

Examination of the Effects of STEM Activities in Physics Subjects on Students' Attitudes and Problem-Solving Skills

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Abstract: *The aim of this study was to examine the effects of STEM activities on students' attitudes towards STEM and problem-solving skills by taking their components into account. An experimental design with pretest-posttest control group was applied in the study. Quantitative and qualitative data collection tools were used. The participants of the study consisted of students studying in two different branches in the 7th grade of a public school. The implementation of the research was carried out for five weeks within the scope of force, work and energy concepts. In the experimental group, STEM activities developed by taking the science curriculum into account were included in the lessons. In the control group, lessons were taught according to the curriculum. The conclusions drawn based on the results of this study can be listed as follows: First, STEM education, which is carried out within the scope of physics subjects in the science course and which also includes mathematics, engineering and technology related acquisitions, ensures that students' attitudes towards STEM develop positively. STEM attitudes progress especially in the direction of establishing a relationship between mathematics, science and engineering learning and STEM. Second, STEM education improves students' problem-solving skills. The increase occurs in all areas of problem-solving skills, including the individual's confidence in problem-solving skills, willingness to cope with difficult problems encountered, and the feeling that they have mastered the situation. Last, when there is no STEM-oriented activity in the science curriculum, students' problem-solving skills, especially in the area of confidence, decrease. Considering that STEM is an interdisciplinary subject combining two or more*

disciplines and is based on authentic contexts; STEM activities provide students for establishing relationships between STEM disciplines and developing problem-solving strategies.

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Introduction

In the current age, the need for individuals who question, think critically, solve problems, collaborate, produce and have the skills to do what machines cannot do has increased. Defined as 21st century skills, these skills include high-level skills and learning tendencies that students need to develop in order to be successful in this age where they can easily access information (Dede, 2010). Students are also expected to have 21st century skills to be employed after graduation. All these needs have led to the emergence of new reforms in education. STEM education is an approach developed for this need. The term STEM education refers to teaching and learning in the fields of science, technology, engineering and mathematics (Gonzalez & Kuenzi, 2012). STEM education allows students to create and apply different strategies by working collaboratively in an engineering design process to produce solutions to daily life problems. STEM is not only an approach that includes four disciplines but also develops skills such as critical thinking, questioning, problem-solving and design beyond disciplines (Force, 2014). STEM education is required for students to gain the abilities that will enable them to look at problems from different aspects and produce solutions, think systematically and creatively, and offer solutions from 21st century skills (MNE, 2016). Accordingly, the aim of this study was to investigate the effects of STEM activities on students' attitudes towards STEM and their problem-solving skills by considering components of their variables.

Conceptual Framework

The concept of attitude is defined as “an individual’s mental, emotional and behavioral reaction to any object, social issue, or event in his/her environment or to himself/herself based on his/her experience, knowledge, feelings and motives” (Inceoglu, 2000, p.13). Attitude change is also a learning process. “Measuring attitude allows educators to plan accordingly by determining students’ habits, study strategies and learning methods” (Ogan-Bekiroglu, 2004, p.76). STEM attitude refers to students’ tendencies towards STEM education. Effective STEM integration depends on the positive development of students’ STEM attitudes. In order to improve students’ STEM attitudes, it is necessary to create spaces in the course where each student can be involved in the process. Since STEM activities are student-centered, ensuring that each student takes responsibility according to his/her interest and ability while doing group work can be effective in developing students’ STEM attitudes.

Factors that are effective in the problem-solving process can be categorized into three groups: attitude, experience and cognitive ability (Fisher, 1990). The stages of problem-solving include defining and

analyzing the problem, generating alternative solutions, planning, implementing and evaluating the most appropriate solution (Polya, 1971). STEM is a meta-discipline that offers a student-centered and research-based method for problem-solving (Madison-Harris, Muoneke & Times, 2012). In STEM applications, students have to use various mathematical concepts and methods while analyzing a problem. The processes of generating creative solutions by analyzing the problem and reaching a solution by choosing the appropriate one among these solutions can affect students' development of problem-solving skills. Using engineering as a problem-solving context that connects science and mathematics knowledge allows students to increase their creativity and find innovative solutions (English, Hudson & Dawes, 2013). Meyrick (2011) also states that incorporating STEM activities into teaching encourages students to work together to design solutions to problems in a basic and authentic environment, using real-world data and problems.

Steps have been taken towards the STEM education approach in our country. In 2017, an applied science and engineering unit was included in the middle school science curriculum. In this unit, learning objectives such as recognizing problems related to the subjects previously covered, defining the problem, presenting different solution methods, choosing the appropriate one by comparing these methods, designing a product and presenting this product were included (MoNE, 2016). It is thought that STEM activities would make important contributions by providing students with the opportunity to test what they have learned and discover how to apply their knowledge in a meaningful way.

Research on the Effects of STEM Education on Attitudes and Problem-solving Skills

In recent years, there has been an increase in the international research (Boyle, 2019; Guzey et al., 2016; Han, 2017; Hussain, Lindh & Shukur, 2006; Lie, Guzey & Moore, 2019; Lou et al., 2011; Martaningsih et al., 2022; Nugent et al., 2010; Parno, Yuliati & Ni'mah, 2019; Popa & Ciascai, 2017; Sari, Selisne & Ramli, 2019; Scott, 2012; Tseng et al., 2013) examining the impacts of STEM education on problem-solving skills or attitude towards STEM. For example, Guzey et al. (2016) worked with 275 middle school students by using one-group pretest-posttest experimental design and found that engineering design-based science education had a positive effect on students' attitudes and achievement. These studies indicated positive aspects of STEM on thinking ability, interest in learning science and mathematics, curiosity, problem-solving skills, and STEM attitude. However, they have limitations because most of them used only quantitative data collection tools and it is difficult to make generalization due to participants' divergent age.

Considering that there is a significant relationship between problem-solving skills, which are in the category of learning and innovation within 21st century skills, and attitude towards STEM education (Akcanca, 2020), there is a need for research examining the effect of STEM education on students' attitudes and problem-solving skills together. In addition, using both quantitative and qualitative methods at the same time increases the validity of the findings.

There is plenty of research about STEM approach in nationwide (Gulhan & Sahin, 2016; Hebebcı & Usta, 2022; Karisan & Yurdakul, 2017; Kirgiz & Koyuncu, 2016; Kucuk & Sisman, 2020; Kurt & Benzer, 2020; Pekbay, 2017; Sari et al., 2022; Yalcin & Erden, 2021). These studies showed increase in students' problem-solving skills, scientific creativity, STEM attitude, and critical thinking skills after they encountered with STEM activities. When the studies conducted in Turkiye are reviewed, it was realized that the studies investigating the effects of STEM education in physics on students' attitudes towards STEM and also on problem-solving skills are rare.

In addition, among the mentioned studies, only Popa and Ciascai (2017) surveyed students' attitudes towards STEM education in the categories of students' attitudes towards engineering careers, interest in different STEM fields, and choice of STEM career. Further research is needed to examine the effects of STEM on problem-solving skills and STEM attitudes by dividing them into subcategories. Therefore, the following research questions were answered in the current study:

What are the effects of STEM activities in physics on students' attitudes toward STEM and its sub-dimensions?

What are the effects of STEM activities in physics on students' problem-solving skills and its sub-dimensions?

Methodology

In this study, an experimental design with pretest-posttest control group was applied. While quantitative data collection methods were used in the experimental and control groups, qualitative data were also collected in the experimental group to support the quantitative findings.

Participants

The participants of the study consisted of students studying in two 7th grade classes in a public school in Istanbul. Accessibility and getting permission from the administration were effective in the selection of the school. There are 13 7th grade classes in the school. Permission taken from the teachers was effective in the selection of the participants. An experimental group was

Table 1. Control and Experimental Groups Implementation Process.

Time	Control Group	Experimental Group
Before the Instruction	Pretest: Application of STEM Attitude Scale and Problem-Solving Inventory	Pretest: Application of STEM Attitude Scale and Problem-Solving Inventory
Wk 1 Lesson 1	Lecture (Mass and Weight Relationship)	STEM Activity (Transportation System)
Wk 1 Lesson 2	Lecture (Mass and Weight Relationship)	Lecture (Mass and Weight Relationship)
Wk 2 Lesson 1	Lecture and Question Solution (Interactive Education Application)	STEM Activity (Amusement Park Rollercoaster)
Wk 2 Lesson 2	Lecture (Force, Work and Energy Relationship)	Lecture (Force, Work and Energy Relationship)
Wk 3 Lesson 1	Lecture (Force, Work and Energy Relationship)	Lecture (Force, Work and Energy Relationship)
Wk 3 Lesson 2	Lecture (General Review for the Exam)	Lecture (General Review for the Exam)
Wk 4 Lesson 1	Lecture (F.7.3.3. Energy Conversions)	Lecture (F.7.3.3. Energy Conversions)
Wk 4 Lesson 2	Lecture (F.7.3.3. Energy Conversions)	Lecture (F.7.3.3. Energy Conversions)
Wk 5 Lesson 1	Lecture and Question Solution (Interactive Education Application)	STEM Activity (Don't Break the Egg)
Wk 5 Lesson 2	Lecture and Question Solution (Interactive Education Application)	STEM Activity (Ship Design)
After the Instruction	Posttest: STEM Attitude Scale and Problem-Solving Inventory	Posttest: STEM Attitude Scale and Problem-Solving Inventory

determined by lot from two 7th grade classes of the teacher who volunteered to participate in the study. The experimental group consisted of 30 students, 18 boys and 12 girls, and the control group consisted of 34 students, 19 boys and 15 girls. The age range of the participants was between 13-14 years old and they had not taken a STEM course before.

Instructional Context

The instruction was carried out in the science class within the scope of force, work and energy subjects for five weeks. In the experimental group, STEM activities were implemented in the lessons. In the control group, the lessons were taught according to the curriculum and interactive education application was used in the lessons. All lessons in the control group and lessons other than STEM activities in the experimental group were taught by their science teacher. In the experimental group, STEM activities were conducted by the first researcher under the supervision of the science teacher. The activities were developed by the researchers by taking the acquisitions in the science curriculum into account. Science lessons were held for four hours a week, two hours a day. Each lesson hour was 40 minutes. As given in **Table 1**, the subjects were completed in equal time in the experimental and control groups. In both groups, students worked as groups.

In the experimental group, four STEM activities (transportation system, amusement park roller coaster, no broken eggs, ship design) were integrated with the science course. While preparing the lesson plans, the 5E

model was used. The first researcher was a practitioner and observer in the experimental group and an observer in the control group. She received 32 hours of STEM Training and four days of STEM Trainer Training. The researcher did not engage in any behavior that would direct the students and affect the results of the research. In order to prevent the experimental group students from being affected by the activities of a different person coming from outside, their own science teacher was also present as an observer in the lesson.

Quantitative Data Collection Tools

STEM Attitude Scale

STEM Attitude Scale (SAS) developed by Guzey, Harwell, and Moore (2014) and adapted into Turkish by Yilmaz et al. (2017), was used to determine students' attitudes. The scale is a 5-point Likert-type scale (1: Strongly Disagree, 2: Disagree, 3: Undecided, 4: Agree, 5: Strongly Agree) and its reliability coefficient is 0.86. The SAS has 24 items and consists of four sub-dimensions: Personal and social implications of STEM (8 items), math and science learning and its relationship with STEM (6 items), engineering learning and its relationship with STEM (6 items), technology learning and use (4 items). The highest score that can be obtained from the scale is 120 and the lowest score is 24. The STEM Attitude Scale was administered to both groups by the researcher and the students were given 30 minutes to answer the questionnaire.

Problem-solving Inventory

The Problem-solving Inventory (PSI), developed by Heppner and Peterson (1982), translated and edited into Turkish by Sahin, Sahin, and Heppner (1993), and adapted by Kardas, Anagun, and Yalcinoglu (2014), was used to determine the problem-solving skills of the students in the study. The inventory is suitable for the middle school level and has 20 items rated on a 4-point Likert scale (1: Strongly Disagree, 2: Agree Occasionally, 3: Agree Mostly, 4: Strongly Agree). The PSI consists of three sub-dimensions: Confidence in problem-solving ability (8 items), approach-avoidance (7 items) and personal control (5 items). Kardas et al. (2014) found the Cronbach Alpha reliability coefficient of the scale to be 0.74. The highest score that can be obtained from the scale is 80 and the lowest score is 20. The PSI was administered to the experimental and control groups as pre-test and post-test by the researcher. Students were given 30 minutes to complete the inventory.

Qualitative Data Collection Tools

STEM Activity Worksheets

Before starting each activity, STEM activity sheets prepared by the researchers were distributed to the students and they were asked to fill them in during the activity. Students filled in the activity worksheets individually for the four STEM activities. The activity worksheets consisted of real-life problems, engineering design processes, design testing steps, and predict-observe-redesign sections.

Sound Recordings

During the STEM activities, voice recorders were placed on the tables where the students divided into groups to record their discourse.

Classroom Observation Form

During the STEM activities, the researcher observed each student and transferred the data she obtained from the notes. These notes included behaviors for STEM attitude goals and problem-solving goals. The photographs and audio recordings taken during the activities were used with the observation data.

Data Analysis

Quantitative Data Analysis

During the quantitative data analysis, kurtosis and skewness coefficients, Kolmogorov-Smirnov and Shapiro Wilk values were examined first. Since the results showed that the data were normally distributed, parametric tests were applied. Paired group t-tests were used to determine whether there was a statistical difference between the pre-test and post-test scores of the experimental and control group students. For intergroup comparisons of the experimental and control group students, independent t-tests were conducted for the SAS and PSI scores. Cohen's d value was used to calculate the effect size. In addition, in order to clearly see the change in detail, t-tests were also conducted for the scores of STEM attitude sub-dimensions and problem-solving sub-dimensions.

Qualitative Data Analysis

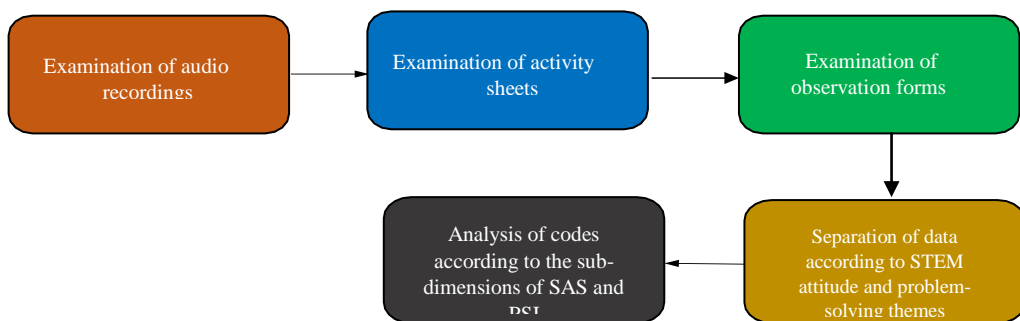


Figure 1. Qualitative Data Analysis Stages.

While analyzing the qualitative data, the voice recorders were listened and the statements were transcribed. Themes were created by using the STEM attitude scale and the problem-solving scale. The data collected from the participants were first separated according to their themes and then matched with the appropriate codes. The codes were determined according to the sub-dimensions of the scales. **Figure 1** shows the stages of analyzing qualitative data. For example, in the audio recording taken during the STEM activity, the student’s statement “we understood the Force and Energy unit better by creating our own designs” was matched with the EL (Engineering Learning and its relation with STEM) code since it was related to engineering learning. When the answers given by the students to the question “What do I know?” related to the real-life problem in the STEM activity papers were examined, the statement “we can benefit from the potential energy of flexibility” was matched with the code PC (personal control) since it is related to problem-solving. In the abbreviations of the codes, the initials of the meaning they express were used.

To understand the reliability of the coding, the codes given by the first researcher were re-examined by the second researcher. When the two researchers compared their coding, the Cohen’s Kappa reliability value for attitude was found to be 0.74 with 88% consensus and the Cohen’s Kappa reliability value for problem-solving was found to be 0.78 with 92% consensus. Since there is a general opinion that the Cohen Kappa value should be at least 0.60 (Wood, 2007), these values show that the coding for attitude and problem-solving have sufficient reliability.

Table 2 presents the codes related to the STEM attitude theme. The engineering approach in STEM education is a strategy for solving a given real life problem. While determining the Engineering Learning and its

Table 2. Codes Related to the STEM Attitude Theme.

Theme 1: STEM Attitude
MSL: Math and Science Learning and its Relationship with STEM
EL: Engineering Learning and its Relation to STEM
PSI: Personal and Social Implications of STEM
TLU: Technology Learning and Use

Table 3. Codes Related to the Theme of Problem-Solving Skills.

Theme 2: Problem Solving
AA: Approach Avoidance
PC: Personal Control
CPSA: Confidence in Problem Solving Ability

STEM relationship (EL) code, the engineering design process stages proposed by Morgan, Moon, and Barosso (2013) were used. These stages are as follows: Identification of the problem and its constraints, research, idea generation, analysis of generated ideas, generation the solution, testing and refining the solution, and communicating and thinking about the solution. The codes belonging to the problem-solving theme are given in **Table 3**. Approach avoidance (AA) refers to one's willingness to cope with the problems encountered; personal control (PC) refers to the feeling of whether one has control over the problem or not; and confidence in problem-solving ability (CPSA) refers to the feeling of confidence in problem-solving skills (Heppner & Petersen as cited in Kardas et al., 2014).

Internal Validity

The high internal validity of the research depends on the fact that the results reflect the reality. In order to ensure internal validity in the study, the participants were selected unbiasedly, data collection tools were applied to the groups by the same person and care was taken not to lose any participant. Effects and bias that would create expectations in the experimental group and cause different results were avoided. Reliability calculations were made for quantitative data collection methods. In addition, inter-rater reliability was calculated for qualitative analysis.

Table 4. Descriptive Statistics Values According to Pre-Test and Post-Test Scores of SAS.

Groups		N	Min	Max	\bar{x}	Skewness	Kurtosis
Experimental Group	Pre-Test	30	3.54	5.00	4.28	0.195	-1.007
	Post-Test	30	3.61	5.00	4.49	0.005	-0.310
Control Group	Pre-Test	34	3.29	4.68	4.20	-0.706	0.409
	Post-Test	34	3.14	4.71	4.19	-0.833	0.462

Table 5. Paired t Test Results of the Experimental Group's STEM Attitude Scale Scores.

Groups	N	\bar{x}	sd	df	t	p	Cohen's d
Pre-Test	30	4.279	0.438	29	3.637	0.001	0.664
Post-Test	30	4.492	0.404				

Results and Discussion

Effects of STEM Activities on STEM Attitude

Quantitative Findings and Discussion

In this section, the findings obtained from the STEM attitude scale before and after the application are given. Since the Cronbach Alpha value calculated for this study was 0.89, the scale is reliable. Kolmogorov-Smirnov and Shapiro Wilk analyses for the pre and post-test values of the experimental and control groups showed normal distribution ($p > 0.05$). **Table 4** shows the descriptive statistics of the STEM attitude scale (SAS) scores. The mean, median and peak values of STEM Attitude Scale pre-test and post-test scores were close to each other. In addition, since the skewness and kurtosis values were in the range of -1.5 and 1.5, it was accepted that the data were normally distributed.

Table 5 shows the dependent groups t-test findings for the STEM attitude scale pre-test and post-test scores of the experimental group. A significant difference was observed between the STEM attitude scale scores before and after the STEM activities in physics subjects ($p < 0.05$). It was observed that the post-test mean scores of the experimental group students

Table 6. Independent Post-Test Results of the Groups' STEM Attitude Scale Scores.

Groups	N	\bar{x}	sd	df	t	p
Experiment	30	4.492	0.404	62	4.08	0.000
Control	34	4.191	0.381			

Table 7. Paired t Test Results of the Experimental Group's Scores for the Sub-Dimensions of SAS.

Sub-Dimensions	N	\bar{x}	sd	df	t	p	Cohen's d
Mathematics and Science Learning							
Post-Test	30	4.472	0.446	29	2.355	0.025*	0.429
Pre-Test	30	4.283	0.463				
Engineering Learning							
Post-Test	30	4.533	0.511	29	4.778	0.000*	0.872
Pre-Test	30	4.177	0.618				
Personal and Social Inferences							
Post-Test	30	4.345	0.506	29	1.773	0.087	0.323
Pre-Test	30	4.204	0.622				
Technology Learning							
Post-Test	30	4.425	0.483	29	1.309	0.201	0.238
Pre-Test	30	4.316	0.549				

*: Sub-dimensions with significant difference

(4.492) were higher than the pre-test mean scores (4.279) ($t = 3.637$). Cohen's d value was found to be 0.664; that is the effect size was moderate.

There was no significant difference between the mean scores of the SAS for both groups before the instruction ($p > 0.05$). **Table 6** indicates that there was a significant difference between the STEM attitude post-test mean scores of the experimental and control groups ($p < 0.05$). The mean score of the experimental group was 4.492 while the mean score of the control group was 4.191. The t value showing the difference between the post-test scores was 4.08. No statistically significant difference was observed between the control group's pre-test and post-test of SAS mean scores ($p > 0.05$). According to these findings, while there was no difference in the STEM attitudes of the students in both groups before the instruction, there was an increase in the experimental group's STEM attitude both within itself and compared to the control group after the instruction. Since there was no

STEM activity in the control group, it is expected that students' STEM attitudes did not change. These results are consistent with the findings of both international (Boyle, 2019; Guzey et al., 2016; Hussain et al., 2006; Kurt & Benzer, 2020; Lou et al., 2011; Melchio et al., 2005; Popa & Ciascai, 2017; Tseng et al., 2013) and national (Gulhan & Sahin, 2016; Karisan & Yurdakul, 2017; Kucuk & Sisman, 2020) studies.

Table 7 shows the t-test results of the experimental group for the sub-dimensions of the STEM attitude scale. It is seen that there was a statistically significant difference between the pre-test and post-test mean scores of "Mathematics and Science Learning and its relationship with STEM" sub-dimension in favor of the post-test ($t_{29} = 2.355$; $p < 0.05$). The Cohen's d value for this sub-dimension was calculated as 0.429 and a small effect size was found. There was also a statistically significant difference between the pre-test and post-test mean scores of "Engineering Learning and its relationship with STEM" sub-dimension in favor of the post-test ($t_{29} = 4.778$; $p < 0.05$). Cohen's d value was calculated as 0.872, indicating that the effect was large. These findings point out that the students were able to establish the relationship between science, mathematics and engineering while doing STEM activities focused on solving daily life problems. Students followed the steps of the engineering design process while generating solutions to the problems and most of the students enjoyed taking part in these activities. Therefore, as expected, it is thought that STEM education also increased the attitude towards engineering education. For the experimental group, there was no significant difference between the pre-test and post-test scores in the "Personal and Social Implications" and "Technology Learning and Use" sub-dimensions. These findings indicate that although the students focused on solving daily life problems, determined the responsibility of each member in the group, evaluated their designs and products, and made self- and peer evaluations, they could not reach a higher level in making personal and social inferences. In addition, although the students created prototypes and selected the materials to be used and justified their reasons, they did not make any progress in technology learning.

Qualitative Findings and Discussion

The findings obtained from the qualitative data by analyzing the experimental group students' audio recordings and activity sheets and the researcher's observation notes are presented in this part. In **Table 8**, examples from the discourse of the experimental group students are given. These statements are included under the attitude codes of Mathematics and Science Learning (MSL), Engineering Learning (EL), Personal and Social Inference (PSI). Statements such as "It was beautiful, it was fun. We increased the air resistance, ours didn't break", "We better understood the

Table 8. Statements Indicating Attitudes Towards STEM Activities.		
Student	Statements	Code
1	It was beautiful, it was fun. We increased the air resistance, ours didn't break.	
2	I'm happy with this class. I've reinforced my knowledge.	
3	We could observe water resistance and the conversion of elastic potential into kinetic energy.	MSL
4	Let's make it aerodynamic, smaller is better.	
5	We took a thin tire. We thought that the thicker one would have less elastic potential and therefore less kinetic energy.	
6	I would like the lessons to continue like this, these lessons are better because we have the opportunity to apply what we know.	
1	We better understood the Force and Energy unit by creating our own designs.	EL
7	We could have made the front of the ship more pointed, but we did a good job.	
8	We can cover it with tape to prevent it from rubbing.	
3	I would like the lessons to go like this, we have fun when it works, we are happy.	
5	It's a lot of fun to teach like this.	
4	We love it when the lessons are like this.	
6	Classes should go like this, it's great. It was a lot of fun.	
8	Lessons can go like this, it can happen.	PSI
1	Of course, I would like the lessons to continue like this.	
2	I have done the egg activity before; of course I would like the lessons to go like this.	
11	I like science lessons but not with these lessons. I don't want the lessons to progress like this.	

MSL: Mathematics and Science Learning, EL: Engineering Learning, PSI: Personal and Social Inference

Force and Energy unit by creating our own designs”, “I would like the lessons to go like this, we have fun when it works, we are happy”, indicated that the students’ attitudes toward STEM were positive. However, some students did not enjoy the STEM activities. For example, Student 11 said that “I like science lessons but not with these lessons. I don’t want the lessons to progress like this”. This situation supports that the personal and social implications sub-dimension did not create a significant difference in favor of the post-test in the quantitative findings. The transcripts of the voice recordings did not include any statements directly related to technology learning and use. The reason for why the students did not consider the simulations and tools used during the activity within the scope of technology may be because they were very intertwined with technology in daily life.

Some examples from the explanations and drawings of the students about their designs in the activity sheets are given in **Figure 2**. The explanation belongs to Student 15 and is about the steps he followed during the Ship Design STEM activity. He wrote that “We made a hole in the sponge. We placed the pushpins on the sponge. These pushpins stretched the tire. After attaching the propeller to the tire, the potential energy of

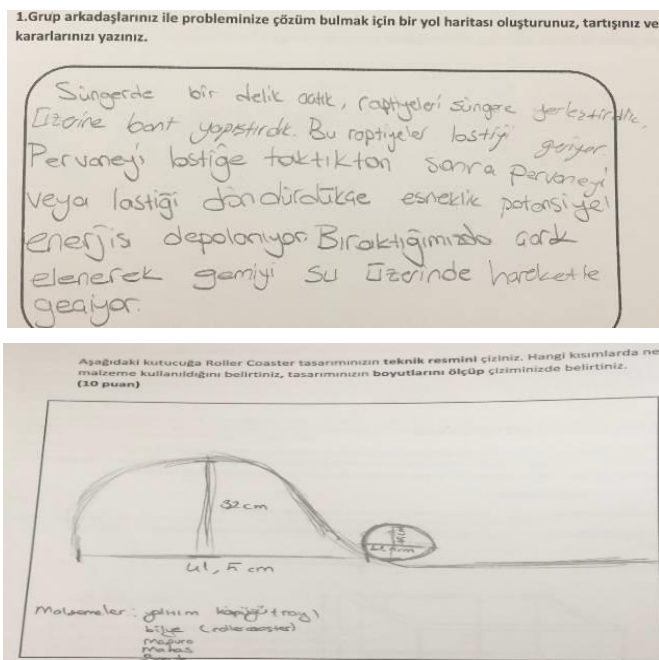


Figure 2. Students' Explanation and Drawings Related to the EL Code During the STEM Activities

flexibility was stored as we rotated the propeller or tire. When we let go, the wheel rotated and moved the ship on the water”. In the drawing in **Figure 2**, Student 24 designed a roller coaster that would rotate 360° once and indicated its dimensions. Student 24 stated that “32 cm was the height at which the marble was dropped, 14 cm was the height of the circle in which the marble rotated, it could rotate 360° . It accelerated when dropped from above, tape and insulation material were used. The diameter of the big place was 41.5, the diameter of the circle was 12.5. When the students’ statements about the engineering design processes in the STEM activities and the whole activities were examined, it was seen that the students realized the stages of determining the problem, researching, generating ideas, analyzing the ideas produced, choosing the most reasonable one among these ideas, testing and improving the solution. The reason for the positive increase in the engineering learning sub-dimension in the quantitative data of the study may be that the students were personally involved in the engineering design process during the STEM activities. Yildirim (2016) also revealed that STEM applications positively affected students’ thoughts about engineering. In addition, Tseng et al. (2013) observed that STEM education positively changed students’ attitudes especially in the field of engineering.

Kullanılacak malzeme	Kullanım amacı
Paraset	Paraset Yapımı
İp	Paraset Yapımı
Yumurta	Sağlanlığı Blanche
Bardak	Yumurta'yı deneme sırasında içine koyduğumuz Paraset
Bant	İplerin sağlanlığı (Paraset yapımı)
Yumurta kapsülü	Yumurta'nın dayanıklılığını sağlamak.

Kullanılacak malzeme	Kullanım amacı
Plastik boru	Ağırlık ve motorun asılması.
Bant, silikon tabanca	Sayılabılır
Mobet kartonu	Gövde
Pipet	Tekerleklerin dönmesi
Çöp şiş	" bağlanması
İp	" Yeter tasıma ve hareketi iletme
Kapaklar	Tekerlek ve yük sepeti.

Figure 3. Students' Statements about the TLU Code in the STEM Activity Papers.

Expressions belonging to the technology learning and use (TLU) code were obtained from the activity worksheets of the students. While the students selected the materials they used in the design process, they wrote what purpose they would use them for in their activity worksheets. Some examples of the students' writings are provided in **Figure 3**. For instance, in the ship design STEM activity, everyday material, such as a tire, was used as the power source of the propeller designed for the progress of the ship. In the do not break eggs STEM activity, the bag was used to make a parachute that would increase the air resistance. Moreover, in the transportation system STEM activity, the straw was used as the part that transmitted the movement allowing the wheels to turn.

Technology is both a type of knowledge that uses concepts and skills obtained from other disciplines (science, mathematics, culture, etc.) and a process in which this knowledge is put into the service of humanity to meet a specific need or solve a specific problem by using materials, energy and tools (MoNE, 2006). For this reason, although the students did not use areas of technology such as coding and robotics during STEM activities, using simulation programs and solving the problems with materials were perceived as technology use and learning. In the quantitative findings of the study, there was no significant increase in the sub-dimension of technology use and learning of the STEM attitude scale after the instruction. This situation might be related to the fact that the students mostly thought that the technologic tools must be electronic devices.

Table 9. Frequency and Percentage Values of the Codes of STEM Attitude Theme.

Codes	Frequency	%
MSL	5	25
EL	4	20
PSI	8	40
TLU	3	15

Table 10. Descriptive Statistics Values According to Pre-Test and Post Test Scores of PSI.

Groups		N	Min	Max	\bar{x}	Skewness	Kurtosis
Experimental Group	Pre-Test	30	2.45	3.6	3.07	-0.109	-1.251
	Post-Test	30	2.65	4.00	3.38	-0.303	-0.809
Control Group	Pre-Test	34	2.35	3.85	3.13	-0.150	-0.371
	Post-Test	34	2.35	3.90	3.105	-0.040	-0.327

Table 9 presents the frequency and percentage values of how often the STEM attitude codes were expressed in the qualitative data. The students most frequently used expressions related to the Personal and Social Inference code (40 %) while they made statements related to the code of Mathematics and Science Learning as the second most frequent. The students used the code of TLU (Technology Learning and Use) the least (25%). These findings pointed out that the students had positive attitude toward STEM.

The Effect of STEM Education on Problem-solving Skills

Quantitative Findings and Discussion

Kolmogorov-Smirnov and Shapiro Wilk analyses for the pre and post-test values of the experimental and control groups showed that the data were normally distributed ($p > 0.05$). Descriptive statistics values for Problem-solving Inventory scores are given in **Table 10**. The mean, median and peak values of the pre-test and post-test scores were close to each other. In addition, since the skewness and kurtosis values were in the range of -1.5

Table 11. Paired t Test Results of the Experimental Group's Problem-Solving Inventory Scores.

Group	N	\bar{x}	sd	df	t	p	Cohen's d
Pre-Test	30	3.086	0.335	29	5.308	0.000	0.969
Post-Test	30	3.381	0.397				

Table 12. Independent Post-Test Results of the Groups' Problem-Solving Inventory Scores.

Groups	N	\bar{x}	sd	df	t	p
Experimental	30	3.381	0.397	29	0.275	0.006
Control	34	3.105	0.372	33		

and 1.5, it was accepted that the data were normally distributed. The problem-solving inventory was reliable ($\alpha = 0.78$) for this study.

Table 11 displays the findings of t-test results for the experimental group's pre and post-test scores gathered from the problem-solving inventory. Experimental group students received higher mean scores on the problem-solving inventory after the STEM activities (3.381) than before (3.086) and the difference was significant ($t_{29} = 5.308$, $p = 0.00$). The effect size of this difference was also quite high (Cohen's $d = 0.969$).

There was no significant difference between the mean scores of the groups before the STEM activities were implemented ($p > 0.05$). **Table 12** demonstrates that the mean scores of the experimental group (3.381) were significantly higher than the mean scores of the control group (3.105) after the implementation. This finding of the study showed that the effect of STEM education on students' problem-solving skills was positive. Each of the STEM activities implemented in the study started with the presentation of a real life problem. Students followed the steps of the engineering design process while solving the real life problems. This process is thought to be effective in developing students' problem-solving skills. These findings are in line with the findings of international (Astuti, Rusilowati & Subali, 2021; Kurt & Benzer, 2020; Nugent et al., 2010; Parno et al., 2019; Sari et al., 2019; Scott, 2012) and national studies (Hebebcı & Usta, 2022; Koyuncu & Kirgiz, 2016; Pekbay, 2017; Yalcin & Erden, 2021; Sari et al., 2022).

Table 13. Paired t Test Results of the Control Group’s Problem-Solving Inventory Scores.

Group	N	\bar{x}	sd	df	t	p	Cohen's d
Pre-Test	34	3.136	0.366	33	-3.547	0.001	0.608
Post-Test	34	3.105	0.372				

Table 14. Paired t Test Results of the Experimental Group’s Scores for the Sub-Dimensions of PSI.

Sub-Dimensions	N	\bar{x}	sd	df	t	p	Cohen's d
Personal Control							
Post-Test	30	3.513	0.537	29	3.255	0.003*	0.594
Pre-Test	30	3.286	0.444				
CPSA							
Post-Test	30	3.408	0.432	29	5.220	0.000*	0.953
Pre-Test	30	3.016	0.342				
Approach Avoidance							
Post-Test	30	3.257	0.460	29	2.475	0.019*	0.451
Pre-Test	30						

According to **Table 13**, the mean problem-solving scores of the control group decreased significantly in the posttest (3.105) compared to the pre-test scores (3,136) ($t_{33} = -3.547$, $p = 0.001$). The effect size of this difference was moderate (Cohen’s $d = 0.608$). Accordingly, there was a decrease in the problem-solving skills of the control group that followed the curriculum.

When **Table 14** is examined, it is seen that there was a statistically significant difference between the pre-test and post-test mean scores of the experimental group in the “Personal Control” sub-dimension in favor of the post-test. ($t_{29} = 3.255$, $p < 0.05$). The effect size of this difference was moderate (Cohen’s $d = 0.594$). Similarly, there was a statistically significant difference between the pre-test and post-test mean scores in the sub-dimension of “Confidence in Problem-solving Ability” (CPSA) in favor of the post-test ($t_{29} = 5.220$, $p = 0.00$). The effect size of this difference was also quite high (Cohen’s $d = 0.953$). There was also a statistically significant difference between the pre-test and post-test mean scores of “Approach Avoidance” of problem-solving skills in favor of the post-test ($t_{29} = 2.475$, $p < 0.05$). The effect size of this difference was moderate (Cohen’s $d = 0.451$).

Table 15. Paired t Test Results of the Control Group’s Scores for the Sub-Dimensions of PSI.

Sub-Dimensions	N	\bar{x}	sd	df	t	p	Cohen's d
Personal Control							
Post-Test	34	3.1588	0.506	33	-1.35	0.184	0.232
Pre-Test	34	3.1765	0.47677				
CPSA							
Post-Test	34	3.0625	0.49261	33	-3.18	0.003*	0.546
Pre-Test	34	3.1066	0.49345				
Approach Avoidance							
Post-Test	34	3.1176	0.35774	33	-1.52	0.136	0.262
Pre-Test	34	3.1429	0.36209				

*: Sub-dimensions with significant difference.

According to these findings, there was an increase in all sub- dimensions of problem-solving skills in the experimental group, and the highest increase was seen in the sub-dimension of confidence in problem-solving ability. Some items belonging to this sub-dimension of the scale are given below (Kardas, et al., 2014):

- 6. *I make decisions when solving a problem and I am happy with them in the end.*
- 8. *When I face a problem, I think about the problem before I decide what to do.*
- 9. *When making a decision, I compare different options and consider the consequences of each option in relation to the other.*
- 13. *I am confident that I can solve problems that are different from the problems I have always faced.*

The table of what I know, what I don’t know and how to solve the IYP that the students filled in while doing STEM activities, determining a road map for themselves, discussing, testing and controlling the solution might have caused them to show progress in all three dimensions of problem-solving skills. Regarding **Table 15**, there was a statistically significant difference between the pre-test and post-test mean scores of the control group’s confidences in problem-solving ability in favor of the pretest ($t_{33} = -3.187$, $p < 0.05$). Cohen’s d value was found to be 0.546, which indicated a medium effect size. Students’ confidence in problem-solving ability decreased, who followed the science curriculum.

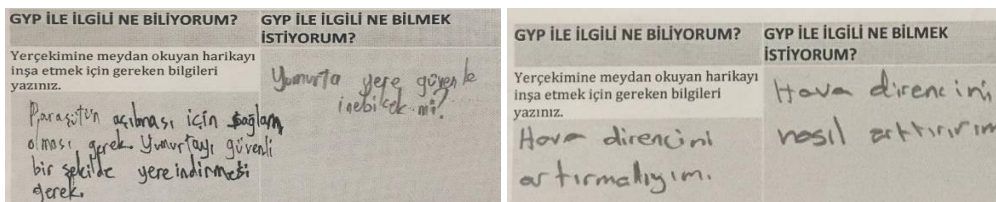


Figure 4. Students' Answers Related to the PC Code from the STEM Activity Papers during the Don't Break the Egg Activity

Qualitative Findings and Discussion

In this section, the findings related to problem-solving skills in the audio recordings, activity sheets and researcher observation notes collected from the experimental group students are provided by giving examples from the real-life problems they solved.

Real Life Problem: You are a member of NASA's team at the US Aeronautics and Space Administration and you need to design a model that will reduce the speed of spacecraft after they enter the planet's atmosphere, preventing them from crashing and ensuring a safe landing. The egg you are given will represent the spacecraft. What kind of model can you design?

Figure 4 presents the statements of the students related to Personal Control code obtained from the worksheets of the Egg Don't Break STEM activity. Student 15 answered the question "What do I know about this real-life problem?" as "The parachute needs to be strong to open. It needs to land the egg safely on the ground". She expressed the necessary conditions for the solution of the problem. Student 6 stated that "I need to increase the air resistance". He put forward the idea of increasing the air resistance after his personal control. In response to the question "What do I want to know about the real-life problem?", Student 21 asked that "Will the egg be able to land safely on the ground?" and Student 22 also asked "How can I increase the air resistance?". As can be seen in the student statements, the STEM activities facilitated the stages for the personal control dimension of problem-solving skills. In other words, STEM activities enabled students to exercise personal control. This situation explained the statistically significant difference between the pre-test and post-test mean scores of the experimental group's personal control sub-dimension in favor of the post-test.

The students answered the following questions after they completed and tested their designs for the Egg Don't Break STEM activity: "What are the points that need to be improved in your design? If you think you were

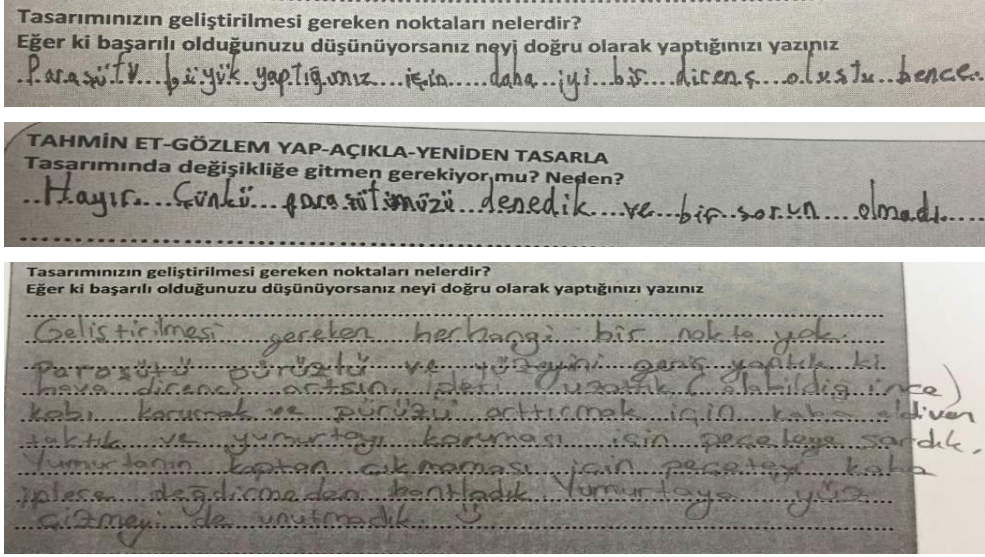


Figure 5. Students' Answers Related to the CPSA Code from the STEM Activity Papers during the Don't Break the Egg Activity.

successful, write down what you did correctly?" and "Do you need to change your design? Why?" and "Do you need to change your design?" questions. Some of the students' answers related to Confidence in Problem-solving Ability code are shown in **Figure 5**. For example, Student 17 said that "There is no point that needs to be improved. We made the parachute rough and the surface wide so that air resistance increases. We extended the ropes, put on gloves to protect the container and wrapped a napkin to protect the egg. We taped the napkin to the container without touching the ropes so that the egg would not come out of the container. We did not forget to draw a face on the egg". In his statement, she stated that the prototypes they designed as a solution to the real life problem were sufficient and explanatory. Student 4 stated the missing aspect of the design he created by saying that "We need to reinforce the bands because it doesn't hold well". Student 19 wrote that "I think there was a greater resistance because we made the parachute bigger. We tried our parachute and there was no problem". That is, they thought that the strategy they applied to solve the problem worked. These findings show that the students were given the opportunity to think about the adequacy and deficiencies of their designs that they presented as solutions to real life problems given during the STEM activities. In the quantitative findings of the study, the highest increase in the problem-solving skills was found in the CPSA sub-dimension.

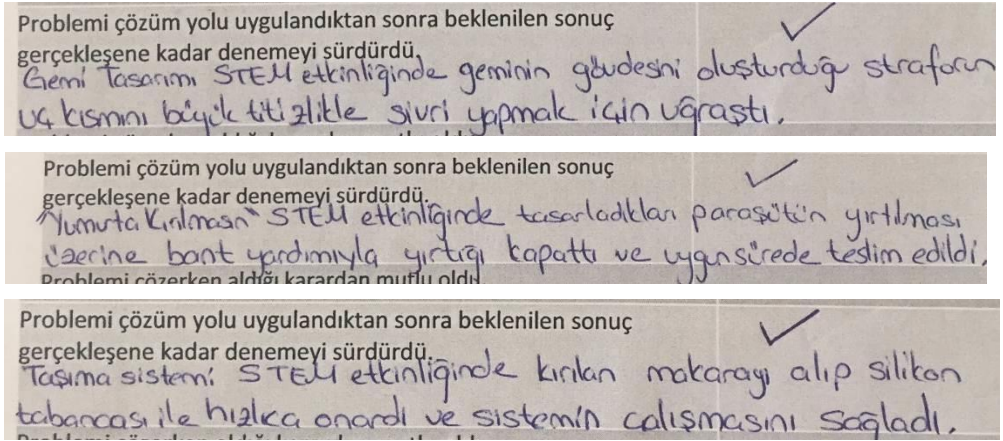


Figure 6. Statements Related to the AC Code from the Researcher's Observation Form.

Table 16. Frequency and Percentage Values of the Codes for Problem Solving Skills.

Codes	Frequency	%
AA	4	23.5
PC	6	35
CPSA	7	41.5

Figure 6 includes sections containing expressions thought to be related to the approach-avoidance sub-dimension of problem-solving skills obtained from the observation notes taken by the researcher. The researcher's statement "In the Ship Design STEM activity, he tried to make the tip of the styrofoam from which he formed the hull of the ship pointed with great care" written for Student 8 showed that the student worked eagerly for the solution of the problem during the activity. The following note taken for Student 14 "The parachute they designed in the Egg Breakage STEM activity was torn, and they closed the tear with the help of tape and it was delivered in the appropriate time" pointed out that the student worked to eliminate the problem and the design was completed within the given time. The statement for Student 13 i.e. "In the transportation system STEM activity, he took the broken pulley and quickly repaired it with a silicone gun and made the system work" revealed how the student acted upon the problem that arose while putting forward the design. These data show that

STEM activities provide students with an environment where they can engage in approach-avoidance behaviors. This situation also supports the conclusion that scores for the approach-avoidance sub-dimension increased in the quantitative findings in favor of the post-test.

Table 16 displays the frequency and percentage values of how often the codes of problem-solving skills were expressed in the qualitative data. According to these values, Confidence in Problem-solving Ability code was found most frequently in student statements.

Conclusion and Recommendations

STEM education has been recognized as key drivers of national development, economic productivity and societal well-being (Tytler, 2020). STEM education is an emphasis on the promotion of mathematics and science in response to the perception that these subjects attract less student interest and engagement (Marginson et al., 2013). Students' positive attitudes towards STEM play an important role in the acquisition of the skills targeted by STEM education (Sirakaya, Alsancak-Sirakaya & Korkmaz, 2020). Therefore, determination of STEM attitude is important in terms of making changes that would increase and support student learning (Mahoney 2010; Tseng et al., 2013). Problem-solving skills motivate students to have a higher cognitive level (Astuti et al., 2021) and help them solve real-life challenges (Martaningsih et al., 2022). Having problem-solving skills enables students to be successful in school, life and employment. In this study, the effects of STEM activities prepared for seventh grade students on students' STEM attitudes and problem-solving skills were measured by implementing STEM activities into the science curriculum. The conclusions drawn based on the results of this study can be listed as follows: First, STEM education, which is carried out within the scope of physics subjects in the science course and which also includes mathematics, engineering and technology related acquisitions, ensures that students' attitudes towards STEM develop positively. STEM attitudes progress especially in the direction of establishing a relationship between mathematics, science and engineering learning and STEM. Second, STEM education improves students' problem-solving skills. The increase occurs in all areas of problem-solving skills, including the individual's confidence in problem-solving skills, willingness to cope with difficult problems encountered, and the feeling that they have mastered the situation. Another conclusion of the study is that when there is no STEM-oriented activity in the science curriculum, students' problem-solving skills decrease, especially in their confidence in their problem-solving skills. STEM is an interdisciplinary subject that combines two or more disciplines, is based on authentic contexts and focuses on problem-solving (Tytler, Appelbaum & Swanson, 2015). At the end of this study, the

fact that students were able to establish relationships between STEM disciplines and develop problem-solving strategies shows that STEM education has achieved its purpose.

The study has some limitations. The activity sheets distributed to the students were asked to be filled in during STEM activities. Although this situation was positive because students wrote their thoughts and actions during the design process without forgetting what they did, some students used short sentences or left some parts blank. Moreover, since STEM education offers a different lesson environment than usual for students, students sometimes wanted to create different designs and tended to move out from the subject. These limitations were tried to be eliminated by the teacher by being in constant observation, paying attention to the activity sheets of the students, asking questions to the students and directing them to discover the information that would lead them to the learning objectives.

This study contributes to the research in the area of STEM and the results obtained offer some suggestions. Telling students the professions related to the tasks they take during the activity may contribute to their perception of professions for their abilities, skills, interests and ideals and to their choice of professions. Since the sub-dimension least positively affected by STEM activities is technology learning and use, it is recommended that the activities be enriched with technological fields such as coding and robotics. Measuring STEM attitudes can provide information about students' learning processes and shed light on educators who plan curricula. Moreover, spreading science and engineering applications in the science curriculum can improve students' problem-solving skills. In addition to all these, providing STEM education as a separate course or establishing relationships with technology and engineering subjects in science and mathematics courses can allow students to establish connections between different disciplines and prepare them for 21st century skills.

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