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ORIGINAL ARTICLE

The Effect of STEM Activities on Primary School Students' Attitudes towards STEM

Neslihan Açıkay[1], Mehmet Akif Bircan[2], & Hamdi Karakaş[3*]

[1] Primary School Teacher, Institute of Educational Science, Sivas Cumhuriyet University, Sivas, Türkiye.
ORCID: 0009-0007-8042-6990

[2] Asst. Prof. Dr., Department of Basic Education, Faculty of Education, Sivas Cumhuriyet University, Sivas, Türkiye.
ORCID: 0000-0003-2442-0600

[3] Assoc. Prof. Dr., Department of Basic Education, Faculty of Education, Sivas Cumhuriyet University, Sivas, Türkiye
ORCID: 0000-0001-9209-4128

Ethical Statement

Before the study, primary school students were given detailed information about the whole process. Primary school students stated that they did not suffer any academic or psychological damage at the end of the study. The authors declare that no unethical action was taken in this study, that the responsibility belongs to the author(s) in all cases that may arise from ethical violations, and that the informed consent/consent form was signed by the participants.

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Conflict of Interest

The authors contributed equally to all parts of the study and there is no conflict of interest between the authors.

ABSTRACT

This study aimed to find out the effect of STEM activities on primary school students' attitudes towards STEM by using a pretest-posttest, experimental-control group quasi-experimental design. The research was conducted with 39 primary school students in the experimental ($N_{experimental}$=21) and control group ($N_{control}$=18) who were studying in the fourth grade of a school located in a city in the Central Anatolia Region of Türkiye in the 2021-2022 academic year. The *STEM Attitude Scale* was administered as a pretest and posttest to measure the changes in primary school students' attitudes towards STEM before and after the STEM activities. The intervention step included nine different STEM activities prepared for primary school students. The data were analyzed using analysis of covariance (ANCOVA) and dependent groups t-test, and the effect size (e-square [η^2]) was calculated according to the variances between the scores. Based on the results, it was concluded that STEM activities foster the positive STEM attitudes of primary school students participating in these activities with a significantly wider effect than the primary school students who do not participate in such activities. The effect of engaging in STEM activities on primary school students' attitude towards STEM sub-dimensions was also examined, which indicated significant improvements in all sub-dimensions compared to the primary school students who did not take part in these activities. Including STEM-based activities in primary schools is highly recommended because STEM activities are design-oriented, enable the use of technology, and involve skills such as creativity, problem solving, communication, and cooperation.

Keywords: STEM activities, STEM attitude, primary school students

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***Corresponding Author:** Assoc. Prof. Dr., Hamdi Karakaş, Faculty of Education, Sivas Cumhuriyet University, Sivas, Türkiye
Email: hamdikarakas58@yahoo.com.tr

INTRODUCTION

The rapid increase in scientific and technological developments in the last century has led to the need for training individuals to help them adapt to the ever-changing and developing age. Rapid developments in information and technology necessitate a change in the knowledge and skillsets that individuals need to have (Çepni & Ormancı, 2017). Individuals need training so that they can be equipped with 21st century skills such as problem-solving, critical, creative and innovative thinking, and working as a team (Azgın & Şenler, 2019; Bowman, 2010; Fitzallen, 2015; Marginson, et al., 2013). Therefore, innovative approaches are needed in education and training in order for individuals to acquire knowledge and skills that they can live by adapting to the society and world they live in. STEM activities are one of the recent approaches that make significant contributions to individuals' adaptation to the changing world.

STEM is an acronym created with the English initials of the words Science, Technology, Engineering and Mathematics (Ministry of National Education [MoNE], 2016; Morrero, Gunning & Germain-Williams, 2014). It is defined as a teaching system that adopts an interdisciplinary and application-oriented perspective and enables the integration of science, engineering, technology and mathematics by establishing links between them (Hacıömeroğlu & Bulut, 2016; Kennedy, Odell, 2014). STEM aims to enable students to look at problems from an interdisciplinary perspective (Şahin, Ayar, & Adıgüzel, 2014; Trevallion & Trevallion, 2020) and to gain knowledge and skills through a holistic education (Kennedy & Odell, 2014). The fact that STEM brings together different disciplines helps students to look at the problems they face from a broad perspective (Karakaya, et al., 2019). Integrating STEM education into curriculum contributes to students' self-confidence and self-efficacy as well (Thomas, 2014). In addition, the preparation of STEM-oriented activities to increase academic success and learning retention is another point drawing a lot of attention (McClain, 2015).

The STEM Education Report (MoNE, 2016), published by the General Directorate of Innovation and Educational Technologies, is a very important document for the Turkish context. This report states that students' positive attitudes towards science, technology, engineering, and mathematics disciplines will have a positive effect on developing their 21st century skills and will increase their scores on international exams such as PISA and TIMSS. The objectives for strengthening STEM were also discussed in the *2015-2019 Strategic Plan* by the Ministry of National Education. In line with these objectives, various STEM centers have been established by national education directorates and municipalities (MoNE, 2016). Besides, MEB has become a part of the SCIENTIX project and prepared a *STEM Education Teacher's Handbook* for teachers. In addition, the workshops and in-service training activities held in certain provinces aimed to help teachers get to know and practice STEM better (Altun & Apaydın, 2022; Sumen & Calisici, 2016).

In countries such as China, South Korea and Japan, which are highly successful in the PISA exam, STEM education is given from primary to tertiary education. In addition, considering the success of these countries in the fields of engineering and technology, the importance of STEM education becomes even more evident (İdin & Kaptan, 2017). The development of science and technology, which have important contributions to national economies, depends on countries' ability to raise a generation that has the necessary pre-knowledge and skills in STEM fields, can take creative perspectives at problems, think freely, question, produce innovative solutions, and care about solidarity (Aydeniz, 2017). Trevallion and Trevallion (2020) draw attention to the primary education as the period during which STEM education can be fully integrated. Çelebi and Özkan (2021) concluded that STEM-related research carried out in primary schools are mostly qualitative. Considering the contributions of the approach in this context, it was considered important by researchers to implement STEM activities in primary schools with an experimental study. Driven by these reasons, the aim of the present study is to determine the effect of STEM activities on primary school students' attitudes towards STEM. For this purpose, answers to the following questions were sought:

1- Does engaging in a STEM activity process affect primary school students' attitudes towards STEM?
    a. When the pretest mean scores of primary school students participating in STEM activities and the primary school students who do not take part in them are controlled, is there a significant difference between their STEM attitude mean scores?
2- Does the STEM activity process affect primary school students' attitudes towards STEM sub-dimensions?
    a. When the pretest mean scores of primary school students participating in STEM activities and the primary school students who do not take part in them are controlled, is there a significant difference between their math attitude mean scores?
    b. When the pretest mean scores of primary school students participating in STEM activities and the primary school students who do not take part in them are controlled, is there a significant difference between their science attitude mean scores?
    c. When the pretest mean scores of primary school students participating in STEM activities and the primary school students who do not take part in them are controlled, is there a significant difference between their engineering and technology attitude mean scores?
    d. When the pretest mean scores of primary school students participating in STEM activities and the primary school students who do not take part in them are controlled, is there a significant difference between their 21st century skill mean scores?

METHOD

Research Design

A quasi-experimental design with pretest-posttest experimental-control group was used in this study. In the experimental design, pretests are applied to the experimental and control groups without any intervention, the experimental procedure is carried out, and then the posttest values between the groups are compared. Thus, the findings can be generalized when similar conditions are met (Gürbüz & Şahin, 2016; Johnson & Christensen, 2014). In the quasi-experimental design, one of the selected groups is taken as the experimental group and the other as the control group, without making an unbiased assignment at the beginning (Büyüköztürk et al., 2016). The research was planned in accordance with the experimental and a control group pretest-posttest experimental design. After the pretest was administered, STEM activities were carried out with the experimental group by integrating them into the lesson, while the control group was taught the curriculum prescribed by the Ministry of Education, and then the posttest was given to both groups. The experimental procedures implemented by the researchers are presented in Table 1.

Table 1. Experimental Procedures

Group	Pretest	Intervention	Posttest
Control Group (Primary School 4th Grade Students)	STEM Attitude Scale (SAS)	Regular Teaching in Classroom	STEM Attitude Scale (SAS)

Experimental Group (Primary School 4th Grade Students)	STEM Attitude Scale (SAS)	Regular Teaching in Classroom + STEM Activities (10 weeks)	STEM Attitude Scale (SAS)

As seen in Table 1, the *STEM Attitude Scale* was administered as a pretest-posttest to measure the change in primary school students' attitudes towards STEM before and after STEM activities. In the intervention step, while the normal course process continued with the control group students, STEM activities, along with the regular course activities, were carried out for 8 weeks with the experimental group. At the end of the intervention, the pre- and post- test data were analyzed and interpreted.

Study Group

The criterion sampling method, which is a type of purposive sampling, was used to select the study group of the research. Criterion sampling allows to examine people, events, objects or situations with certain qualities (Büyüköztürk et al., 2016). The criteria used to determine the study group of the research were: taking science and mathematics courses, being enrolled in the fourth grade (so that the participants would answer the pre- and posttests sincerely and be more active in carrying out the activities), easy accessibility by the researchers, and having at least two different classes in the school (to include as the experimental and control). As part of these criteria, 39 primary school students studying in the fourth grade of a primary school in a province located in the Central Anatolia Region in the 2022-2023 academic year were included in the study.

STEM Attitude Scale pretests were used to test whether the students in both fourth grade classrooms were identical groups. The average scores of the classrooms were compared with the independent groups t-test, and the results are presented in Table 2

Table 2. Comparison of Pretest Average Scores by Classroom

	Group	N	$\bar{X}$	S	t	Sd	p
STEM Attitude Scale	Classroom -1	21	3.93	.520	-.515	37	.61
	Classroom -2	18	3.85	.471			

When the pretest mean scores were compared, no significant difference was found between the mean scores of the two classrooms ($p<0.05$). Therefore, they were accepted as identical and by drawing lots, Classroom 1 was determined as the experimental (N:21) and Classroom 2 as the control (N:18) group.

Intervention Process

Before starting the research, books containing STEM-based activities published by Gaziantep Directorate of National Education (2021) and Muğla Directorate of National Education (2021) were reviewed. Afterwards, a nine-week intervention plan covering different STEM activities was prepared. The prepared STEM activity plans were presented to two education experts in terms of relevance for the purpose, clarity of the expressions, and content validity. The activities revised in line with the expert opinions were given their final form. A meeting was held with the parents of the experimental group students and they were informed about the practices. Afterwards, consents of parents and school administrator were obtained.

The intervention process was planned to be 10 weeks, including the pretest and posttest. The process of intervention began by administering the pretest to both groups. No STEM-based activities were organized by the researcher with primary school students in the control group. The researcher taught the control group the mathematics and science subjects within the curriculum, completed the activities of the lessons (subject revision, problem solving, evaluation, etc.) and spent as much time with the control group as the experimental group. In addition to the regular science and mathematics curriculum, STEM activities were carried out in the lessons with the experimental group primary school students. Just like in the control group, the researcher taught mathematics and science subjects within the curriculum, completed the activities of the lessons (subject revision, problem solving, evaluation, etc.), but implemented the prepared STEM activity plans with students (three individual, six group activities) in addition. If there was no time left for activities, free activity class hours were used instead. Groups of three or four were formed by the researcher, taking into account the characteristics such as the gender, performance, and interests of the students in the study group. The researcher took the role of a guide in the STEM activities that the students had difficulty in starting, and increased their participation in the activities by supporting and encouraging them. At the end of the process, posttests were administered to both groups and the intervention process was ended. The activities and the intervention process are presented in Table 3.

Table 3. Information on Prepared Activities

Week	Activity	Activity Type
1	Preliminary testing / Flying plane	Individual work
2	Parachute Rescue	Individual work
3	Balance and Scales	Individual work
4	Let's Separate the Mixtures	Group work
5	My Own Carpet	Group work
6	Birdhouse	Group work
7	Fruit Yoghurt	Group work
8	Dancing Grapes	Group work
9	Designing a Poster with Canva	Group work
10	Administering the Posttests	Individual work

Data Collection Tool

In this study, as the data collection tool, the STEM Attitude Scale (SAS) was administered to fourth grade primary school students as a pretest and posttest. The scale was developed by Unfried, Faber, Stanhope, and Wiebe (2015) to maximize STEM education and was adapted into Turkish by Öztürk (2017). It is a five-point Likert-type scale, with each item presenting the options of "Strongly Disagree" (1), "Disagree" (2), "I am undecided" (3), "Agree" (4) and "Strongly Agree" (5). There are 37 items in the scale and it consists of 4 sub-dimensions named Mathematics Attitudes (MA), Science Attitudes (SA), Engineering and Technology Attitudes (ETA), and 21st Century Learning (CL). According to the results of the reliability analysis of the Turkish version of the scale, the internal consistency coefficient (Cronbach's Alpha) was calculated as 0.64 for MA, 0.81 for SA, 0.81 for ETA, and 0.84 for CL.

Reliability coefficient calculations were performed for the STEM Attitude Scale, which was administered to primary school fourth grade students as a pretest and posttest. After the calculations, reliability coefficients close to the values for which the scales were developed were obtained. Based on these calculations, the results obtained from the scales were found to be reliable. The Cronbach's Alpha reliability coefficient calculation results for the scales are presented in Table 4.

Table 4. Reliability Analysis of the Administered Scales

Test	Dimension	Item No.	Cronbach's Alpha	Reliability*
Pretests	Mathematics Attitudes (MA)	8	0.87	Highly Reliable
	Science Attitudes (SA)	9	0.86	Highly Reliable
	Engineering and Technology Attitudes (ETA)	9	0.85	Highly Reliable
	21st Century Learning (CL)	11	0.84	Highly Reliable
	Whole Scale	37	0.83	Highly Reliable
Posttest	Mathematics Attitudes (MA)	8	0.83	Highly Reliable
	Science Attitudes (SA)	9	0.85	Highly Reliable
	Engineering and Technology Attitudes (ETA)	9	0.83	Highly Reliable
	21st Century Learning (CL)	11	0.83	Highly Reliable
	Whole Scale	37	0.82	Highly Reliable

* Büyüköztürk et al., (2016).

Data Analysis

SPSS and Excel package programs were used in the analysis of the scales administered before and after the STEM activities. In the analysis of the data, firstly, Kolmogorov-Smirnova and Shapiro-Wilk tests were performed to determine the normality of the data distribution. Since the number of data was lower than 29, it was analyzed through Shapiro-Wilk test results, and as this value was greater than 0.05 for both the pretest and posttest, and the skewness and kurtosis coefficients ranged between +3 and -3, it was concluded that the mean scores had normal distribution (Kline, 2005). The pre- and posttest Normality Test results of the scales used for the experimental and control groups are presented in Table 5.

Table 5. Pretest – Posttest Normality Distribution Results of the Scales

			Kolmogorov-Smirnov[a]			Shapiro-Wilk			Skewness Value	Kurtosis Value
			Statistic	df	Sig.	Statistic	df	Sig.		
Experimental Group	Mathematics Attitudes	Pre Test	.135	21	.200	.940	21	.221*	-.011	-1.260
		Post Test	.190	21	.045	.857	21	.006	-1.175	.553
	Science At	Pre Test	.172	21	.105	.940	21	.217*	-.576	-.583

			Kolmogorov-Smirnov[a]			Shapiro-Wilk			Skewness Value	Kurtosis Value
			Statistic	df	Sig.	Statistic	df	Sig.		
		Post test	.139	21	.200	.950	21	.337*	-.535	-.270
	Engineering and Technology Attitudes	Pre Test	.114	21	.200	.965	21	.624*	.193	-.689
		Post Test	.147	21	.200	.936	21	.183*	-.693	.036
	21st Century Learnings	Pre Test	.222	21	.008	.926	21	.116*	-.516	-.770
		Post Test	.215	21	.013	.832	21	.002	-1.509	2.092
	STEM Attitude	Pre Test	.099	21	.200	.978	21	.891*	-.209	-.309
		Post Test	.167	21	.129	.898	21	.032	-1.395	2.629
Control Group	Mathematics Attitudes	Pre Test	.105	18	.200	.959	18	.583*	-.487	-.272
		Post Test	.150	18	.200	.930	18	.194*	-.983	1.255
	Science Attitudes	Pre Test	.144	18	.200	.969	18	.775*	-.217	-.428
		Post Test	.178	18	.137	.906	18	.074*	-.671	-.693
	Engineering and Technology Attitudes	Pre Test	.169	18	.185	.957	18	.542*	-.216	.038
		Post Test	.148	18	.200	.936	18	.251*	.277	-1.127
	21st Century Learnings	Pre Test	.119	18	.200	.937	18	.262*	-.630	1.380
		Post Test	.178	18	.136	.860	18	.012	-1.443	2.307
	STEM Attitudes	Pre Test	.220	18	.021	.912	18	.094*	-1.080	2.728
		Post Test	.171	18	.178	.908	18	.080*	-1.173	2.039

*p>0.05

Examining the data in Table 5 were examined, it was observed that both pretest and posttest data of most of the scales administered to the experimental and control groups in the Shapiro-Wilk normality analysis showed normal distribution (p>0.05). However, the mathematics attitudes, 21st century learning and STEM Attitude posttest scores of the experimental group and the 21st century learning posttest scores of the control group did not show a normal distribution (p<0.05). The skewness and kurtosis coefficients of these data were found to fall in the range of -3 to +3. Therefore, parametric tests were performed in pretest-posttest data analysis and the responses of primary school students to data collection tools before and after STEM activities were analyzed using frequency, arithmetic mean, analysis of covariance (ANCOVA) and dependent groups t-test, and the effect size (et square [$ή^2$]) was calculated according to the variances between the scores. ANCOVA is performed to test the difference between the posttest scores of the groups and to statistically control the effect of the pretest or other variables on the posttest (Büyüköztürk, et al., 2016).

RESULTS AND DISCUSSION

This study determined the effect of STEM activities on primary school students' attitudes towards STEM. The problem statement and the results obtained for the sub-problems are presented in the form of sub-headings.

Results Regarding the Effect of STEM Activities on Primary School Students' Attitudes towards STEM

Analysis of covariance (ANCOVA) was used to test the STEM attitude posttest mean scores of primary school students in the experimental and control groups by controlling their STEM attitude pretest scores. Before the analysis, the relationship between the control variable STEM attitude pretest mean scores and the dependent variable STEM attitude posttest mean scores was examined ($r=0.31$; $p<0.000$) and a linear relationship was identified, verifying the assumption that the regression trends are homogeneous.

The ANCOVA results for the comparison of the posttest mean scores between the groups by controlling the STEM attitude pretest scores are presented in Table 6.

Table 6. ANCOVA Results Regarding the Comparison of Posttest Mean Scores between Groups Controlling for the STEM Attitude Pretest Scores

Source	Sum of Squares	sd	Mean Squares	F	p	Effect Size
Pretest	1.672	1	1.672	7.80	.008	0.412
Group	5.393	1	5.393	25.17	.000*	
Error	7.713	36	.214			
Total	671.428	39				

*$F(1, 36)=25.17$; $p=0.000$; ή^2=0.412

When Table 6 is examined, the F values calculated as a result of ANCOVA can be seen to be significant for the pretest (covariant). The significant F value of the pretest ($F(1, 36)=1.672$; $p<0.05$) shows that primary school students' pre-intervention STEM attitudes explain a significant variance. When the STEM attitude pretest average scores were statistically controlled, a significant difference was found between the STEM attitude posttest average scores of the primary school students who participated in STEM activities and the STEM attitude posttest average scores of the primary school students who did not engage in such activities ($F(1, 36)= 25.17$; $p<0.05$). The eta square (ή^2) value was found to be 0.412, and 41.2% of the variance in primary school students' STEM attitude posttest average scores was due to the difference in the STEM activity intervention. According to Cohen, Manion, and Morrison (2018), this value (0.14<ή^2) is widely accepted.

The STEM attitude posttest adjusted average scores ($\bar{X}_{experiment\ adjusted}=4.44$) of the primary school students participating in the STEM activities were significantly higher than those ($\bar{X}_{control\ adjusted}=3.69$) of the primary school students who did not participate in these activities ($p<0.05$), which indicates that getting involved in STEM activities significantly strengthen the positive STEM attitudes of primary school students compared to those who do not take part in these activities.

Results Regarding the Effect of STEM Activities on the Sub-dimensions of Primary School Students'

Attitudes towards STEM

Analysis of covariance (ANCOVA) was used to test the STEM attitude sub-dimensions' pretest scores of primary school students in the experimental and control groups, and to test the posttest mean scores of the STEM attitude sub-dimensions. Analyses of the sub-dimensions are presented below.

Results Regarding Mathematics Attitude Sub-dimension

The relationship between the pretest mean scores, which is the control variable, and the mean scores of the math attitude posttest, which is the dependent variable, was examined ($r=0.91$; $p<0.000$), and a linear relationship was found. This shows that the assumption that the regression trends are homogeneous is fulfilled. The ANCOVA results for the comparison of the posttest mean scores between the groups by controlling for the pretest scores of mathematical attitudes are presented in Table 7.

Table 7. ANCOVA Results Regarding the Comparison of Posttest Mean Scores between Groups Controlling for the Mathematic Attitude Pretest Scores

Source	Sum of Squares	sd	Mean Squares	F	p	Effect Size
Pretest	4.910	1	5.093	12.573	.001	0.316
Group	6.489	1	4.910	16.618	.000*	
Error	14.057	36	6.489			
Total	668.594	39				

*$F(1, 36)=16.618$; $p=0.000$; $ή^2=0.316$

Examining Table 7, the F values calculated through ANCOVA can be seen to be significant for the pretest (covariant). The fact that the F value of the pretest was significant ($F(1, 36)=12.573$; $p<0.05$) shows that primary school students' pre-intervention mathematics attitudes explain a significant variance. When the mathematics attitude pretest average scores were statistically controlled, a significant difference was found between the mathematics attitude posttest average scores of the primary school students taking part in the STEM activities and the mathematics attitude posttest average scores of the primary school students who did not perform the activities ($F(1, 36)= 16.618$; $p<0.05$). The eta square ($ή^2$) value was found to be 0.316, and 31.6% of the variance in the mathematics attitude posttest average scores of primary school students is due to the STEM activity intervention. This value ($0.14<ή^2$) is widely accepted.

The mathematics attitude posttest adjusted average scores ($\bar{X}_{experiment\ adjusted}=4.44$) of the primary school students performing STEM activities were significantly higher than the mathematics attitude posttest adjusted average scores ($\bar{X}_{control\ adjusted}=3.62$) of the primary school students who did not engage in these activities ($p<0.05$). This result can be interpreted to show that the engaging in STEM activity processes significantly improves the positive mathematics attitudes of primary school students compared to primary school students who do not participate in such activities.

Results for Science Attitude Sub-dimension

The relationship between the science attitude pretest mean scores, which is the control variable, and the science attitude posttest mean scores, which is the dependent variable, was examined ($r=0.31$; $p<0.000$) and a linear relationship emerged. This data shows that the assumption of homogeneity of regression is fulfilled. The ANCOVA results for the comparison of the posttest mean scores between the groups by controlling for the science attitude pretest scores are presented in

Table 8.

Table 8. ANCOVA Results Regarding the Comparison of Posttest Mean Scores between Groups Controlling for the Science Attitude Pretest Scores

Source	Sum of Squares	sd	Mean Squares	F	p	Effect Size
Pretest	2.325	1	2.325	6.002	.019	0.224
Group	4.027	1	4.027	10.398	.003*	
Error	13.943	36	.387			
Total	637.901	39				

*F(1, 36)=10.398; p=0.003; $\acute{\eta}^2$=0.224

When Table 8 is examined, the F values calculated through ANCOVA are observed to be significant for the pretest (covariant). The significant F value of the pretest (F(1, 36)=6.002; $p<0.05$) shows that primary school students' pre-intervention science attitudes explain a significant variance. When the science attitude pretest average scores were statistically controlled, there was a significant difference between the science attitude posttest average scores of the primary school students who engaged in the STEM activities and the science attitude posttest average scores of the primary school students who did not (F(1, 36)= 10.398; $p<0.05$). The eta square ($\acute{\eta}^2$) value was found to be 0.224, and 22.4% of the variance in primary school students' science attitude posttest average scores is due to the STEM activity intervention. This value ($0.14<\acute{\eta}^2$) is widely accepted.

The mean scores of the primary school students participating in the STEM activities ($\bar{X}_{experiment\ adjusted}$=4.28) were significantly higher than the science attitude posttest adjusted average scores of the primary school students who did not participate in them ($\bar{X}_{control\ adjusted}$=3.60) ($p<0.05$), which can be interpreted that STEM activities significantly improve the positive science attitudes of primary school students compared to primary school students who do not participate in this type of activities.

Results Regarding the Engineering and Technology Attitude Sub-dimension

The relationship between the engineering and technology attitude pretest mean scores, which is the control variable, and the engineering and technology attitude posttest mean scores, which is the dependent variable, was examined (r=0.82; $p<0.000$) and a linear relationship was revealed, and thus, the assumption that the regression trends are homogeneous is fulfilled. The ANCOVA results for the comparison of the posttest mean scores between the groups by controlling for the engineering and technology attitude pretest scores are presented in Table 9.

Table 9. ANCOVA Results Regarding the Comparison of Posttest Mean Scores between Groups Controlling for the Engineering and Technology Attitude Pretest Scores

Source	Sum of Squares	sd	Mean Squares	F	p	Effect Size
Pretest	8.299	1	8.299	33.710	.000	0.525
Group	9.778	1	9.778	39.716	.000*	

Error	8.863	36	.246
Total	649.111	39	

*F(1, 36)=39.716; p=0.000; ή²=0.525

Examining Table 9, the F values calculated through ANCOVA can be seen to be significant for the pretest (covariant). The fact that the F value of the pretest is significant ($F(1, 36)=33.710$; $p<0.05$) shows that the pre-intervention engineering and technology attitudes of primary school students explain a significant variance. When the engineering and technology attitude pretest average scores were statistically controlled, a significant difference was found between the engineering and technology attitude posttest average scores of the primary school students who took part in the STEM activities and the engineering and technology attitude posttest average scores of the primary school students who did not have the STEM activities (F). (1, 36)= 39.716; $p<0.05$). The eta square ($ή^2$) value was found to be 0.525, and 52.5% of the variance in the engineering and technology attitude posttest average scores of primary school students is due to the STEM activity intervention. This value ($0.14<ή^2$) is widely accepted.

The engineering and technology attitude posttest adjusted average scores of the primary school students who engaged in the STEM activities ($\overline{X}_{experiment\ adjusted}=4.46$) were found to be significantly higher than the engineering and technology attitude posttest adjusted average scores of the primary school students who did not ($\overline{X}_{control\ adjusted}=3.45$) ($p<0.05$). Controlling for the engineering and technology attitude pretest scores, this result shows that getting involved in STEM activities brings significant improvements in the engineering and technology attitudes of primary school students.

Results Regarding the 21st Century Skills Sub-dimension

Focusing on the relationship between 21st century skill pretest mean scores, which is the control variable, and 21st century skill posttest mean scores, which is the dependent variable ($r=0.80$; $p<0.000$), a linear relationship was revealed, indicating that the assumption that the regression trends are homogeneous is correct. The ANCOVA results for the comparison of the posttest mean scores between the groups by controlling for the 21st century skill pretest scores are presented in Table 10.

Table 10. ANCOVA Results Regarding the Comparison of the Posttest Average Scores Between Groups Controlling for the 21st Century Skill Pretest Scores

Source	Sum of Squares	sd	Mean Squares	F	p	Effect Size
Pretest	1.567	1	1.567	5.16	.029	0.212
Group	2.943	1	2.943	9.69	.004*	
Error	10.925	36	.303			
Total	761.711	39				

*F(1, 36)=9.69; p=0.004; ή²=0.212

Looking at Table 10, the F values calculated through ANCOVA are observed to be significant for the pretest (covariant). The fact that the F value of the pretest is significant ($F(1, 36)=5.16$; $p<0.05$) shows that primary school students' pre-intervention 21st century skills explain a significant variance. When the 21st century skill pretest average scores were statistically controlled, a significant difference was found between the 21st century skill posttest average scores of the primary school students who participated in the STEM activities and those of the primary school students who did not (F). (1, 36)= 39.716; $p<0.05$). The eta square ($ή^2$) value was found to be 0.212, and 21.2% of the variance in the engineering and technology attitude posttest average scores of primary school students is due to the implemented STEM activity intervention. This value ($0.14<ή^2$) is widely accepted.

The 21st century skill posttest adjusted average scores of the primary school students who took part in the STEM activities ($\overline{X}_{experiment\ adjusted}=4.63$) were significantly higher than those of the primary school students who did not partake in these activities ($\overline{X}_{control\ adjusted}=4.06$) ($p<0.05$), which can be interpreted to indicate that STEM activities significantly improve the 21st century skills of primary school students compared to primary school students who do not participate in such activities.

CONCLUSION AND RECOMMENDATIONS

This study attempted to determine the effect of STEM activities on primary school students' attitudes towards STEM. Based on the obtained results, it was concluded that the STEM activities improve the positive STEM attitudes of primary school students with a significantly wider effect compared to the primary school students who do not get involved in such activities. Examining the relevant literature revealed similar findings. Bircan and Çalışıcı (2022), in their research with primary school fourth grade students, concluded that STEM activities have a positive and significant effect on STEM attitudes. Yıldırım and Cumhur (2017) determined in their research with female students that STEM activities improve the attitude towards STEM. The female students in their study, who had a negative attitude towards the engineering profession before participating in STEM activities, began to think that women could also become engineers after the activities. STEM activities have been found to be effective in developing positive attitudes towards STEM at different education levels (Güzey, Harwell, & Moore, 2014; Irak, 2019; Rehmat, 2015; Seong-Hwan, 2013; Shin & Lee, 2010; Uz, 2022). STEM activities are composed of science, technology, engineering and mathematics disciplines. These activities allow students to learn the achievements of these disciplines in a more entertaining and interesting way than traditional approaches. The activities implemented during the nine weeks in the current study are activities that cover various learning outcomes for STEM disciplines and allow students to make designs using engineering design methods. Therefore, based on the results, it can be concluded that STEM activities are effective in improving students' attitudes towards STEM. However, some studies have also found that STEM activities have no effect on students' attitudes towards STEM (Cosentino, 2008; Kong & Huo, 2014; Kong, Huh & Hwang, 2014; Yıldırım, 2016) which may be due to the short length of intervention, insufficient student readiness, and the inadequate field-specific knowledge or expertise of the practitioner.

The effect of the STEM activities on primary school students' attitude towards STEM sub-dimensions was also examined within the scope of this study, and it was concluded that there was a significant improvement in all sub-dimensions compared to the primary school students who did not participate in the activities. In the studies on mathematics attitude, which is one of these sub-dimensions, Ceylan (2019) and Koçyiğit (2019) reached the conclusion that STEM-oriented teaching has a positive effect on students' mathematics attitude. However, Doğan (2019) and Şahin (2016) concluded that STEM activities do not have a positive effect on students' attitudes towards mathematics. Some of the activities implemented during the current research were mathematics-oriented. In addition, activities requiring the use of knowledge and skills related to mathematics were carried out in all STEM activities, which also had a positive effect on students' attitudes towards mathematics.

This study concluded that the engaging in STEM activities significantly improved the science attitudes of primary school students compared to the primary school students who did not participate in such activities. Gazibeyoğlu (2018) and Toma ve Greca (2018) found that STEM activities have a positive effect on students' science attitudes. On the contrary, Büyükbastımcı (2019) concluded that STEM activities do not have a significant effect on motivation towards learning science. The research result revealed here is related to the aforementioned interpretation of the attitude towards mathematics.

The findings of the current study indicate that participating in STEM activities significantly improves the engineering and technology attitudes of primary school students compared to primary school students who do not take part in this type of activities. While Tseng, Chang, Lou, and Chen (2013) concluded that STEM activities significantly foster students' positive attitudes towards engineering, Yıldırım (2016) stated that STEM practices change students' perceptions of engineering in a positive way. While Gülhan and Şahin (2016) concluded that STEM activities have a positive effect on students' perceptions of engineering and technology, Bircan and Çalışıcı (2022) found that these activities also improve students' attitudes towards technology by improving their knowledge and skills of using technology. STEM activities increase students' engineering knowledge and skills. In each activity implemented during the research process, the students were asked to make designs in line with the scenario and problem situation presented to them, which can be interpreted to have a positive effect on students' attitudes towards engineering. In addition, students used technological devices in this process and conducted research and created designs through computers, which may have had a positive effect on students' technology attitudes.

Based on the findings of the current study, it was concluded that participating in STEM activities significantly improves the 21st century skills of primary school students compared to the primary school students who do not engage in such activities. Many previous studies have reported the positive effect of STEM activities on the development of students' 21st century skills (Bircan & Çalışıcı, 2022; Çorlu, Capraro & Capraro, 2014; Demirel, 2022; Flagan, 2020; Khanlari, 2013; Meyrick, 2011; Tanrıöver, 2022; Uzun, 2022; Ünlü, 2022). As STEM activities are design-oriented, enable the use of technology, and include skills such as creativity, problem solving, communication, and collaboration, students' development of their 21st century skills can be seen as a natural outcome.

Limitations, Suggestions and Implications

This study was conducted with 37 primary school students. It is recommended to increase the number of samples and increase the experimental and control groups, especially since the results obtained in quantitative research have the concern of generalization to the population. In determining the experimental and control groups, the researcher turned to easily accessible (convenient) sampling. Although there was no significant difference between the pretest scores of the groups, the fact that the group with the highest pretest score was determined as the experimental group was considered as a limitation. To eliminate this limitation, it was analyzed with ANCOVA. This study is limited to nine weeks, and further studies are recommended to have longer-term interventions. Qualitative research methods can also be included, and the attitudes of the students can be examined in depth by collecting qualitative data. The STEM activities implemented in this study had a positive effect on the STEM attitudes of the students. Thus, practitioners in each grade of primary school are recommended to have STEM activities in their classrooms. In addition, it is important for practitioners to participate in STEM trainings so that they can develop their own STEM activities.

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