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The effects of STEM activities on students' STEM career interests, motivation, science process skills, science achievement and views

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ABSTRACT

This research aimed to determine the effects of science, technology, engineering and mathematics (STEM) activities on seventh grade secondary school students' STEM career interests, motivation, science process skills, science achievement, and their views on STEM education. The sample of research consisted of 44 students. The sample was divided into two groups, 22 students in experimental group and 22 students in control group at the seventh grade of a secondary school. Mixed research approach was used in this research. The results showed that STEM activities improved experimental group students' science process skills, STEM career interests and motivation for STEM fields compared to the students in the control group. The qualitative findings revealed that STEM activities developed positive views towards interdisciplinary education and 21st century skills such as creativity, collaboration, critical thinking and problem solving. Findings suggested that STEM activities can be implemented to improve students' science process skills, STEM career interests and motivation and views about STEM education.

1. Introduction

Despite the rapid development of technology and the production of new technological tools, there was insufficient number of individuals who effectively benefit from these tools to produce new technological tools. STEM education has been expected to overcome this deficiency (Guzey, Harwell & Moore, 2014). In addition, students' interest in STEM disciplines has been decreasing day by day. For this reason, the improvement of students' interest and approaches to STEM disciplines and the leading students into STEM fields was important. Only in this way, countries could grow individuals who were open to competition for the future, developed in terms of job competencies, keeping up with the age, producing entrepreneurs and innovations (Wang, 2012). Therefore, many countries have been trying to integrate STEM education approach to their curricula in order to educate individuals with knowledge and skills in STEM fields.

Different pedagogical approaches were suggested to improve students' motivation and interest in STEM disciplines. In this research, inquiry-based STEM education was used. Teaching approaches are changed from teacher-centered, traditional teaching to student-centered, active teaching to promote student engagement in STEM disciplines and provide effective education (Kennedy & Odell, 2014).

Inquiry-based learning was effective pedagogical approach that improves the ability of students to make investigations, solve problems, analyze data and evidence, ask questions, make interpretations and conclusion, and communicate findings (Pedaste et al.,

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2015). In all STEM disciplines, inquiry-based learning approaches were contributed to facilitate students to participate in authentic, meaningful, and contextualized with real-world. There were many different definitions of scientific inquiry in the research literature. A widely used concept given by the National Research Council was as follows: scientific inquiry is composed of skills and comprehensions that cover inquiring scientific questions, making scientific investigations to respond questions, applying suitable tools to evaluate and analyze findings, making evidence-based scientific interpretations, and reporting and explaining relationships (National Research Council [NRC], 2012).

The design based learning principles supported inquiry-based learning in the integration of engineering and technology in STEM education. The design based learning concentrated on the production of new artifacts and original solutions and systems (Puente, van Eijck & Jochems, 2013). Students were faced with real life issues and engaged in reflective reasoning processes and applications. This process covered planning, design and communication of findings (Doppelt, Mehalik, Schunn, Silk & Krysinski, 2008). It covered authentic learners, iterative decision-making and making prediction. Engineering design was one of the most notable issues in the field of educational literature, because it helped students to overcome problems in the real world (Purzer, Goldstein, Adams, Xie & Nourian, 2015). The Engineering Design process consisted of three elements: explanation of the problem, including limitations and restrictions; solution, including solutions tested and refined; design and evaluation, final design improvement (NRC, 2012).

Students became aware of how scientists work by actively participating in authentic science research in collaborative groups (Bricker & Bell, 2008; NRC, 2012). The students showed an increase in interest and motivation in science and also increase in performance as a result of engaging in practical-based learning activity associated with real world science activities (Fang & Wei, 2010). Inquiry based science curriculum has been shown to promote student science achievement (Sandoval & Morrison, 2003) and promote the engagement in inquiry based activity practices including scientific thinking and data analysis (Ebenezer, Kaya & Ebenezer, 2011). Therefore, STEM-based activities were supported by the problems of daily life. In addition, the STEM-based activities prepared the students for daily life in order to produce solutions based on different disciplines. Through STEM activities, students were expected to develop skills of experimenting, designing, collecting data, analyzing, making inferences and interpretations, and associating scientific knowledge to natural events. STEM-based activities helped students make sense of the information and make it more permanent, as it transferred information to students through a life (Wang, 2012). Therefore, there was a great need for scientific research focusing the implementation of STEM-based activities in the classroom (Ormanci, 2020). However, studies about the implementation of STEM education in classroom were limited and did not include detailed research in Turkey (Baran, Canbazoglu Bilici, Mesutoglu & Ocak, 2016; Şahin, Ayar & Adiguzel, 2014). Similarly, studies on how STEM disciplines could be integrated and applied in the classroom were limited in the literature (Bahar, Yener, Yilmaz, Emen & Gurer, 2018; Gülhan & Şahin, 2016). In addition, there was limited number of studies examining students' views on STEM activities and STEM education applied at different levels and on different subjects (Aydın & Karslı Baydere, 2019; Gülhan & Şahin, 2018; Sarı, Duygu, Şen & Kırındı, 2020).

Science process skills; observation, prediction, communication, classification and measurement skills are defined as the skills that secondary school students should have (Akgün, Özden, Çinici, Aslan & Berber, 2014). In daily life, where knowledge is gained systematically, not randomly, on the contrary, having science process skills not only provides the opportunity to solve problems in daily life, but also adds science literacy, which is the aim of science education (Harlen, 1999). It can contribute to science literacy by improving science process skills with the opportunities offered by STEM to individuals. Because STEM is a learning area that helps to find new solutions to the problems that may be encountered in daily life with the disciplines in its content (Sarı et al., 2020).

Students' attitudes and interests towards science and mathematics in secondary school will also affect their career choices in the future. For this reason, the high interest of students in STEM fields is an incentive for them to choose a career in these fields (Buxton, 2001). According to Christensen and Knezek (2017), the fact that students are not informed about career opportunities in STEM fields at an early age is an effective factor in decreasing their interest in professions in these fields. Therefore, determining the interests and career goals of secondary school students in STEM fields is very important in terms of preparing the future of the STEM workforce (Christensen & Knezek, 2017).

In the science education literature, there is a widespread belief that participation in science, technology, engineering and mathematics (STEM) courses is low (Osborne, Simon & Collins, 2003). It has been stated in many studies that career interest, science achievement and motivation are the solutions in ensuring this participation (Master, Cheryan, Moscatelli & Meltzoff, 2017; Restivo, Chouzal, Rodrigues, Menezes & Lopes, 2014; Rosenzweig & Wigfield, 2016). One of the main themes in the science education literature is the increasing reluctance of students to participate in STEM education (Bøe, Henriksen, Lyons & Schreiner, 2011). Students with high career interest, science achievement and motivation continue to participate in STEM fields over the years, while students with low career interest, science achievement and motivation tend to leave more over time. (Skinner, Furrer, Marchand & Kindermann, 2008). This research will contribute to the literature in terms of revealing the effects of STEM activities on students' interest in STEM careers, science achievement, science process skills and motivation.

In the research, the learning outcomes of "energy and astronomy" subjects from science subjects were used. The subjects of energy and astronomy were generally known as a complex subject by students. These subjects would contribute to understanding transformation of the energy we frequently encountered in daily life and we used in our homes. In addition, it was aimed to strengthen the sense of cooperation of the students with group work. In order to integrate students in daily life problems, students gained an active and problem-based learning experience with STEM activities including engineering design process. It would give students more opportunities to create scientific ideas and different ideas on energy and astronomy. In this way, students' scientific process skills, problem solving and creativity skills were tried to be developed. The students were motivated by activities involving real life problems and engineering designs on energy and astronomy to finish the designs.

Astronomy and energy issues are seen as problems that we encounter in our daily lives. Students always have a curiosity about space. In addition, there are many problems that need to be overcome in space studies (such as destroying space garbage). In addition, energy is important for many countries today. Problems such as energy sources and the search for renewable energy sources are again encountered as daily life problems. At the core of STEM, emphasis is placed on engaging students with real-life problems. In this context, astronomy and energy come first among the subjects that we can expose students to real life problems in the lessons. For this reason, astronomy and energy subjects were chosen while preparing the activities for STEM in the research. In the research, by developing activities on astronomy and energy subjects, both to provide resources for teachers in this field and to determine the effects of these activities on students' scientific process skills, career interests in STEM, their motivation towards STEM, their success in energy and astronomy, and their views on STEM. To reveal the usability of the activities and in this sense, the effectiveness of STEM-related activities will be revealed. The aim of the research was to determine the effect of Science-Technology-Engineering-Mathematics (STEM) activities on the science process skills, motivation, career interests, academic achievements and views towards STEM education of seventh grade students. This study attempts to answer the following research questions:

1 Is there significant difference in the science process skills for the experimental group and the control group, while controlling for their pre-test scores?
2 Is there significant difference in the science achievement scores for the experimental group and the control group, while controlling for their pre-test scores?
3 Is there significant difference in the interest in STEM careers for the experimental group and the control group, while controlling for their pre-test scores?
4 Is there significant difference in the motivation in STEM for the experimental group and the control group, while controlling for their pre-test scores?
5 What are the views of students about STEM education after participating in STEM activities?

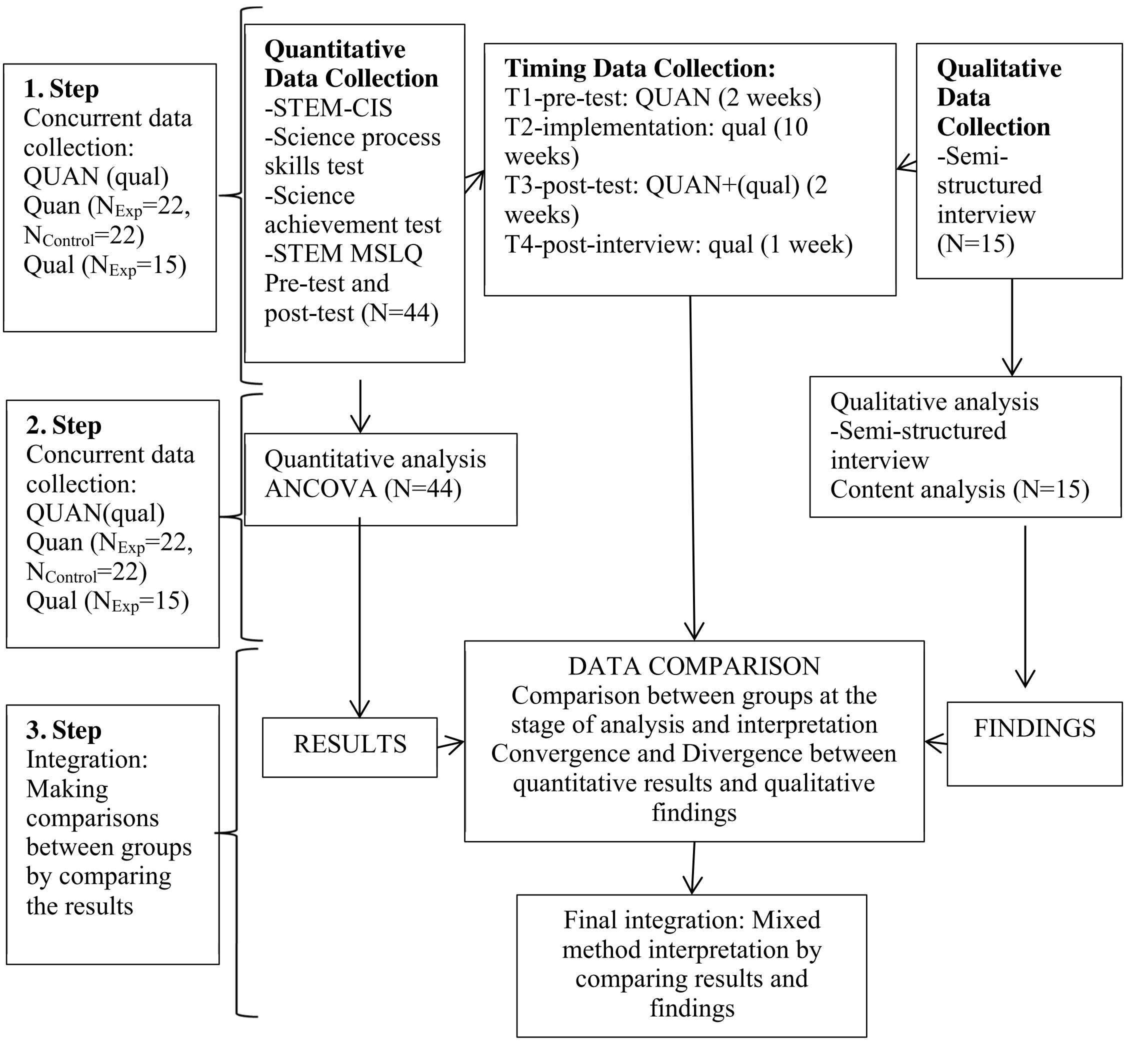

Fig. 1. Embedded mixed methods design.

2. Methods

In this research, the qualitative research was embedded in quantitative research. For this reason the embedded mixed method design was used (Creswell, Clark & V., 2011). The pretest-posttest quasi-experimental research was used as a quantitative research. Primarily, the quantitative research was implemented and statistical data was obtained. Then, interviews were realized with selected participants from experimental group to research the results more depth. Two classes from a secondary school located in a middle socioeconomic region were chosen, because randomly assignment of participants in the groups is difficult (Gay, Mills & Airasian, 2005). The entire seventh grade classes from one school were compared by using academic achievement in science, math and technology courses to select equivalent experimental and control groups. According to academic achievement in science, math and technology courses, no significant differences of two classes from a secondary school were randomly selected as control and experimental group. The STEM activity based education program, including 10 activity weeks, was implemented with the students in experimental group. The implementation lasted 14 weeks and two hours a week. Conversely, the students in control group were engaged in conventional learning method based activities included in the Science, Math and Technology textbooks (Ministry of National Education [MoNE], 2018). Subsequently, researchers made interviews with selected participants to obtain views of students in-depth. After performing of the experimental implementation, researchers interviewed with students in experimental group about their STEM views by using a semi-structured interview form in the spring semester of the 2016–2017 academic year (Fig. 1).

3. Participants

The experimental research was implemented in two intact classes from a secondary school in the middle socioeconomic region. There were 16 girls (72.7%), 6 boys (27.3%), and a total of 22 students (50%) in the experimental group. There were 12 girls (54.5%), 10 boys (45.5%), and a total of 22 students (50%) in the control group. All students were thirteen years old. The school science, math and technology achievements of participants in the two classes were not significantly different ($p > .05$) according to independent t-test results. STEM views of students in the experimental group were researched by using a semi-structured interview form. The maximum variation sampling technique was used as a purposive sampling method to obtain more detailed comprehension of students' STEM views after engage in the STEM activities. Students' post-test STEM career interest survey scores were the criteria used for maximum variation cases in this research. Interviews were realized with a total of 15 (10 girls, 5 boys) students who had low (5 students), medium (5 students) and high (5 students) scores from STEM career interest survey in the research. Students participating in the research were aged 13 to 14 years. Students were similar in terms of socioeconomic level (income level, education level of parents, conditions of the house and access to technological tools, etc.) and academic success.

4. Data collection tools

4.1. Quantitative instruments

In this research, Science, Technology, Engineering and Mathematics Career Interest Survey (STEMCIS) developed by Kier, Blanchard, Osborne and Albert (2014), which was a type of 5-point-Likert scale, was used. The survey was composed of 44 questions and four sub-dimensions in terms of science, technology, mathematics, and engineering dimensions. The hypothesis model was supported according to results of confirmatory factor analysis of tested items with 197 secondary schools students at 7th grade level. Moreover, the four-factor model of the STEM-CIS was theoretically assessed in four subscales and confirmed ($\chi2= 2222.46$, $df= 896$, $\chi2/df= 2.48$, $NFI= 0.85$, $CFI= 0.91$, $GFI= 0.93$, $RMR= 0.040$, $RMSEA= 0.068$) (Tabachnick & Fidell, 2013). Cronbach alpha coefficients were 0.88, 0.90, 0.91, 0.92 and 0.93 for science, technology, mathematics, engineering, and the overall scale, respectively.

Motivated Strategies for STEM Learning Questionnaire (MSLQ) was developed by Pintrich, Smith, García and McKeachie (1991), which was a type of 7-point-Likert scale, was used in this research. The questionnaire was composed of 31 items and six sub dimensions. The items were classified under extrinsic goal orientation, intrinsic goal orientation, task value, self-efficacy for learning and performance, control beliefs and test anxiety sub-factors. The hypothesis model was supported according to results of confirmatory factor analysis of tested items with 192 secondary schools students at 7th grade level. In addition, the six-factor model of the STEM-motivation scale was theoretically assessed in six subscales was confirmed ($\chi2= 665.58$, $df= 414$, $\chi2/df= 1.61$, $NFI= 0.90$, $CFI= 0.96$, $GFI= 0.82$, $RMR= 0.072$, $RMSEA= 0.056$) (Tabachnick et al., 2013). Cronbach alpha coefficients were 0.71, 0.70, 0.75, 0.88, 0.70, 0.71 and 0.89 for extrinsic goal orientation, intrinsic goal orientation, task value, self-efficacy for learning and performance, control beliefs and test anxiety and the overall scale, respectively.

In this research, Science Process Skills Test was type of multiple choice and composed of 16 items, was used. The test measured the skills to create problems, to distinguish the terms of hypothesis, observation, prediction, theory, explanation, to determine variables, to decide what needs to be considered in measurement (e.g. reliability), to draw conclusions based on data, to read graphics and tables and ability to perform unbiased testing. The content reliability of the test was justified according to the views of the scholars, and KR-21 reliability coefficient was found to be 0.81 according to pilot study with 111 secondary schools students at 8th grade level.

Science Achievement Test was developed by researchers and consisted of 27 multiple choice items. In order to ensure the content validity of the achievement test, a table of specification containing the content of the questions in the test was prepared. For the validity of the achievement test, the opinions of five field experts were consulted and necessary corrections were made according to their opinions. Semantic and visual errors in the questions and answer options of the test items were corrected according to opinions of five field experts. The table of specification of the test items in this test was examined and the errors in the order of the Bloom taxonomy

Table 1
Overview of STEM activities and relationships of STEM disciplines.

Activity	Science	Technology	Engineering	Mathematics
Recycled Car	Understanding and application of recycled materials and force of air pressure	Using recycled materials, designing of wheels, vehicle body type and other components	Designing of recycled car	Measurement and calculations of force, air pressure and motion
The Endangered Livings	Understanding of importance of Biodiversity and endangered livings	Understanding of GPS trackers for endangered livings and other technological devices for endangered livings	Designing a product for endangered livings by using trackers, sensors or information systems to save livings	Measurement and calculations of living area of endangered livings to decide where to install the tracking device and sensors
Solar Car	Electrical and mechanical energies	Understanding of solar panel and motor	Designing a solar car	Measurement and calculations of motion and energy
Solar Oven	Temperature and heat energy	Understanding of space technology	Designing a heat-conserving solar oven	Calculating the relationship between temperature and time under sunlight
Biosphere	Understanding of importance of Biosphere	Designing self-sufficient biosphere and caring biodiversity	Designing a biosphere for biodiversity	Measurement and calculations about temperature, water, living spices in biosphere
Water Tribune	Forces, motion, and electrical energy	Understanding the function and limitations of the water turbine	Designing a water turbine	Measurement and calculations involving newton’s and ohm’s laws
Water Rocket Making	Understanding of effect of water pressure and gravity	Understanding the function and limitations of the water rocket	Designing a water rocket that can reach the highest	Measurement of rate of water pressure
Soft Landing on Mars	Understanding the force of air friction and gravity	Understanding the function and limitations of airbag	Designing airbag for soft landing	Measurement of force of air friction

were corrected with the consensus of all experts. The test evaluated science achievement of students in units of domestic wastes and recycling, mirror reflection and light absorption, human and environmental relations, electric power, and solar system in seventh grade level. The science achievement test was applied to 125 students representing the sample as a pilot study to decide whether students easily comprehended and answered. The item and reliability analysis of the achievement test was made with the Iteman for Windows 3.50 program. After the first analysis, items 4, 8, 10, 15 and 19 were excluded from the test because their discrimination values were 0.19 and below and the difficulty scores were not above 0.60 (Turgut & Baykul, 1992). The remaining items were analyzed again with Iteman for Windows 3.50 program. Biserial correlation values were calculated as the item validity coefficient. The final test consisting of 22 questions was justified according to the views of the scholars, and KR-21 reliability coefficient was found to be 0.73. Item discrimination indices ranged from 0.20 to 0.60, and item difficulties ranged from 0.40 to 0.94.

4.2. Qualitative instruments

A semi-structured interview form was used to research students' views about STEM in the experimental group. Some examples of the open-ended questions used in the interview were as follows:

1 Which disciplines do you think science is related to?
2 What is the relationship between science and technology, engineering and mathematics?
3 What are the benefits of STEM activities?
4 What are the advantages of STEM activities and practices in science classes?
5 What are the disadvantages of STEM activities and practices in science classes?
6 Which difficulties did you experience when implementing STEM-based designs?
7 What are your recommendations for better implementation of STEM-based activities in science classes?

Before using the interview form were examined by taking the opinions of two field specialists and a teacher in terms of their face and content validity. The questions of interview form were applied to four students representing the sample as a pilot study to decide whether students easily comprehended and answered. After that, necessary revisions were made and the latest version of the interview form was put into final form. The latest version of the interview form consisted of seven questions. After students involved in the STEM activities, the interviews were conducted with students. Each students' interviews were audio-recorded to prevent missing data and enhance active listening. The interviews were lasted for 20–25 min. The participants were informed by using the informed consent form before interviews.

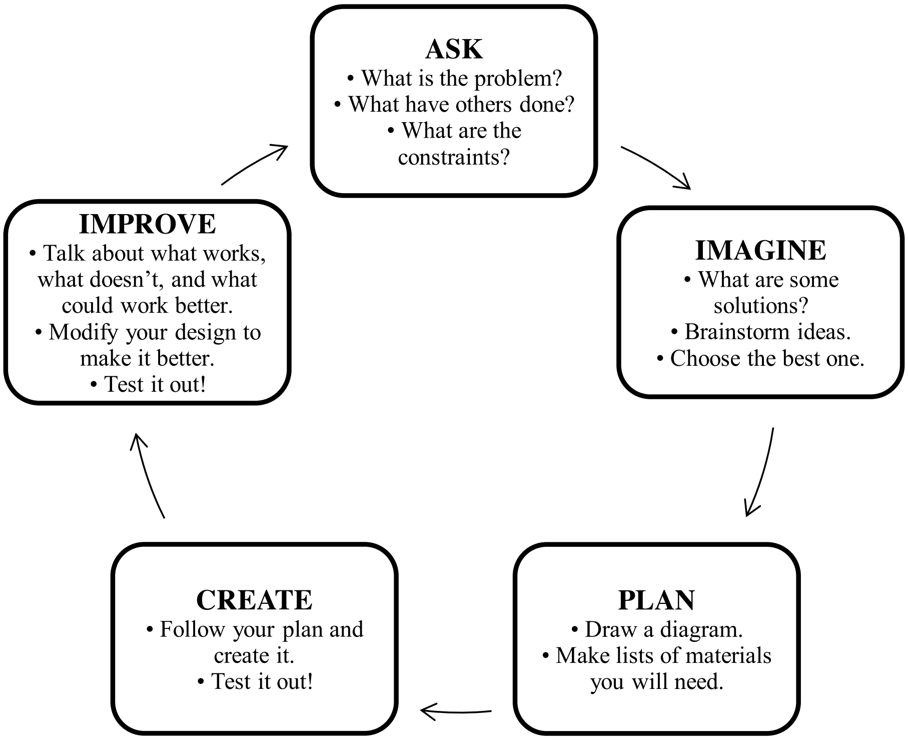

Fig. 2. The engineering design process (Cunningham & Hester, 2007).

4.3. Development and implementation of STEM activities

During development of the STEM activities, it was taken into consideration that students produce solutions for basic environmental issues and interdisciplinary problems related to alternative energy, electrical energy, human and environmental interaction, matter and change, reflection in mirrors and absorption of light from selected units and topics in current science education programs in Turkey. The activities for STEM education should be structured using 5E learning model based on constructivist education as suggested by current science education programs in Turkey (MoNE, 2018). STEM activities were applied in the classroom for 10 weeks and over 20 lesson hours. The students worked in groups of 4 students. During implementation process, 8 activities were applied to the students and 5 activities of these activities were carried out in the classroom. STEM activities were modified activities from the literature and NASA STEM activities based on the steps of engineering design process.

In STEM activities, the subjects of energy and astronomy from science subjects were addressed, while the subjects of mathematical expression, measurement and data processing from mathematics subjects were discussed. In the technology aspect of STEM activities, it was benefited from simulation programs (https://phet.colorado.edu/tr/) to establish a model and show science and math subjects visually for students. In the engineering aspect of STEM activities, the design task was suitable to be conducted by using engineering design process (repeatable steps) so that design products can be improved and enhanced. Examples of products developed by students were given in Appendix A. In Table 1 below, a complete list of STEM activities and the relationship of STEM disciplines were provided.

The activities were based on the engineering design process. Students were expected to make a design by using the engineering design process which they learned in the first week in this context by giving them a problem situation from daily life in the activities. This engineering design process consisted of determining the problem or need, developing the possible solutions, determining the most suitable solution, prototyping and testing, and communication. Firstly, the students determined the criteria of the design, their limitations, and researched about the design by asking questions. Secondly, students brainstormed possible solutions, researched about these proposals, prepared draft reports and build prototypes, did group work and used experimental data. Thirdly, the students decided the most suitable solution by making a profit and loss analysis and provided reasons for the best solution. Fourthly, students made prototypes, test the prototype by performing appropriate tests, evaluate the prototype in accordance with the test results, and finalize the design with improvements and redesigns. Finally, students presented final design, tested and modified their designs to make best. This engineering design process was summarized in Fig. 2.

5. Data analysis

Our analysis was performed by using the quantitative data from the STEM-CIS, Motivated Strategies for STEM Learning Questionnaire, Science Process Skills Test and Science Achievement Test. The data were distributed normally according to skewness and kurtosis values. Therefore, the covariance analysis (ANCOVA) was performed to determine whether there was a statistically significant difference between the post-tests. Assumptions were checked to perform covariance analysis. In order to eliminate the differences between the control and experimental groups and the effect of the pre-test from the internal validity threats, the pre-test scores of the groups from the scales and tests were determined as covariant and included in the analysis. The eta-square (effect size) coefficient was used to determine the effect power of the independent variable on the dependent variable.

Content analysis technique was used to analyze qualitative data derived from interviews. Firstly, interview data were converted to text and checked by the researchers. Secondly, the researchers generated preliminary table of coding categories. Later, the relevant categories were associated into more general categories. Moreover, researchers read over all form and labeled the answers of students into the convenient categories. Finally, data obtained from interview form were quantified as frequencies and illustrated by sample students' statements. Answers of students were coded by the researchers twice, and intra-rater reliability was determined as 0.81 to check coding consistency (Miles & Huberman, 1994).

Table 2
Analysis of co-variance for all dependent variables by group.

Measure	Experimental group				Control group				*F*	*p*	η^2
	Pre-test		Post-test		Pre-test		Post-test				
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*			
Science process skills	11.10	2.32	22.91	4.16	11.59	4.14	14.00	2.98	69.38	.000	.629
Science achievement	11.05	5.09	14.59	3.61	12.09	5.15	12.95	3.43	3.95	.054	.088
Career interest in science	46.23	4.16	50.23	3.54	44.05	7.86	40.50	6.32	37.51	.000	.478
Career interest in math	39.86	8.80	47.68	5.67	39.64	12.46	34.73	6.66	60.30	.000	.595
Career interest in technology	43.27	7.13	48.05	5.13	44.73	7.35	44.32	7.34	5.65	.022	.121
Career interest in engineering	40.55	8.27	49.18	4.44	41.77	7.98	41.59	7.85	16.18	.000	.283
Control beliefs	18.77	5.79	21.64	4.50	19.68	3.48	20.36	3.06	1.51	.226	.036
Intrinsic goal orientation	18.27	6.59	22.50	4.09	18.73	4.40	20.14	3.03	5.35	.026	.116
Task value	27.82	9.36	34.14	6.56	32.18	4.18	29.55	4.87	7.29	.010	.151
Extrinsic goal orientation	18.05	6.40	22.64	4.36	22.50	2.58	19.73	3.18	8.20	.007	.167
Self-efficacy for learning and performance	36.77	13.13	44.73	7.65	41.59	5.09	39.32	6.06	7.87	.008	.161
Test anxiety	22.86	7.67	26.95	4.96	23.50	4.32	24.59	4.23	2.72	.107	.062

6. Findings

6.1. Quantitative findings

To determine the effect of the STEM activity based education program, ANCOVA was employed to analyze whether there was significant differences in the science process skills, science achievement, and interest in pursuing STEM careers and motivation in STEM education between the control and experimental groups. The post-tests for the science process skills, science achievement, interest in pursuing STEM careers and motivation in STEM education was used as the dependent variable and the pre-tests of these variables was used as the covariate.

For science process skills, the result of the ANCOVA indicated that there was a significant difference between the two groups: $F(1, 41) = 69.383$, $p < .05$, $\eta^2 = 0.629$ (see Table 2). The effect size for the science process skills was large according to Cohen (1988). The STEM activity education program could increase predominately students' science process skills in the STEM education.

For science achievement, the result of the ANCOVA indicated that there was no significant difference between the two groups: $F(1, 41) = 3.950$, $p > .05$, $\eta^2 = 0.088$ (see Table 2). The STEM activity education program could enhance students' science achievement in the STEM education process but it was statistically non-significant.

The result of the ANCOVA showed that there was a significant difference between two groups for career interest in science, math, technology, engineering ($p<.05$). The effect size for the career interest in all STEM disciplines was large according to Cohen (1988). The STEM activity education program could enhance significantly students' career interest in all STEM disciplines in the STEM education process.

The result of the ANCOVA indicated that there was a significant difference between two groups for intrinsic goal orientation, task value, extrinsic goal orientation and self-efficacy for learning and performance. However, there was no significant difference between the two groups for control beliefs and test anxiety. According to Cohen (1988), the effect size for the intrinsic goal orientation, task value, extrinsic goal orientation and self-efficacy for learning and performance was large. The STEM activity education program could enhance influentially students' intrinsic goal orientation, task value, extrinsic goal orientation and self-efficacy for learning and performance in the STEM education process.

Table 3
Theme, codes and frequencies of student views about STEM activities.

Theme	Codes	Frequency
STEM disciplines	relationship between science, math and technology	11
	relationship between science and technology	6
	relationship between science, math, technology and engineering	3
	relationship between science and mathematics	2
Advantages of STEM education	making designs for daily life	13
	life skills	13
	development of stem products	12
	permanent learning	7
	out-of-class activities	7
	entertainment and design	7
	learning efficient use of energy	6
	practice-based education	5
	active participation	5
	meaningful learning	5
	academic achievement	5
	learning of energy transformation	4
	increasing motivation	4
	making experiments	2
Limitations of STEM education	lack of task sharing	4
	scheduling	3
	lack of handcraft	3
	disagreement during the activities	3
	failure of design	3
Suggestions for STEM education	implementing in science courses	24
	to be in math courses	10
	hands-on activities for science courses	9
	to increase the time for designing	5
	designs to be realistic in size	5
	activities to be based on technology and design	5
	to be integrated into other courses	5
	design based	4
	more improved materials	2
	working design	2

6.2. Qualitative results

According to results of the interviews, students' views on interdisciplinary and science-engineering integration, advantages and limitations in implementation process of STEM activities and their suggestions for the activity process were determined. Main themes, codes and frequency values of codes were given in Table 3.

6.2.1. STEM disciplines

When the answers to the question "What disciplines do you think science is related to? What is the relationship between science and technology, engineering and mathematics?" were examined; the students had variety of views on the interdisciplinary relationship among STEM disciplines. According to the codes that emerged from students' answers, students viewed that there was mostly the relationship between science, math and technology and the relationship between science and technology. However, the relationship between science and mathematics, the relationship between science, math, technology and engineering were less emerged from the statements. According to the students' views, students could establish the relationship between science, mathematics and technology. Below are examples of some of the views:

We have learned interdisciplinary topics in science and mathematics by using the theoretical knowledge in math and science; we conducted experimental studies in technology and design areas. We took mathematical measurements and used them in engineering and design. We learned STEM topics in interdisciplinary approach. (Student HT)

We have also used science, technology and engineering knowledge to design STEM projects. Actually, STEM projects based on science, technology and engineering. (Student HA)

STEM products were about math when we took measurements to make design. We used more science, math and technology together in the solar-powered car system. (Student SI)

6.2.2. Advantages of STEM education

When the answers to the question *"What are the benefits of STEM activities? What are the advantages of STEM activities and practices in science classes?"* were examined; students were found to have mostly positive views towards STEM teaching. Students' views about the advantages of STEM education were making designs for daily life, daily living skills, the development of STEM products, permanent learning, out-of-class activities, entertainment and design, learning efficient use of energy, practice-based education, active participation, meaningful learning, academic achievement, learning of energy transformation, increasing motivation and making experiments. Students were found to benefit most from STEM activities in designing for daily life, gaining daily life skills, and developing STEM products. Students supported their answers with design examples for everyday life. Below are examples of some of the views:

I planned to operate the solar panels by mounting them on our lawn mower to mow the lawn in the garden in everyday life. I used to run it on solar power. (Student MT)

I think cars with gasoline and diesel pollute the air. So I used to design big solar-powered cars instead of air-pollutant cars. We could have kept the air clean and lived better. (Student AAS)

6.2.3. Limitations of STEM education

When the answers to the question "What are the disadvantages of STEM activities and practices in science classes? What difficulties did you experience when implementing STEM-based designs?" were examined; students talked about the limitations they faced in implementing STEM activities. Students experienced difficulties such as lack of task sharing, scheduling, lack of dexterity, disagreement and failure of design during the activities. Below are examples of some of the views:

During group working, two participants in the foursome were making all the work, not everyone was participating. So, we had no equal group working and participation to activities. (Student HT)

There was trouble with the duration. Due to the fact that our projects were generally not completed within the given time. It took a long time to design and create. (Student EK)

For example, we had a little difficulty in the solar car. It was kind of hard to set up. The materials were both very small and using a screwdriver made it a bit difficult. (Student MC)

It was difficult to make decisions within the group. We had a hard time making an agreed decision. (Student ST)

Our solar cooker did not work exactly as planned. In another design, electricity engine did not run as efficiently as we wanted. (Students GY)

6.2.4. Suggestions for STEM education

When the answers to the question *"What your recommendations are for better implementation of STEM-based activities in science classes?"* were examined; students presented suggestions for the integration of STEM activities into science and other courses. STEM activities for students to be in science courses, math lessons, hands-on activities for science courses, and the increase of the time for designing, designs to be realistic in size, activities to be based on technology and design, to be integrated into other courses, design based, more improved materials and the working design were suggestions of students for STEM activities. It was inferred that students wanted that simple machines and energy subjects were integrated especially in science classes. Below are examples of some of the views:

We could design with small spool systems to use in our science and math courses through STEM activities even if it wasn't as big as the real spool system. (Student AAS)

We could apply our STEM activities directly on heat and energy issues. (Student HT)

Integration of STEM in science subjects would be very good. The subjects would be energy types, light and heat. Because we could integrate engineering and technology in science courses to make designs about science and engineering. (Student BA)

Integration of math subjects with STEM activities would be very good. Because we would use math knowledge to measure and design science related products. (Student IA)

For example, we could make the water rocket bigger and send the water rocket further away with the compressor. (Student MT)

As I said, I'd put a dynamo in the solar-powered car and make it with a lamp. In this way, I could turn my design into a real car. (Student AAS)

7. Discussion and conclusion

In this research, the effect of STEM activities on the science process skills, motivation and career interests, science achievements and views about STEM of 7th grade students were studied. The findings showed that the mean scores of science process skills of the students in the experimental group significantly differed from the control group. In STEM activities, students identified a problem, formulated a hypothesis, designed the process for the development of the experiment or product, and drew sketch to create a model. As these steps were similar with the steps in scientific process skills, students could improve their science process skills. Moreover, the successful integration of STEM activities into the courses improved the science process skills of the students. In this way, it helped them to learn the content of science courses successfully (Çavaş, Bulut, Holbrook & Rannikmae, 2013). STEM activities were seen as a process in which students could use their science process skills (Strong, 2013). There were similarities between the engineering design process used in STEM activities and the use of science process skills. According to the engineering design process, firstly, the problem was defined and the determination of the variables related to the problem came as similar with the science process skills. Similarly, in the design process, while students were searching for possible solutions and making the prototype of the most appropriate solution, they used science process skills such as experimenting, measuring, using appropriate tools, recording data, using data and modeling, interpreting data and drawing a conclusion. Therefore, the development of the science process skills of the students who engaged in engineering design process in the implementation of STEM activities was an expected result.

Students' science achievement increased when they engaged in STEM activities but this increase was not statistically significant compared to the students in the control group. Studies about STEM education revealed controversial results on this subject whether STEM-based activity program had statistically significant effect on academic achievement or not. For example, James (2014) showed that although seventh grade students who received STEM education showed improvement in science achievement, students in experimentation group were less successful than the traditional students. STEM training was ineffective in increasing the success of students in national examinations. Similarly, Clifford (2016) examined the standard test scores of disciplinary and interdisciplinary science schools applied at the eighth grade and found that there was not a significant difference between the academic achievements of the disciplinary and interdisciplinary science schools. In the light of the literature and achievement test results in this research, the controversial results were obtained about the standardized tests of students' academic achievement. Because, the standardized tests evaluated what students know about scientific knowledge. However, STEM-based activity program aimed to develop actually what the student knows, as well as what they do with it and how they can use it (NRC, 2011; Saxton et al., 2014). For this reason, traditional measurement methods based on product were not sufficient to decide the achievement of students in STEM education and so the process based assessment and evaluation methods covering the whole process was recommended (Akgündüz et al., 2015).

In STEM activities, the opportunity to conduct research inquiry as a scientist and to design like an engineer increased their career interests. The participation of students in STEM activities increased their career interest in STEM fields in the interviews with the sixth grade students about STEM activities (Gökbayrak & Karışan, 2017). Ralston, Hieb and Rivoli (2012) found that students who engaged in STEM activities during four-year secondary school, pursued to high schools suitable for STEM careers at the end of secondary school. In his research with African students, Hare (2017) found that participating in STEM activities and receiving STEM training positively influenced on students' interest in STEM careers and fields. In the light of the findings, the students' participation in STEM education for the first time had a positive effect on their STEM career interests, allowing them to understand the integration of STEM fields and to realize the activities by following the engineering design process.

In this research, STEM activities improved students' motivation. Due to the STEM activities, students were excluded from a process in which they only used their memorization knowledge and engaged in activities that attached importance to their affective and psychomotor skills. Although the students were only listeners and inactive participants in traditional class atmosphere, they made their own designs, presented their own ideas and motivated to be successful through the guidance of teacher in the application of STEM activities. Similarly, there were many studies suggesting that STEM activities increased students' motivation (Kong & In-Cheol, 2014; Park & Yoo, 2013). As a result of integrating STEM with the media for 21 weeks, 8th grade students in a public school, their attitudes towards science and media design process improved, their motivation improved, their willingness to engage in class discussions and their scientific content increased (Karahan, Canbazoglu Bilici & Ünal, 2015). The students' engagement in engineering design process increased their motivation and their permanent learning (Bozkurt Altan, Yamak & Bulus Kırıkkaya, 2016; Yıldırım, 2016).

Although the students were internally and externally motivated to engage in STEM-based activities, they were negatively affected by test anxiety. In order to overcome this situation, STEM activities needed to be more practical, integrated into science and mathematics courses, and designs should be made in more realistic dimensions, and there should be more time and equal distribution of work to complete the task. The studies in the literature and the findings of this research were parallel to each other. Gökbayrak and Karışan (2017) stated that the sixth grade students' views on STEM activities were instructive, entertaining, motivating and mind-enhancing. Students were able to learn more fun and more comfortable because they did not have note anxiety, and they motivated them to work. English (2017) had examined many studies and found that STEM integrated courses and practices would have a positive effect on students' motivation and success.

Within the scope of the research, STEM activities based on realistic life problems, prepared with an understanding based on research and inquiry, increased students' interest and views on STEM fields and careers. For this reason, it was beneficial to integrate with science, mathematics and technology courses to provide experience in engineering design process and to consider the needs of students.

In the traditional learning approach, participants act passively and wait for the information. This situation usually reduces students' motivation, career interest in STEM, science achievement and science process skills. Therefore, teachers should implement alternative learning methods to attract students' interest and effectively attend them in activities. At this point, STEM activities were very effective. STEM activities appealed to students' different skills. While students in control group made experiments with demonstration methods, students in experimental group could set up the experiment, develop suggestions for the solution of the problem by using problem solving skill, and develop products using the engineering design process under the guidance of the teacher. For example, while students in control group were given scientific knowledge about unit of absorption of light directly by making presentations and demonstrations, students in experimental group was taught how to use this scientific knowledge about absorption of light by designing solar oven and solar car projects. Since STEM activities include real-life situations, they enable them to connect with daily life. Consequently, STEM activities made significant difference on students' STEM career interests, motivation, science process skills, science achievement and their views on STEM education.

The reasons for the difference between the experimental and control groups in terms of scientific process skills, career interests and motivation can be explained by the fact that they structured their knowledge about the subject presented within the scope of STEM activities as a result of their own research and found the opportunity to transform this knowledge into engineering design by using technology. In addition, students have the opportunity to realize and use their own talents in STEM activities, the technological tools and materials used during the activities affect the interest in STEM fields, and the products based on the engineering design process in STEM activities. During STEM activities, students have the opportunity to use important skills such as doing research, working in groups, using technology, designing and making presentations more than traditional classes. Therefore, there are differences in skill development, STEM career interest and motivation between classrooms where STEM activities are applied and traditional classrooms.

8. Suggestions

In this study, it was limited to 22 students in the experimental and control groups and 20 h of STEM activity practice, two hours a week. The classrooms were not designed in accordance with group work and the materials required for STEM activities are not available in the classroom. In addition, the arrangement of the tools and equipment used in the activities and the preparation of the necessary space and infrastructure for the use of technological equipment require a special time before the lesson. Particularly in the product design process, it was tried to provide sufficient space and order in the classroom for group work. Despite these limitations of the study, there were significant changes in students' science process skills, career interests, motivations and views about STEM activities even during the 20-hour STEM activity period. For this reason, it was often recommended to integrate STEM activities in other courses as well.

When STEM education started at the secondary school level, the students' readiness levels for STEM education were inadequate in hand skills, design skills, STEM knowledge and skills according to qualitative findings in this research. The students did not conduct engineering design and hands-on activities in the other courses. It might be insufficient for students to experience STEM education only at secondary school level in order to acquire STEM skills and motivate them to pursue STEM careers. Therefore, further integration of STEM education into secondary education programs and courses was recommended.

In the research, students' interest in engineering fields increased. STEM integration was needed to improve students' engineering design skills. Science, mathematics and technology design courses might be conducted in an interdisciplinary sense in order to maximize students' engineering design skills and their ability to offer creative products.

The views of the students about STEM activities showed that the students wanted to engage hands on activities in design and daily life context. For this reason, STEM activities for students should have real life context, be realistic, and be based on engineering skills.

In the interviews, the students stated that the workload was not evenly distributed while working collaboratively. The lack of STEM activities in the lessons and the fact that students were not accustomed to such collaborative activities hindered working in cooperation in the implementation of STEM activities. The integration of STEM activities in the lessons can increase the tendency of students to work in groups, and this is an important feature to be gained in today's professions.

Author statement

Emrah Higde: Conceptualization, Methodology, Software **Emrah Higde & Hilal Aktamış**: Data collection, Writing- Original draft preparation. **Emrah Higde**: Visualization, Investigation. **Hilal Aktamış***:* Supervision.**:** **Emrah HİĞDE**: Software, Validation.: E**mrah Higde & Hilal Aktamış:** Writing- Reviewing and Editing.

Appendix A

Examples of students' design.Solar.Owen, Soft Landing on Mars, Solar Car

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