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Research Article

The Impact of Socio-Scientific Activities on Middle School Students' Attitudes and Views towards STEM

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Abstract: In this study, middle school students were encouraged to develop STEM based socio-scientific activities, and as a result, their attitudes and opinions towards STEM were investigated. Mixed nested method was used in this research. Sample of the study consists of 16 seventh grade students, who got educated during the 2017-18 academic year in an eastern province of Türkiye. The study lasted 24 weeks during an academic year. Data was collected by using STEM Attitude Scale, STEM Interview Form, Field Notes and Informal Meetings. The research findings indicated that engagement in STEM-based socio-scientific activities significantly enhanced participants' attitudes towards STEM disciplines. Moreover, this active involvement positively impacted their skills and aspirations, fostering a greater inclination toward selecting professions and careers geared towards creating innovations to enhance human life. Additionally, it was concluded that the activities positively affected their knowledge and motivation about STEM and socialization features such as communication, interaction and sharing.

Keywords: STEM, Middle School, Science, Attitudes, Socio-Scientific Activities

1. Introduction

Today, information is changing rapidly. In order to exist in a globally competitive environment, individuals need to acquire new knowledge by following up the developments in science and technology. It is important that individuals, who will ensure the development of countries in the industry and workforce, have the required skills for the 21st century. Therefore, countries also compete for raising qualified individuals (Tas & Yenilmez, 2008). A qualified education is needed to raise a qualified workforce (Aykac, 2018). Qualified individuals are required to have skills in science, mathematics, technology, and engineering. Therefore, countries have started to attach importance to STEM (Science, Technology, Engineering, and Mathematics) education, which aims to teach these four areas by integrating them into education systems (Ulutan, 2018).

1.1. What is STEM?

STEM is not a new concept. The National Science Foundation (NSF) designed the concept of STEM in the 90s (Blackley & Howell, 2015). This organization initially created the abbreviation SMET, however, they reconsidered it due to negative feedback and suggested the concept of STEM. STEM has become widespread since its emergence to this day. In particular, significant changes have occurred in STEM education over the past two decades (Ozcan & Kostur, 2018; Williams, 2011).

In STEM education, the education process is organized by combining science, mathematics, engineering, and technology. In this way, the qualities of individuals improve as a result of gaining knowledge and skills related to these fields. Thanks to qualified individuals, the production in the labor market can increase significantly, and as a result, countries can succeed in the global competitive environment. STEM is considered vital since it enables students to develop the skills necessary in the 21st century (Bybee, 2013; Gull et al., 2022). Most of the developed or underdeveloped countries, organizations, and

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global companies are aware of the importance of STEM. For this purpose, countries have revised their science curricula and included STEM. This is because STEM education is important for being financially powerful (Lacey & Wright, 2009).

According to Next Generation Science Standards (NGSS, 2013), STEM professions have already become prominent all around the world. Many countries in the world have allocated a certain amount of their budget for STEM in their education systems to carry out various projects and programs for students to acquire skills related to STEM fields at each education level, from kindergarten to university. The purpose of STEM instruction is to generate STEM literate individuals (Fitzpatrick, 2007). In STEM literacy, students can understand what STEM is, follow up scientific developments related to STEM, solve problems, create products using STEM fields, search STEM-related resources, and conduct research.

1.2. Teaching STEM

In STEM education, it is beneficial for students to follow engineering design processes to understand the related procedure (Gencer, 2015). An engineering design process includes (1) defining the problem, (2) doing research, (3) creating solutions, (4) selecting the best explanation, (5) preparing the prototype, (6) testing and evaluating, (7) presenting, (8) revising, and (9) finalizing (Hynes et al., 2011).

1.3. Socio-Scientific issues

Scientific problems that concern society but do not have a clear solution are called socio-scientific issues. Controversial scientific issues such as vaccination, pregnancy sugar loading test, biodiversity, organ transplantation or cloning can change based on different cultures, societies and regions (Klop & Severiens, 2007; Walker & Zeidler, 2007). Every subject we encounter in daily life may not be a socio-scientific issue. There are several criteria for an issue to be a socio-scientific issue. Socio-scientific issues have two main features: (1) They should be related to science, and (2) they should be significant in public (Eastwood et al., 2012). Additionally, a scientific issue that contains contradictions, that does not have a single definitive solution, and that can change depending on people's beliefs, political and ethical values may also be accepted as socio-scientific issues. In this study, socio-scientific issues with a scientific and social content indicate features varying from society to society.

In the Science Curriculum renewed by the Ministry of National Education in 2018, socio-scientific issues are explained as ways which are used "to develop reasoning ability, scientific thinking habits and decision-making skills" (MoNE, 2018, p.9). When the 2019-2020 academic year science textbooks prepared by the Ministry of National Education are examined, it is seen that they include various socio-scientific topics in all 5th, 6th, 7th and 8th grades. The seventh grade program is examined within the scope of the study and it is found out that social issues such as "space pollution/space technology", "domestic waste", "recycling", "solar energy" and "in vitro fertilization" are included (MoNE, 2018).

According to the 2018-2019 MoNE curriculum, the skills related to socio-scientific topics to be acquired in the seventh grade are as follows: explaining space technologies, expressing possible causes of space pollution and predicting the possible consequences of this pollution, explaining the relationship between technology and space research, distinguishing between recyclable and non-recyclable materials in a household waste, designing projects for the recycling of domestic solid and liquid waste, questioning recycling in terms of efficient use of resources, taking care of waste control in their immediate surroundings, developing a project to deliver reusable items to those in need, giving examples of innovative applications of solar energy in daily life and technology, and discussing the ideas they produce on how to benefit from solar energy in the future. In the scope of this study, six separate socio-scientific subject matters have been used: household waste/recycling, wind/kinetic energy, solar energy, technology, global warming, and space.

1.4. Significance of the research

STEM education aims to provide students with 21st-century skills (Ministry of National Education [MoNE], 2016). Students who receive STEM education can develop 21st-century-skills such as critical thinking, creativity, and problem solving. Since the 1990s, there have been several studies related to STEM education and socio-scientific issues in Türkiye as well as in different parts of the world. In literature review, it is determined that studies on STEM education mainly focuses on scale adaptation, teachers'/prospective teachers'/students' views towards STEM, attitude towards science and STEM, academic achievement, STEM integration, mathematical achievement, and STEM career (Khishfe, 2017; Sadler et al., 2017). It is also determined that studies discussing socio-scientific issues along with STEM education are very limited in Türkiye as well as the world. As a result of the review, it is found out that there is a study carried out on prospective teachers by Bozkurt Altan et al. (2018). The researchers concluded that prospective teachers found it appropriate to create STEM problem situations based on socio-scientific issues because socio-scientific topics can offer features such as relevance to real life, multiple criteria and compatibility with other disciplines (Bozkurt Altan et al., 2018). In addition, Benek and Akcay (2022) concluded that STEM activities integrated with socio-scientific issues had a positive effect on students' 21st-century-skills and permanently improved these skills. Most countries recognize the importance of science, technology, engineering and mathematics education (collectively known as STEM education) in preparing citizens for the future (Treagust & Won, 2023) and to create a scientifically literate society (Cheng & Leung, 2022). In conclusion, because our study aims to develop, and make students' attitudes and opinions towards STEM permanent with socio-scientific STEM application, we believe that our study will be unique and significant.

1.5. Purpose of the study and Sub-Problems

The goal of this study is to find out how students' attitudes and views on STEM have changed by researching a problem in socio-scientific issues and producing solutions for the problem. In this context, we seek an answer to the question "How do STEM-based socio-scientific activities affect students' views and attitudes toward STEM?"

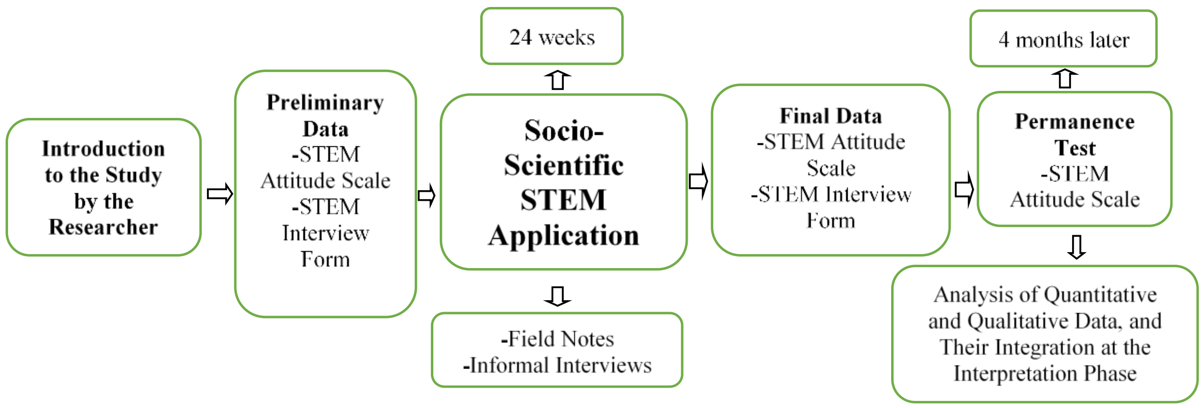
2. Method

2.1. Research model

This research was designed according to Mixed Nested Design. In a mixed nested design, a qualitative process is added to an experimental study (Creswell & Plano-Clark, 2011). The symbolic representation of the study is provided in Figure 1.

Figure 1

Flow chart of the study



2.2. Study group

The sample of the study consists of 16 seventh grade students (11 female and 5 male) from public middle school. The study was carried out in the region of Van, located in the east of Türkiye. Participants were selected using a simple random sampling method. The school is located in a socially and culturally disadvantaged district of the Van province according to the data of the Ministry of Industry and Technology (Acar et al., 2019). The school was damaged due to the 2011 Van earthquake, and as a result, it was demolished, rebuilt, and reopened in November 2013 with 10 classrooms. Therefore, the school does not have the necessary study areas for educational technologies, science laboratories, art activities, physical activities and eating and dining areas.

None of the students' fathers have a university degree, and there is no illiterate father. All of the students' mothers and fathers are alive and live together (Table 1). Participants' families monthly salaries were found to be between 138-972 (1$ was 3,6TL when the study was conducted in September 2017). According to the results of the subsistence minimum index for Türkiye in September 2017, it is observed that the monthly salaries of families of all participants are below the "poverty threshold". The minimum wage was 1,404 TL (about $ 390) in 2017 in Türkiye when this study was conducted. Therefore, it was determined that participants' socio-economic levels were low.

Table 1

Demographic Information About Parents

	Graduation	f	%	Job	f	%
Father	Illiterate	-	-	Unemployment	3	18,7
	No education	1	1	Building attendant	4	25
	Elementary school	7	43,7	Tradesman	4	25
	Middle school	3	18,7	Barber	1	1
	High school	5	31,2	Worker	2	12,5
	University	-		Accountant	1	1
				Officer	1	1
Mother	Illiterate	3	18,7	Housewife	16	100
	No education	5	31,2			
	Elementary school	3	18,7			
	Middle school	1	1			
	High school	1	1			
	University	1	1			

The data gathered also indicates that 18.7% of students live in a rented house, 68.7% do not have their own rooms, 37.5% have their home heated with a stove, 87.4% come to school on foot, 68.7% have no computer at home, 56.2% of them do not have the internet connection, and more than half of them do not get any kind of educational support. The participating students have 2 to 14 siblings. Five of the students have siblings studying at a university, while 11 students do not.

2.3. Data collection tools

STEM Attitude Scale for Middle School Students: It was developed by Benek and Akcay (2019). It is a five-point Likert scale consisting of 33 items and 6 sub-factors. The reliability coefficient (α) value of the scale was .887. The scale has six sub-dimensions including (1) Science, (2) Mathematics, (3) Engineering, (4) Technology, (5) Science-Mathematics-Engineering-Technology and (6) Career.

STEM Interview Form: Aim of this form is to find out participants' views about STEM and how the application has affected these views. The STEM Interview Form developed by the researchers has four open-ended questions (Appendix 1). Ten students were randomly selected for the interviews and the interviews lasted around 12 minutes on average. The interviews took place in the counseling service, which was relatively quieter than other parts of the school. All interviews were recorded and transcribed.

Field Notes: In this process, the researcher, as a "participant-observer", tried to note the interesting events in a notebook. Throughout the study, the researcher kept detailed "field notes" for the application process immediately after the application. While the researcher was keeping the notes, he tried to determine the feelings and the levels of satisfaction felt by the students during the application process.

Informal Meetings: In this study, the researcher also served as a teacher. He spent a lot of time with students in practice during the breaks in hallways and the garden five days a week, holding various informal discussions with them, and cordially chatting with them. The students discussed their experiences during the application process, their opinions and suggestions regarding the process, the questions they wondered about the socio-scientific issues addressed in the applications, and their opinions and thoughts about the applications, and as a result, any situation considered important was noted by the researcher.

2.4. Data analysis

The quantitative data was analyzed statistically, whereas the qualitative data including STEM Interview Form, Field Notes and Informal Meetings was analyzed using content analysis and descriptive analysis methods. Each student was given a code (S1, S2…). In the analysis of qualitative data, two different researchers evaluated the data. The consistency between the evaluators was assessed according to Miles and Huberman' formula (1994) and determined as 89%.

2.5. Information about the researcher and his role in application

Since the coordinator of the application is also the science teacher of the study group, he acted as a researcher and a teacher during the research period. The researcher is a male science teacher with ten years of experience. He has worked in the same school for nine years and completed his doctorate degree in Science Education in 2018.

2.6. Research process

Main application of the study was performed in the 2017-2018 academic year. Before the study, the required permissions were obtained from the Ministry of National Education. The classroom did not receive sunlight, but adequate lighting was provided with several lamps. There was no smart board application in the classroom, instead, there was a whiteboard with a board marker.

The research started in September 2017 and continued until the last week of May 2018 (Table 2). However, the activities of the study were completed in 24 weeks. The study was applied in the Science Applications course, which was given as an elective course for two hours a week. The studies were carried out in light of the guided inquiry method. In this context, the teacher told the groups about which subject to be studied, but the students decided what kind of design would be made on the given subject.

Table 2

Research Process

Period	Week	Implementation	Time (hour)	Data collection tool
	1-week	Description of the research to participants		
Fall	1-week	Application of pre-tests	2	-STEM Attitude Scale -STEM Interview Form
	4-weeks	Recycling -Domestic Wastes	8	-STEM Application Form -Field Notes -Informal Interviews
	4-weeks	Motion Energy-Wind Energy	8	
	4-weeks	Solar Energy	8	
Spring	4-weeks	Technology	8	
	4-weeks	Global Warming	8	
	4-weeks	Space	8	
	1-week	Application of post-tests	2	-STEM Attitude Scale -STEM Interview Form
First Week of Fall	4 months later	Persistence test	1	-STEM Attitude Scale

In the study, no work was carried out in the first week of schools, due to the orientation of the students. In the second week, the participants were informed about the research and the groups were formed. The groups were formed by the students, and their groups were named as “4X4” (S4, S9, S11, and S14), “Ladybug” (S1, S10, and S16), “Crazy” (S5, S12, and S13), “Fantastic” (S2, S7, and S8) and “The Talented Ones” (S3, S6, S15). In the third week of the official calendar, the implementation started by applying pre-tests.

Students followed the Engineering Design Process proposed by Hynes et al. (2011) while creating their designs (Table 3). The details of one of the works (Technology: Remote Control with a ring) designed by the groups following the engineering design process during the application are as follows:

Table 3

Stages of Engineering Design Process

Engineering Design Steps	Week	Hour
1. Defining the need or problem 2. Researching the need or problem	Fist week	2
3. Developing possible solutions 4. Choosing the best solution	Second week	2
5. Prototyping 6. Testing and assessing the solution 7. Presenting the solution	Third week	2
8. Redesign/revision 9. Decision to Finalize	Fourth week	2

2.6.1. Studies conducted in the first week

The groups defined the problem and specified the requirements to solve the problem. For this purpose, the students tried to get an idea about the design to be made by using a tablet, mobile phone, and a computer for an hour. The groups exchanged ideas both within the group and between the groups, as well as with the teacher-researcher, and discussed how they would make a design on the "technology" determined by the teacher. In this regard, they discussed what kind of design people would need, what they would do in their daily lives, and whether the design would be functional, useful, and beneficial. Firstly, each group made a decision within the group, and they wrote down their decisions on a piece of paper and gave it to the teacher. The teacher took ideas from all groups and assessed these ideas with all the students. With the teachers and students meeting on common ground, it was discussed how to develop a solution to find the lost remote control at home and what kind of design could be made for this purpose. As a result, each group developed various alternative solutions to make lost remote controls easier to find.

2.6.2. Studies conducted in the second week

The groups developed their possible solutions and selected the best solution. In this process, the groups reconsidered the design they intended to make. In the end, the teacher and students found a common idea: they agreed that the best solution would be the "remote control with a ring" project.

STEM Compatibility Form (Appendix 2) was established by the researchers to conclude whether the activities are suitable for STEM. Before the study, students' remote control plans were evaluated according to the STEM Compatibility Form to decide whether it was compatible with STEM, and the "remote control with a ring" project was found to be compatible. After examining the forms, it was observed that the students would benefit from the topics/concepts related to the four fields in STEM for the designs they would make, and these designs would be suitable for STEM education.

In all groups, each group member first drew drafts on how to make their design. Then, all drawings were discussed and evaluated within the group and it was decided which drawing would be used in the project. The groups decided which materials they would use for their prospective design. It was agreed that the researcher would provide the materials which the students could not provide themselves.

Table 4

Materials Required for the "Remote Control with a Ring" Design

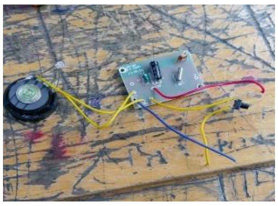
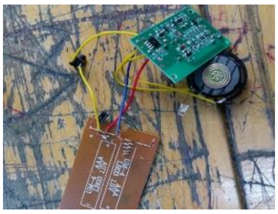
TV remote control unit	Wireless doorbell	Conducting wire	Soldering device	Heat Silicon Gun	Scissors & Utility knife	Adhesive, tape, ruler	Screwdriver, Pliers
							

2.6.3. Studies in the third week

All groups prepared the materials necessary for making the prototype. For the missing materials, they consulted the teacher and completed the missing parts(Table 4). Then, the groups developed their first prototypes (Table 5). After creating their designs, students tested and presented it to the teacher and the other groups.

Table 5

Phases of Making the "Remote Control with a Ring" Design

1- Firstly, the students separated and opened the cases of the remote controller and wireless doorbell using a screwdriver, pliers, etcetera.	 
2-Then, they separated the electrical mechanism inside the wireless doorbell from the bell device.	 
3-After removing the mechanism of the wireless doorbell, they connected the two cables of the mechanism to the positive and negative poles of the remote control, which was already opened, using a soldering device.	 
4- After making the electrical connections of the wireless doorbell mechanism and the remote control, they attached the mechanism of the bell inside the remote control with the on-off button remaining outside, and then closed the case of the remote and restored it to its original state.	 

2.6.4. Studies in the fourth week

The groups revised and finalized their designs. In the last week of their work, all groups reconsidered their designs and further developed the design. Those, who had completed the missing parts, and those, who wanted a revision, revised and finalized their designs. After making the necessary corrections, they finalized the design of the remote control with a ring (Figure 2).

Figure 2

The Final Version of the Students' Designs

The button of the doorbell was affixed to any wall of the house. This button was pressed when the remote disappeared, then a ringing sound was heard from the remote control. In this way, it would be ensured that the lost remote controls were found. After all the groups had completed their designs, the created designs were tested in the classroom by acting as if there was a search for a remote control lost inside the house. It was determined that the "remote control with a ring" designs created by all groups were working in the desired quality, and all groups were able to easily find the lost remote controls.

All groups benefited from the STEM fields which was developed by the groups, and what they did as a group are given detailed below:

Table 6

The Work of the Groups in STEM Fields

Design	STEM Fields	Studies Conducted
Remote Control with a Ring	Science	- Electrical connections (connecting the electrical mechanism of the wireless doorbell with the electrical mechanism of the remote controller, installing conducting wire, on-off button/switch).
	Mathematics	-Calculate/measure the effective distance between the button and the lost remote control.
	Engineering	-Preparing drawings related to the design to be made. -Doing works on cutting, attaching, integrating, and gathering the materials such as bell, remote control, pliers, screwdriver, etc.
	Technology	-Using a wireless doorbell with a tune.

2.7. Validity, reliability and ethics of the study

Participants of the study were randomly selected from the two separate seventh grade classes in the school to increase internal validity. All studies were carried out on the same day, same hour, and in the same classroom environment every week. All scales were applied in the classroom by the researcher (course instructor). Also multiple qualitative data tools were used to support each other. Two independent researchers were involved in the process of analyzing qualitative data. The data obtained from the interviews were shared with the participants and confirmation about their accuracy was obtained.

2.7.1. Ethical principles

The ethics committee approval for this study was granted by İstanbul University Rectorate Research Ethics Committee with decision file and number 2017/89-126531 on 26.10.2017.

3. Results

3.1. The impact of Stem-Based Socio-Scientific activities on the students' attitudes towards stem

The STEM Attitude Scale and all sub-dimensions of the scale were tested to see if the pre-test, post-test, and permanence test scores showed normal distribution. For this purpose, (1) Skewness-Kurtosis test, (2) Kolmogorov-Smirnov Test, (3) Shapiro-Wilk test, and (4) Histogram graphics methods were used. When the data showed a normal distribution, whether there was a significant difference between the test scores of the students was determined by the t-test from the parametric tests, and by the Wilcoxon signed-rank test from the non-parametric tests when it did not show a normal distribution. In the methods used, it was observed that the pre-test, post-test, and permanence test scores of the attitude scale showed a normal distribution, while the sub-dimensions of the scale did not show a normal distribution. Therefore, the t-test from parametric tests was used to test whether there was a significant difference between the STEM attitude scale pre-test and post-test scores as well as post-test and permanence test scores. The Wilcoxon signed-rank test from non-parametric tests was used for related measurements among pre-test and post-test scores of the scale sub-dimensions as well as post-test and permanence test scores.

As a result of the normality analysis conducted for the pre-test and post-test of the STEM attitude scale, it was seen that the skewness and kurtosis scores were within the normal distribution limits. The Kolmogorov-Smirnov and Shapiro-Wilk test results also provided a normal distribution ($p>.05$). The t-test results for the relevant samples conducted to determine whether the pre and post-test scores of students significantly differed is given in Table 7.

Table 7

The Results of the T-Test on the STEM Attitude Scale

	Test	N	Mean	SS	df	t	p
STEM Attitude Scale	Pre-test	16	101.13	8.24	15	-31.964	.000
	Post-test	16	154.69	5.38			

Analyzing the STEM Attitude Scale of the students, the pre-test mean is 101.13, and the post-test mean is 154.69. According to these results, a statistically significant difference was determined in favor of the post-test ($p <.05$) (Table 7).

Skewness-Kurtosis Test, Kolmogorov-Smirnov Test, Shapiro Wilk test and Histogram graphics methods were used to decide which statistical method to use before examining whether there was a significant difference between the students' pre-test and post-test scores regarding the sub-dimensions of the STEM attitude scale. When all methods were evaluated together, the data obtained from the pre-test and post-test scores of the STEM attitude scale sub-dimensions did not show a normal distribution. It was decided that it would be appropriate to use nonparametric tests to analyze the data. Therefore, the Wilcoxon signed-rank test was performed for the repeated measurements to determine whether the sub-dimensions of the STEM Attitude Scale's pre and post test scores differed significantly. The results showed that there was a statistically significant difference in favor of the post-test scores (p <.05) (Table 8).

Table 8

The Results of the Wilcoxon Signed-Rank Test for Sub-Dimensions of STEM Attitude Scale

Sub Dimensions	Pre-Post test	N	Mean of Rank	Sum of Rank	z	p
Science	*NR*	0	.00	.00	-3.536	.000
	PR	16	8.50	136.00		
	Equal	0				
Mathematics	*NR*	0	.00	.00	-3.526	.000
	PR	16	8.50	136.00		
	Equal	0				
Engineering	*NR*	0	.00	.00	-3.535	.000
	PR	16	8.50	136.00		
	Equal	0				
Technology	*NR*	0	.00	.00	-3.527	.000
	PR	16	8.50	136.00		
	Equal	0				
Science-Mathematics-Engineering-Technology	*NR*	0	.00	.00	-3.540	.000
	PR	16	8.50	136.00		
	Equal	0				
Career	*NR*	0	.00	.00	-3.526	.000
	PR	16	8.50	136.00		
	Equal	0				

*NR: Negative Rank PR: Positive Rank

It is seen in Table 8 that there is a positive change in the students' attitudes towards the STEM fields. To determine whether this change was temporary or not, the scale was applied four months after the study to the same students as a permanence test. The t-test results for the relevant samples conducted to determine whether the pre and post-test scores of students differed significantly for the STEM attitude scale are provided in Table 9.

Table 9

The Results of Permanence Test Scores of STEM Attitude Scale

	Test	N	Mean	SS	df	t	p
STEM Attitude	Post-test	16	154.69	8.38	15	2.099	.053
	Permanence test	16	150.12	5.28			

Table 9 shows that the STEM Attitude Scale post-test mean score of the students in the study group is 154.69, and the permanence test mean score is 150.12. According to the analysis, there was no statistically significant difference between the scores obtained from the post and permanence test (p>.05). In order to determine whether there was a significant difference between the pre-test and post-test scores of the STEM Attitude Scale sub-dimensions, the Wilcoxon signed-rank test was used in repeated measurements, and the results are given in Table 10.

Table 10

Wilcoxon Signed-Rank Test'S Results for the Comparison of Post-Test and Permanence Test Scores of the STEM Attitude Scale Sub-Dimensions of the Study Group

Sub Dimensions	Post-test -Permanence test	N	Mean	Sum	z	p
Science	*NR*	11	7.36	81.00	-1.824	.068
	PR	3	8.00	24.00		
	Equal	2				
Mathematics	*NR*	10	6.10	61.00	-1.088	.276
	PR	3	10.00	30.00		
	Equal	3				
Engineering	*NR*	8	5.25	42.00	-.812	.417
	PR	3	8.00	24.00		
	Equal	5				
Technology	*NR*	8	6.56	52.50	-1.811	.070
	PR	3	4.50	13.50		
	Equal	5				
Science-Mathematics-Engineering-Technology	*NR*	7	6.29	44.00	-.399	.690
	PR	5	6.80	34.00		
	Equal	4				
Career	*NR*	6	7.08	42.50	-.854	.393
	PR	5	4.70	23.50		
	Equal	5				

*NR: Negative Rank PR: Positive Rank

Table 10 shows that there is no statistically significant difference between the post-test and permanence test scores of all sub-dimensions of the STEM Attitude Scale ($p > .05$).

3.2. Comparison of students' opinions about before and after STEM applications

A five-question on STEM Interview Form was used to examine the opinions of students in the study group before and after STEM application. Although there are different opinions about how many participants will be interviewed, it is generally stated that this number can be between a minimum of 5 and a maximum of 50 people (Baker & Edwards, 2012; Cobern & Adams, 2020). Factors such as the content of the study, access to the sample, and research questions are important in determining this number of participants (Creswell & Creswell, 2018). In this context, interviews were held with 10 students who stated that they would voluntarily participate in the interview before and after the study. The interview was conducted with ten (10) students with the codes of S2, S3, S6, S8, S9, S12, S13, S14, S15, and S16 selected from the study group. Students' opinions were analyzed by content analysis, themes, sub-themes, and codes. The frequency and data analysis are given in Table 11.

Table 11

Analysis of Pre and Post Interviews

			Pre-Application Interview		Post-Application Interview	
Theme	Sub-theme	Code	f	Quotation	f	Quotation
STEM Profession	Engineer	*Automotive engineer*	1	"Dear Teacher, I can be a designer or an architect. Automotive engineers..."(S8)	-	
		Aerospace engineering	1	"..For airplanes. Aerospace engineering." (S8)	-	
		Computer engineering	1	"Dear Teacher, I can be an engineer. For example, computer engineering." (S9)	2	"Engineers, civil engineers, computer engineers,..." (S9)
		Civil engineer	1	"Civil Engineer. Nothing else comes to my mind. I want to be a civil engineer." (S13)	3	"Computer engineer, civil engineer." (S13)
		Engineer	1	"Engineering. For example, Mimar Sinan was an engineer." (S2)	10	"Engineers, architects." (S12)
	Architect		5	"Architect. I do not know what an architect does." (S3)	6	"Architect, mathematics teacher, engineers,..." (S8)
	Scientist		2	"Well, Scientist, doctor. I think they use science, mathematics, engineering, and technology." (S15)	-	
	Doctor		2	"Engineer, doctor." (S16)	3	"Doctor, teacher, for example, science teachers, engineering." (S2)
	Teacher	*Teacher*	1	"..for example, teachers, architects. The architect prepares and draws the design of a building." (S6)	-	"Architecture, engineering, doctors, some specialized teachers (science and mathematics teachers)." (S6)
		Science	-		2	"Engineers, architects, doctors, teachers. Mathematics, science, informatics, technology design teachers." (S15)
		Mathematics	-		2	"… Math and science teachers." (S9)
		Technology design/IT	-		2	"..., informatics, technology design teachers." (S15)

	Astronaut		-		1	"... astronauts, for example" (S6)
	Operator		-		1	"… engineers, operators." (S8)
STEM Related Tool/Product	Tools / Products	*I do not know.*	7	"No, I've never seen any around me." (S15) "I do not know. I do not remember." (S3)	-	
		Computer	2	"Teacher, we use mathematics, science, and technology to make ships out of a tin can. It can be a phone and a computer." (S12)	7	"There are space rockets, cars, technological products, there are a lot of things in hospitals." (S12)
		Car	1	"Yes. For example, cars, computers, fans, planes, phones." (S5)	3	"Cars, computers,..." (S8)
		Aircraft	1	"Car, plane." (S8)	1	".. the plane, phone." (S13)
		Construction Machines	1	"Construction Machines" (S8)	-	
		Armored/Radar vehicles	2	".. armored vehicles, vehicles using radar." (S8)	-	
		Phone	1	"No, sir. I do not know. For example, the phone." (S2)	66	"Computer, phone, projection, camera, dishwasher, refrigerator, all of the white appliances." (S2)
		White Appliances	-		5	"Things that provide benefits to us are useful. Refrigerator, washing machine, phone, tablet, television." (S10)
		Television	-		1	"Car, television,..." (S13)
		Tablet	-		3	"Computer, tablet, phone." (S3)
		Educational technologies	-		5	"Smartboard, computer, tablet, all technological tools, phone, refrigerator, food processor." (S14)
		Bicycle	-		1	"...for example, it can be a bike." (S8)
		Space Rocket	-		1	"There are space rockets, cars, technological products, there are a lot of things in hospitals." (S12)

		Construction	-		1	“Houses, constructions. There is mathematics. Engineering is used. Washing machine, dishwasher.” (S15)
		Hospital devices	-		1	“There are space rockets, cars, technological products, there are a lot of things in hospitals.” (S12)
	Benefit	*Beneficial*	3	“Think about we invented the new car, it could go both in the air and in the sea as well as on the railways. When an accident occurs on land, it goes in the air immediately, and if there is a problem in the air, it goes on the sea. It is important for quick transportation from one place to another.” (S8)	8	“Yes, it is useful. Fast transportation is done by car, communication is established by phone, and exercise is done by bicycle.” (S8)
		Both beneficial and harmful	2	“On the one hand, yes, on the other, no. It can be used for communication, but it is harmful. Because it prevents conversations and communication among humans.” (S2)	2	“On the one hand, it's useful, but not on the other. For example, television gives us information, but when we watch too much, it hurts our eyes and is addictive.” (S10)
	It meets people's needs/makes their job easier		5	“Yes, Professor. Let's say we are going to watch a video for research on our computers, or for example, we can watch an educational video from there or using our mobile phones.” (S9)	10	“It makes our jobs easier. For example, our mother cannot put the food everywhere, but only put it in the refrigerator. She washes clothes using a machine, not by hand. While making a cake, she puts the walnuts in the machine and making them smaller.” (S9)
Engaging in a STEM Related Activity	Desire		10	“I would love to. So I like doing those things. I like it if we do. It improves our brain. It improves our creativity.” (S12)	15	“I would love to. Because I'm curious. It is beneficial to people.” (S6)
		Loving	5	“Yes, Professor. I love because.” (S2)	2	“Yes. Because I like it. Developing tools is fun. It helps me.” (S9)
	Affective features	*Enjoyment*	3	“Yes, Teacher. I enjoy it. I want to design something; I enjoy designing something.” (S8)	2	“Yes. I like it and it will improve me a lot.” (S3)
		Interest	1	“Yes. Because teacher, I am interested in mathematics and science...” (S14)	3	“Yes. I am very interested...” (S8)

		Fun	-		2	"Yes. Fun. I am very interested. Professor! It is useful. For example, imagine I will make an electronic product, we will do something useful, we will learn something and it is fun." (S13)
	Individual features	*Contribution/Benefit to the Individual*	6	"Yes, Teacher. I love because. It has contributions to me. For example, I can be more successful in my classes..." (S2)	6	"Yes. Teacher, these are very nice activities, I love them. It helps me tremendously." (S15)
		Individual development	-	"Yes. Because both my handcraft improves and I learn more. It has contributions to me." (S16)	2	"Yes. I love it, it's fun. Thanks to these lessons, I have been improving myself. These fields are good for me." (S2)
		Influencing the next educational life	2	"I would love to. Yes. I think it will be useful to me. So, it positively affects our future education." (S6)	1	"..These lessons are important for a better future." (S8)
		Creativity	1	"Yes. It's a good thing. I gain information about them. It improves me. It improves our brain. It improves our creativity." (S12)	21	"Yes. Because my handcraft improves..." (S16)
		Academic achievement	1	"It is beneficial for me, for example, makes our mathematics lessons easier. These lessons are important for a better future." (S8)	1	"..It is beneficial for me, for example, makes our mathematics lessons easier..." (S8)
		Career choice	1	"..For example, when I have a good job, I can do that job better because I know about them." (S2)	1	"Yes. It's funny. It would be a lot of fun when they come together. It can positively change my career thoughts." (S14)
		Learning	-		2	"...I learn more. It has contributions to me." (S16)
Feeling the STEM Fields Close to You	Science		6	"Science, mathematics, and technology. I like them. Science tells us about the human body, cells, or other topics, and I love mathematics since we will always use it, and I love technology, for it has both fun and research." (S9)	8	"Science and mathematics. Math is fun, I also love science." (S2)
	Mathematics		6	"Science and mathematics. I am very good at math calculations. I love science as well because there is mathematics in science." (S8)	8	"Mathematics. Because I love it and I find it easy." (S6)

	Technology	4	"I love technology very much. I like surfing on YouTube. I say let me do it. I take videos, make changes, and edit them." (S12)	1	"I'm already doing things related to technology." (S12)
	Engineering	1	"Engineering field" (S2)	1	"Science, engineering. These things are interesting to me." (S13)

Table 11 shows that there is no change in the main themes stated by the students in the semi-structured interviews. However, the sub-themes of “Astronaut”, “Operator”, “Engineer”, “Architect”, “Scientist”, “Doctor” and “Teacher" emerged in the post-application interviews. The field note of the participant researcher on 05.03.2018 states “It is seen that students love the space theme. They enjoy doing an activity or a design on this subject. It is observed that they are more enthusiastic, have more motivation with an increased feeling of curiosity and excitement towards space compared to other studies.” , which supports the finding of the formation of the code “astronaut”. In both the pre and post-application interview, students thought that “Teaching” is a STEM profession. But only in the post-application interview, students stated in detail that specialized teachers (i.e. science, mathematics, technological design, informatics) could perform STEM professions.

It can be seen that there is no change in the theme of “STEM Related Tools/Products” and its sub-themes, but there is a notable change in the codes that constitute the sub-theme "Tools/Products". While students could give seven tools/product examples applicable for STEM fields in the pre-application interview, this number increased to 16 in the post-application interview. The biggest change is observed in computer and telephone products. Again, in the pre-application interview, no student gave the example of household appliances (washing machine, refrigerator, oven, etc.), while in the post-application interview, five students stated that these products were also STEM products. The informal interview field note of the participant researcher on 01.04.2018, states that *“Students could heat domestic water and could cool the warm house by using solar energy, which is an environmentally-friendly energy. In my conversations with some students during the day, they made me think that the solar panels that students use in their home designs are very useful for people, that they do not spend money on electricity thanks to this design, and that it is very beneficial to make such products.”*, which supports these findings.

No observable change is seen in the codes obtained in the pre-application and post-application interviews under the theme of “Engaging in a STEM Related Activity” and the sub-themes of “Desire”, “Affective Features”, and “Individual Features”. In the post interview, the students stated that it was fun to do activities related to STEM.

In terms of the theme “Feeling STEM Fields Close to You”, it was observed that students' perceptions of science and mathematics increased positively, their views on engineering remained unchanged, and their perspectives on technology decreased

4. Discussion and Conclusion

As a result of the STEM Attitude Scale, a positive change was detected in the attitudes of the students towards STEM fields. In addition, a positive change was also found between the pre-test and post-test scores related to all sub-dimensions of the STEM Attitude Scale including Science, Mathematics, Engineering, Technology, Science-Mathematics-Engineering-Technology and Career.

The results obtained in the research are similar to the studies in the literature that examine students' attitudes towards STEM with different ages and practices. Yavuz (2019) and Yasak (2017) stated that STEM-related practices had a positive impact on middle school students' STEM attitudes. Similarly, Akin (2019) argued that according to the results of a quasi-experimental study, STEM activities had a significant positive effect on seventh-grade students’ attitudes towards STEM in favor of the experimental group in Science, Mathematics, Technology and Engineering sub-dimensions. Akin (2019) concluded that students expressed positive thoughts about the engineering profession, stating that it was enjoyable and that it could be among the professions they could choose in the future.

Dogan (2019) discussed that seventh-grade students’ attitudes towards the “Mathematics” dimension of the STEM Attitude Scale did not change. In his study with seventh-grade students, Ercan (2014) concluded that some students, who did not think of engineering in terms of career planning before the applications, started to consider engineering as an alternative after the applications. In terms of the

“Science-Mathematics-Engineering-Technology” sub-dimension, no results were found in the literature for middle school students.

Four months after the original study, the STEM Attitude Scale was re-applied as a permanence test to determine whether the change in students' attitudes was temporary. The results indicated that no statistically significant difference was observed between the students' scores on the posttest and the permanence test for the scale. Based on these findings, it was concluded that STEM practice significantly and permanently improved students' attitudes towards STEM. In the literature, there is no study investigating the effect of STEM applications on the permanence of students' STEM attitudes.

The analysis of qualitative data showed that STEM activities had a positive effect on students’ attitudes toward STEM related fields. The pre and post applications of STEM Interview Form showed that students acquired new information about the STEM professions, for example, they thought that the teaching profession was a STEM profession, but unlike the pre-application interview, they explained in detail which branches of teaching professions should be considered STEM professions in the post-application interview. Also, the number of students, who considered engineering and architecture as STEM professions, increased in favor of the post-application interview. From this point of view, it was concluded that STEM application positively affected students' level of knowledge about the STEM professions. Bozkurt Altan, Ucuncuoglu, and Zileli (2019) found that over half of the eighth-grade students in regional boarding middle schools provided examples of professions suitable for STEM fields. Most of the examples cited were related to engineering professions, such as computer science, electronics, civil engineering, environmental engineering, and more. Gencer (2015) conducted a STEM activity with seventh-grade students in his study and stated that the activity would contribute to students developing career awareness in the field of science.

In the context of the theme of "STEM Related Tools/Products", in the post-application interview, most of the students thought that tools and products such as cars, planes, phones, computers, tablets, televisions, telescopes, space rockets, calculators, smart boards, cameras, bikes, white appliances, etc. were produced thanks to STEM fields. From this point of view, it can be said that this application increases the knowledge levels of the students about the areas of use of the STEM fields.

It was observed that there was no noteworthy change in the codes obtained in the pre and post-application interviews in the theme of "Engaging in a Stem-Related Activity" and its sub-themes. The “entertainment/fun” code was added in the post-application interview in addition to the codes in the sub-theme of affective features in the pre-application interview. Having such a thought in the post-application interview leads us to the conclusion that the students enjoy the STEM application throughout the process. Additionally, the “learning” code was included in the post-application interview. This indicated that students acquired new knowledge and learned different things during the STEM-related activities conducted before the application. As a result, it was concluded that the program had a positive impact on students' acquisition of new and diverse information.

In their study on fifth-grade students, Gulhan and Sahin (2016) stated that STEM activities increased students' conceptual learning in science and their professional interests in STEM fields. In addition, it was concluded that within the scope of the theme of “Feeling the STEM Fields Close to You” and the sub-themes of “Science”, “Mathematics”, “Technology” and “Engineering”, students' views on science and mathematics fields increased positively, but their views on engineering were not changed, whereas there was a decrease in their opinions regarding technology.

It was seen that in the post-application interview, the students gave the example of an astronaut as a profession and also, rocket and telescope products as tools/products, and a rocket was among the products that they would consider to make. Contrary to the pre-application interview, it is thought that the reason for using the expressions related to space in the post-application interview was the effect of designing “space shuttle” and “rocket” on this subject as well as addressing the subject of “space” in the STEM application study. Therefore, it is concluded that the application positively affects students' thoughts on space. Ozsevgec et al. (2018) concluded from their study on middle school students that male students at all grade levels were more interested in astronomy than female students. The findings of this study overlap with the findings we have obtained in our research, that is, “The students have positive thoughts on space”.

Considering the opinions expressed by the students in the pre and post-interviews, it is seen that their thoughts of making a tool/product using STEM fields were more positive in the post-interview than in the pre-interview. Consequently, it was concluded that the application positively influenced students' ideas of designing useful products used in daily life by utilizing STEM fields. Bottia et al. (2017) concluded that students, who took STEM education, were more successful in their relationship with STEM. Upon completing his study involving seventh-grade students, Higde (2018) concluded that students experienced a sense of being an engineer, which enhanced their skills in design and measurement. Additionally, they exhibited qualities akin to a scientist, demonstrating idea generation, possessing scientific knowledge, and engaging in experiments while participating in STEM activities. Also, in a study with seventh-grade students at a middle school, Dogan (2019) concluded that the students wanted and loved STEM, their interest in STEM professions increased, and they found STEM practices fun. These findings in the literature overlap with the findings we obtained in our research. In general, this research is considered to affect students' perceptions of STEM professions positively, and it is effective in realizing that most of the products that they see in their environment are created by using STEM fields.

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Appendices 1: STEM Interview Form

1-Can you tell a profession that uses STEM knowledge or skills together?

2-Can you name a tool/product made using a combination of STEM skills that you see or know around you?

a) Do you think this tool/product is beneficial for society?

b) Do you think this tool/product has features that will meet the needs of people and make their job easier?

3-Would you like to participate in activities where STEM skills are used together, if so, why?

4-Which area(s) of STEM do you feel close to? Why?

Appendices 2: STEM Compatibility Form

The STEM Compatibility Form is intended to be a form that tests the compatibility of an activity related to STEM education or a product designed with STEM education. This form needed to demonstrate whether the designs or activities that the students in the study group made/would make were suitable for the STEM fields. To this end, a draft form was developed by the researchers. The developed draft form was sent to seven (7) experts, including two faculty members specialized in science education, one faculty member in physics education, a science teacher with a doctorate in science education, two graduate students in science education, and one science teacher. In light of the suggestions from the experts, some of the concepts/topics in the form were removed, some were combined because they serve the same purpose, and some missing concepts/topics were added to the form. The revised form with necessary adjustments was finalized. In this study, the researcher evaluated the creation of designs made by students by integrating at least three STEM fields. Before starting the design study, design plans of the students were evaluated according to the STEM Compatibility Form. If there were at least three topics/concepts, it was thought that the design would be compatible with STEM, hence it was allowed to be made. There is room for a check mark beside each concept/topic in the form. The teacher-researcher conducting STEM education will fill this form for the event or design. The developed form is given below:

STEM Compatibility Form							
Science							
Buoyancy	*Volume*	*Speed/ Velocity*	*Strength*	*Balance*	*Friction force*	*Heat*	*Weight*
Energy/Energy conversions	*Pressure*	*Lenses/ Mirrors*	*Mass*	*Gravity*	*Electricity*	*Temperature*	*Voice*
Metals/ Non-metallic element	*Light*	*Space missions*	*Environment*	*Swimming/ Submersion*	*Experimenting*	*Mixture/ Solution*	*Observation/ Forecast / Making inferences*
Magnetism	*States of Matter (solid, liquid, etc.)*	*Process change (boiling, melting, etc.)*	*Weight/ Volume*	*Ecosystem*	*Organisms*	*Inheritance / Genetics*	*Conducting/ Dielectric materials*
Sense organs	*Reflection/ Refraction*	*Microscopic creatures*	*Internal Organs*	*Physical/ Chemical changes*	*Life cycle*	*Food pyramid*	*Transplantation (face, blood, etc.)*
Medication	*Socio-scientific issues*	*Photosynthesis/ Respiration*	*Biotechnology*	*Simple machines*	*Atom*	*Acid and alkaline*	*Climate/ Meteorological events/Seasons*
Insulation materials	*Element/ Compound*	*Periodic table*	*Extinct/ Endangered species*	*Layers of the world*	*Natural events (earthquakes, hurricanes, etc.)*	*Systems in our body*	
Technology							
Car/Aircraft / Ship/Train	*Phone/ Computer/Tablet usage*	*TV-Radio*	*Solar panel/Chargers/Battery usage, etc.*	*Virtual reality/Augmented reality applications*	*Using multimedia systems*	*Using sensory techniques (light, sound, touch, etc.)*	*Using infrared sensors and remote control systems*

Using the Internet	*Innovation*	*Robotic systems*	*3D printer*	*Hologram*	*Applications such as e-food/e-curriculum/ e-ticket, etc.*	*Simulation-Animation studies*	*Information and Communication Technology*
Making Engine/Machine	*Using social media*	*Nano card/Arduino*	*Cardiac pacemaker*	*Microprocessor*	*Medical tools and equipment*	*Using the virtual environment*	*Developing new fuel systems*
X-Ray	*Ultraviolet*	*Taking Photograph/ Video*	*Hybrid vehicles*	*Space technology (rocket, fuel, etc.)*	*Lego-Robotic applications*	*Seismography*	*LED bulbs*
Digital measuring devices							
			Engineering				
Drawing	*Prototyping*	*Designing*	*Using engineering design phases*	*Bridge-Building Construction*	*Mechatronics*	*Urban Planning*	*Infrastructure/ Sewage construction*
Construction	*Manufacturing*	*Revising*	*Designing/ reviewing automation systems*	*Applied engineering*	*Using technical systems*	*Building power plants*	*Developing software*
Drawing City - Building - Bridge - Park projects	*Taking precautions against natural disasters (earthquake, flood, fire, etc.)*	*Designing a toy car*	*Constructing models such as aircraft/car, etc.*	*Design thinking skills*	*Producing heat/sound insulation products*	*Building a coding system*	*Developing a setting for an event*
Using integrated parts							
			Mathematics				
Calculation	*Problem-solving*	*Angle*	*Using geometric shapes*	*Creating Chart/ /Table*	*Counting*	*Calculating Area-Land*	*Analytical thinking*
Measuring	*Ruler / Compasses / Meter*	*Ratio*	*Using a spreadsheet*	*Calculating from the memory*	*Mental calculation*	*Factorial calculations*	*Solving Puzzle, Sudoku, etc.*
Logic	*Making inferences*	*Probability thinking*	*Algorithmic Thinking*	*Duration/Time control*	*Data analysis*	*Data collection and evaluation*	

Article Information Form

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