such as team work, problem solving, cooperation and creativity skills. Thus, in light of questionnaire and interview findings, it can be argued that the PBL activities improved the students' attitudes towards 21st century skills and enhanced these skills. The finding is consistent with the findings of Canavan (2008) who argued that students reported the PBL approach fostered more generic skills, such as communication skills, group work, critically evaluating information, and task management. Similarly, Prince (2004), Akınoğlu and

Tandoğan (2007) reported that problem-based learning positively affects some attitudes of students in relation to such areas as problem-solving, thinking, group works, communication, information acquisition and sharing information with others.

According to study result, while the PBL activities developed the students' attitudes towards the 21st century skills, engineering and science, there is no significant effect on their attitudes towards mathematics. This finding is also supported by the fact that the most frequently mentioned difficulty by the students during the interviews is "difficulties in mathematical operations". Gülhan and Şahin (2016) also found positive changes in students' attitudes towards science, engineering and the 21st century skills but not in attitudes towards mathematics. Stone, Alfeld and Pearson (2008) reported that students' low interest in mathematics was due to the perceived difficulty of the subject. Also, Bingolbali et al. (2007) suggested that the major reason for students' low interest in mathematics was because its principles are difficult and too much time needed to understand.

In the current study it was also determined that besides their attitudes towards STEM disciplines, the students' perceptions of STEM careers and interest in STEM-related occupations also positively changed. Before the application, the occupation thought to be a future career by the students was mostly related with life sciences (agriculture and food scientist, veterinarian, biologist, microbiologist, pharmacist, nurse, doctor and laboratory technician). The greatest extent with 68.2% and the least preferred one was engineering-related occupations. On the other hand, following the application of the STEM-integrated PBL activity, the students' interest in the occupations related to STEM disciplines increased and almost 91 percent of student interested in the occupations related to engineering and technology disciplines. Throughout the applications, the students were most affected from creating an engineering product, designing and taking the role of an engineer. According to Tyler-wood, Knezek, and Christensen (2010), determination of students' perceptions about STEM careers is important to identify their career potential. At this early stage of the education, students' positive perception about having a career in STEM areas is promising for the number of people in STEM careers in future (Yerdelen, Kahraman & Tas, 2016). Similarly, Sadler et al. (2012) suggested that pre-high school activities are important to improve students' interest in STEM careers because of the stability in students' interest level during the high school.

The students' relatively higher interest in the occupations related to life sciences before the application might be because of their considering their families' viewpoints. Having a career in life sciences, particularly in the field of medicine as a doctor, is very popular in Turkey not only for students but also for their families. According to a survey in Turkey, one of the five parents expects their child to be a doctor in the future (Yerdelen, Kahraman & Tas, 2016).

The first place among the occupations considered by the students as their possible future career was taken by life sciences-related occupations before the application. On the other hand, occupations in STEM disciplines can be recognized as the occupations of future as they are needed by a nation for technological innovations, economic growth and improvement of living standards (Langdon et al., 2011). In this regard, it seems to be necessary to increase the number of students working in STEM disciplines. According to the literature, if STEM-centered career choices of students are desired to be affected, career awareness of students should be improved by early intervention in the education system (Moore & Richards, 2012; Wyss, Heulskamp & Siebert, 2012). Building and developing an interest in STEM fields are of great importance for students to join the workforce in these areas in the future (Knezek et al., 2013). This study clearly shows that problem-based STEM activities are very effective in increasing secondary school students' interest in STEM disciplines and STEM-related occupations.

Additionally, it was found that the students experienced some difficulties in STEM-integrated PBL activities. Though these difficulties are mostly related to knowledge and skill, there are some other difficulties related to activities such as lack of materials, demanding and long-lasting activities. Though the students stated that they experienced the greatest difficulties during the activities in creating an engineering product and mathematical operations, they also pointed to some of the difficulties such as inadequate materials, lack of knowledge, difficulty in mathematical operations, difficulty in using materials, forming a hypothesis, creative thinking, designing and cooperation.

These STEM integrated PBL activities have had considerable effects on the students' attitudes towards STEM and STEM career interest. PBL can increase the effectiveness of STEM education, make meaningful learning possible and affect students' attitudes towards their future careers. As a conclusion, the current study suggests that educators can design suitable PBL instructional strategies to increase students' interest in STEM education and facilitate students' development necessary for their future careers.

Reference:

Akınoğlu, O. & Tandoğan, R. (2007). The effects of problem-based active learning in science education on students' academic achievement, attitude and concept learning. *Eurasia Journal of Mathematics, Science and Technology Education, 3*(1), 71-81.

Baine, C. (2009) *Women and minorities in STEM Careers: Advancing our World*. Report of the Congressional Commission on the Advancement of Women and Minorities in Science, Engineering and Technology Development; National Science Foundation. 1-2

Bingolbali, E., Monaghan, J., & Roper, T. (2007). Engineering students' conceptions of the derivative and some implications for their mathematical education. *International Journal of Mathematical Education in Science and Technology, 38*(6), 763–777. doi:10.1080/00207390701453579

Bransford, J. D., Vye, N., & Bateman, H. (2002). Creating high-quality learning environments: Guidelines from research on how people learn. In P. A. Graham & N. G. Stacey (Eds.), *The knowledge economy and postsecondary education: Report of a workshop* (pp. 159–197). Washington, DC: National Academy Press.

Bybee, R. W. (2010). What is STEM education? *Science, 329*(5995), 996-996.

Canavan, B. (2008). A summary of the findings from an evaluation of problem-based learning carried out at three UK universities. *International Journal of Electrical Engineering Education, 45*(2), 175–180.

Cooper, R., & Heaverlo, C. (2013). Problem solving and creativity and design: What influence do they have on girls' interest in STEM subject areas? *American Journal of Engineering Education, 4*(1), 27-38.

Corlu, M. S., Capraro, R. M., & Capraro, M. M. (2014). *Introducing STEM education: Implications for educating our teachers in the age of innovation. Education and Science, 39*(171), 74–85.

Creswell, J. W. (2003). *Research design: Qualitative, quantitative, and mixed method approaches*. Thousand Oaks, Calif: Sage Publications.

David, G. H. & Sharon, K. S. (2006). Conference Prologue. In G. H. David & K. S. Sharon (Eds.), *Proceedings of the conference on K-12 outreach from university science* *departments*. (pp. 6-7). Raleigh, NC: The Science House, North Carolina State University.

Davis, F. J., Lockwood-Cooke, P.L., & Hunt, E. M. (2011). Hydrostatic pressure project: Linked-class problem-based learning in engineering. *American Journal of Engineering Education, 2*(10), 43-50.

Demirel, M. & Arslan-Turan, B. (2010). The effects of problem based learnıng on achıevement, attıtude, metacognıtıve awareness and motıvatıon. *HU Journal of Education, 38*, 55-66.

Demirel, M. & Dağyar, M. (2016). Effects of Problem-Based Learning on attitude: A meta-analysis study. *Eurasia Journal of Mathematics, Science & Technology Education, 12*(8), 2115-2137.

Dewaters, J. & Powers, S. E. (2006). Improving science and energy literacy through project-based K-12 outreach efforts that use energy and environmental themes. *Proceedings of the 113th Annual ASEE Conference & Exposition* (pp.262-276). Chicago, IL.

Doppelt, Y., Mehalik, M. M., Schunn, C. D., Silk, E., & Krysinski, D. (2008). Engagement and achievements: a case study of design-based learning in a science context. *Journal of Technology Education, 19*(2), 22-39.

Faber, M., Unfried, A., Wiebe, E.N., Corn, J. Townsend, L.W. & Collins, T.L. (2013). *Student attitudes toward STEM: the development of upper elementary school and middle/high school student surveys*. 120th ASSE Annual Conference & Exposition, Paper ID #6955.

Fan, S., & Ritz, J. (2014). *International views of STEM education. In PATT-28 Research into Technological and Engineering Literacy Core Connections* (pp. 7-14). Orlando: International Technology and Engineering Educators Association. Retrieved from http://www.iteea.org/Conference/PATT/PATT28/Fan%20Ritz.pdf

Gülhan, F. & Şahin, F. (2016). Fen-teknoloji-mühendislik-matematik entegrasyonunun (STEM) 5. sınıf öğrencilerinin bu alanlarla ilgili algı ve tutumlarına etkisi [The effects of science-technology-engineering-math (STEM) integration on 5th grade students' perceptions and attitudes towards these areas. *International Journal of Human Sciences, 13*(1), 602-620. doi:10.14687/ijhs.v13i1.3447

Hmelo-Silver, C.E. (2004). Problem-based learning: What and how do students learn? *Educational Psychology Review, 16*(3), 235-266.

Hung, W. (2009). The 9-step problem design process for problem-based learning: Application of the 3C3R model. *Educational Research Review, 4*(2), 118-141.

Hunt, E.M., Lockwood-Cooke, P.L., & Kelley, J. (2010). Linked-Class problem-based learning in engineering: Method and evaluation. *American Journal of Engineering Education, 1*(1), 79-88

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

Langdon, D., Mckittrick, G., Beede, D., Khan, B. & Doms, M. (2011). STEM: Good jobs now and for the future, U.S. *Department of Commerce Economics and Statistics Administration, 3*(11).

Lattuca, L. R., Terenzini, P. T., Volkwein, J. F., & Peterson, G. D. (2006). The changing face of engineering education. *The Bridge, 36*(2), 6–44.

Lincoln, Y. S., & Guba, E. G. (2000). Paradigmatic controversies, contradictions, and emerging confluences. In N. K. Denzin, & Y. S. Lincoln. (Eds.), *Handbook of qualitative research*, 163-188. Thousand Oaks, CA: Sage.

Lou, S. J., Shih, R. C., Diez, C. R. ve Tseng, K. H. (2011). The impact of problem-based learning strategies on STEM knowledge integration and attitudes: an exploratory study among female Taiwanese senior high school students. *International Journal of Technology and Design Education, 21*, 195–215.

Matthew, R. G. S., & Hughes, D. C. (1994). Getting at deep learning: A problem-based approach. *Engineering Science & Education Journal*, *3*(5), 234-240.
Miles, M. B., & Huberman, A. M. (1994). *Qualitative data analysis*. Thousand Oaks, CA: SAGE.
Milner, D. I., Horan, J. J., & Tracey, T. J. (2013). Development and evaluation of STEM Interest and Self-Efficacy Tests. *Journal of Career Assessment, 22*(4), 642-653.
Ministry of National Education (2009). *MEB 2010-2014 stratejik planı [MoNE 2010-2014 strategic plan]*. Ankara, Turkey: Milli Eğitim Bakanlığı Strateji Geliştirme Başkanlığı.
Moore T. & Richards L. G. (2012). P-12 engineering education research and practice. *Introduction to a Special Issue of Advances in Engineering Education, 3* (2), 1-9
Morrison, J. (2006). *TIES STEM education monograph series, Attributes of STEM education*. Baltimore, MD: TIES
National Academy of Engineering (NAE). (2005). *Educating the engineer of 2020: Adapting engineering education to the new century.* Washington, DC: The National Academies Press.
National Academy of Engineering. (2010). *Committee on standards for K-12 engineering education*. Washington, DC: National Academies Press
National Research Council (2012). *Successful K-12 STEM Education: Identifying Effective Approaches in Science, Technology, Engineering, and Mathematics*. Committee on Highly Successful Science Programs for K-12 Science Education. Board on Science Education and Board on Testing and Assessment, Division of Behavioral and Social Sciences and Education. Washington, DC: The National Academies Press. Retrieved from http://www.nap.edu/catalog/13158/successful-k-12-stem-education-identifyingeffective-approaches-in-science
Prince, M. (2004). Does active learning work? A review of the research. *Journal of Engineering Education, 93*(3), 223–232.
Rehmat, A. P. (2015). *Engineering the Path to Higher-Order Thinking in Elementary Education: A Problem-Based Learning Approach for STEM Integration* (Doctoral dissetation). Retrieved from ProQuest Dissertations and Theses database. (1734004410)
Sadler, P. M., Sonnert, G., Hazari, Z., & Tai, R. (2012). Stability and volatility of STEM career interest in high school: A gender study. *Science Education*, 96, 411-427.
Schultz, N., & Christensen, H. P. (2004). Seven-step problem-based learning in an interaction design course. *European Journal of Engineering Education, 29*(4), 533-541
Smith, K. A., & Starfield, A. M. (1993). Building models to solve problems. In J.H. Clarke & A.W. Biddle, (Eds.), *Teaching critical thinking: Reports from across the curriculum* (pp. 254- 263). Englewood Cliffs, NJ: Prentice-Hall.
Starfield, A. M., Smith, K. A., & Bleloch, A. L. (1994). *How to model it: Problem solving for the computer age*. Edina, MN: Burgess International Group, Inc.
Stepien, W. J., Gallagher, S. A., & Workman, D. (1993). Problem-based learning for traditional and interdisciplinary classrooms. *J. Educ. Gifted, 16*, 338–357.
Stohlmann, M., Moore, T., Roehrig, G. & McClelland, J. (2011). Year-long impressions of a middle school STEM integration program. *Middle School Journal, 43*(1), 32–40.
Stone III, J. R., Alfeld, C., & Pearson, D. (2008). Rigor and relevance: Enhancing high school students' math skills through career and technical education. *American Educational Research Journal*, *45*(3), 767-795.
Tseng, K., Chang, C., Lou, S., & Chen, W. (2013). Attitudes towards science, technology, engineering and mathematics (STEM) in a project-based learning (PBL) environment. *International Journal of Technology and Design Education, 23*(1), 87–102.

Tyler-Wood, T., Knezek, G., & Christensen, R. (2010). Instruments for assessing interest in STEM content and careers. *Journal of Technology and Teacher Education*, *18*(2), 341-363.

Wyss, V. L., Heulskamp, D. & Siebert, C. J. (2012). Increasing middle school student interest in STEM careers with videos of scientists. *International Journal of Environmental Science Education*, *7*(4), 501-522.

Yamak, H., Bulut, N. & Dündar, S. (2014). 5. sınıf öğrencilerinin bilimsel süreç becerileri ile fene karşı tutumlarına FeTeMM etkinliklerinin etkisi [The ımpact of STEM activities on 5th grade students' scientific process skills and their attitudes towards science]. *Gazi Üniversitesi Eğitim Fakültesi Dergisi. 34*(2): 249-265.

Yerdelen, S., Kahraman, N., & Taş, Y. (2016). *Low socioeconomic status students' STEM career ınterest in relation to gender, grade level, and STEM attitude. Journal of Turkish Science Education. 13*(Special Issue), 59-74

Yıldırım, A. ve Şimşek, H. (2011). *Sosyal bilimlerde nitel araştırma yöntemleri[Qualitative research methods in the social sciences]* (8. Baskı). Ankara: Seçkin.

Yıldırım, B. & Altun, Y. (2015). STEM Eğitim ve Mühendislik Uygulamalarının Fen Bilgisi Laboratuar Dersindeki Etkilerinin İncelenmesi [Investigating the effect of STEM education and engineering applications on science laboratory lectures]. *El-Cezerî Fen ve Mühendislik Dergisi, 2*(2); 28-40.

Yıldırım, B. & Selvi, M. (2015). Adaptation of STEM attitude scale to Turkish. *Turkish Studies*, *10*(3), 1107-1120.

APPENDIX A

Sample Scenario

Alarm System Activity: "Ahmet's Village Adventure"

Ahmet, a middle school student, will go to grandfather's home in the village for the summer vacation. His grandfather asks Ahmet to follow the water needs of the sheep. Ahmet promises that he will not neglect his mission. Ahmet wants to play with his friends in the village and wants to keep his promise. There he thinks that he must to design a simple electric circuit system that will warn that the water in the tank is exhausted. Therefore, he will have time to play with his friend in the village. In this regard, Ahmet decides to get help from the neighbor, Mustafa, an Electrical Engineer.

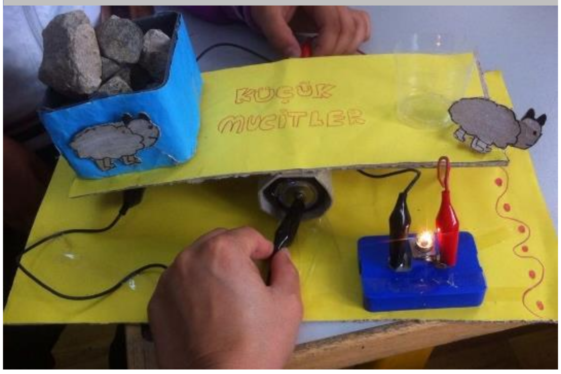
What kind of systems do you design if you are in Ahmet's place? Which one would you craft?

APPENDIX B

Examples from student work

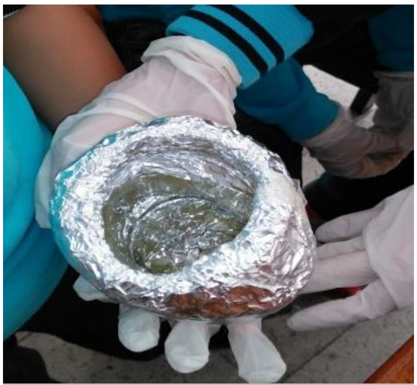
Friction force and motion

Alarm system with electric circuits



Force measurement

Reflection of light and mirrors



Heat-insulated container

APPENDIX C

The STEM Interview Form

Dear students,
The questions in this form have been prepared to receive your views on the STEM activities we have carried out together. It is very important for the reliability of the information to be obtained that you answer the questions as detailed as possible. Thank you for your participation.

1. Do you want to include such activities in your science courses? Explain why.
2. What is the thing that affects you the most during the STEM activities? What are the positive or negative points of the STEM activities?
3. In which parts of this activity are you challenged? Explain with your reasons.
4. What skills can STEM education provide for students? Explain why.
5. Are the engineering designs you have developed as a result of your work with STEM events important to you? Explain why.