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ORIGINAL ARTICLE

STEM-Based Course Design: A Way to Develop Attitudes toward STEM and Science Course

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ABSTRACT

The study aimed to investigate the effects of a STEM-based course design on students' attitudes toward STEM and a science course. STEM activities were prepared per learning outcomes relating to the "illumination and sound technologies" learning domain in the Grade 4 science course. The study was carried out based on an experiment and control group quasi-experimental design. The study was carried out at a state school in Mersin in 2021. The experimental group of the study consisted of 32 and the control group consisted of 32 Grade 4 students. STEM-based activities were performed in the experimental group. However, non-STEM activities were performed based on usual experimental setups in the control group. At the end of the study, the experimental and control group students' attitudes toward STEM and science course were examined to determine whether there were statistically significant differences. As part of this study, student opinions on STEM were examined. A STEM attitude test and open-ended opinion form were used as data collection tools. Normality tests were conducted, and the homogeneity of variances was examined. Dependent and independent t-tests were conducted in quantitative data analysis and content analysis in the qualitative data analysis. The results suggested that STEM-based course design significantly increased students' STEM attitudes and their attitudes toward science course more than the attitudes of students not exposed to STEM-based course design. In addition, students considered STEM practices fun and informative. Accordingly preparing STEM-based course design for science course has been suggested.

KEY WORDS: Experimental design; primary school; science course; STEM

INTRODUCTION

In recent years, it has seen that there has been a growing number of initiatives focused on developing children's knowledge and skills in the fields of science, technology, engineering, and mathematics (STEM) (MacDonald et al., 2020). Besides, scientific and technological innovations gaining momentum have become more and more vital to meet the challenges of globalization and a knowledge-based economy in the 21st century. One of the most recent of these innovations is STEM. Today, students are expected to improve their skills in STEM education to be successful in education (National Science Foundation, 2016). The term STEM includes an understanding of the integrated disciplines of science, technology, engineering, and mathematics as well as their significance in academic success of children and economic well-being (Herro and Quigley, 2016). STEM signifies an integrated educational approach combining the disciplines of science, technology, engineering, and mathematics with diverse topics in real-life contexts simultaneously by building the content in the context of real-life situations (Hom, 2014; Moore et al., 2013). Apart from these, STEM education is essentially defined as an educational approach notable with its interdisciplinary character from preschool to college education (Gonzalez and Kuenzi, 2012).

STEM depends heavily on Lev Vygotsky's sociocultural theory which points out that learning occurs in a social process and children's experiences in the social environment determine their perceptions of the world (Vygotsky, 1978, as cited in Aguilar, 2016). In other words, occurrence of learning is based on social interactions in society and culture in this theory. Similarly, in STEM education, children are provided knowledge that will promote their adaptation process to current social changes and conditions by means of activities (Baltsavias and Kyridis, 2020). In this respect, it is noteworthy to create an effective learning environment for the students to provide their adaptation to social developments. At this point, students and teachers have critical responsibilities for the successful implementation of STEM education.

The Role of Teachers in STEM Education

STEM education activities, which are intended actions aimed at developing student STEM capabilities and fostering STEM dispositions (Murphy et al., 2018), are shaped by educators' beliefs, attitudes, and self-perceptions of their competences and skills during the process of STEM (Aldemir and Kermani, 2017; Alexander et al., 2014; Atiles et al., 2013; Eng Tek et al., 2016; Hedlin and Gunnarsson, 2014; Park et al., 2017). In other words, teachers are a basic part of the STEM education system (Bybee, 2013). According to Sanders (2009), the mission of teachers is to direct students, and they are supposed to be expert in all fields of STEM and STEM education. Successful implementation of STEM education by

Science Education International
33(4), 345-355
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teachers is crucial (Vescio et al., 2008). Accordingly, Yildirim (2017) points out that STEM pedagogical content knowledge is required for teachers to provide quality and effective STEM education. Notably, STEM education necessitates professional development and teacher education (Van Eck et al., 2015). Studies related to STEM have focused on educators' occupational capabilities (Aldemir and Kermani, 2017; Eng Tek et al., 2016) and capabilities about teaching and pedagogy (Atiles et al., 2013; Bers et al., 2013). Furthermore, involvement of educators in STEM professional development provides a confident educational environment and increase positive attitudes related to STEM education (Alexander et al., 2014; Bers et al., 2013).

The Role of Students in STEM Education

Sanders (2009) and Ritz and Fan (2015) claim that STEM education approaches should encourage students to practice knowledge of mathematics, technology, science, and engineering, as they design and fulfill investigations, analyze and clarify data, and study in a cooperative learning way. Students can learn by experiencing real-world situations through STEM integration practices (Tsupros et al., 2009). Drake et al. (2014) and Rahm (2014) claim that any learning must be based on the acquisition of knowledge and skills shaped by students' experiences. According to related literature, real-world contexts and authentic problems or projects to study on are required to perform STEM education activities best (e.g., Hefty, 2015; Kelley et al., 2010; Redmond et al., 2011). According to English (2017), well-designed STEM experiences can provide learning affordances that enable the engagement of a more diverse range of students. With varying entry and exit points, combined with opportunities to entertain new and more advanced concepts, such experiences have the potential to increase students' achievement and motivation levels.

According to Portz (2015), integrated STEM education provides benefits for both low-level and high-level students and authentic learning environment created during the process of STEM help students apply knowledge in real-life context and situations (Ayar and Yalvac, 2010; Chinn and Malhorta, 2002). From this perspective, it is understood that these activities bring together different disciplines by providing permanent learning and enable students to be equipped with social skills. In this respect, successful implementation of STEM is a critical issue.

Implementation of STEM Education

STEM is based on an integrated approach. Integrated STEM, which means combination of science and math education theories with the use of technology and engineering (Satchwell and Loepp, 2002), includes the interdisciplinary education, and aims to search for solutions to the problems with the knowledge obtained through STEM disciplines (Nadelson and Seifert, 2017; Nite et al., 2017). STEM curriculum and pedagogy can be integrated into elementary and secondary classrooms to create awareness about STEM education. According to National Academy of Engineering (NAE) and National Research Council (NRC) (2014), STEM literacy signifies: (1) Awareness related to the functions of science, technology, engineering, and mathematics in today's society; (2) understanding some of the basic concepts from each field; and (3) a basic level of practice fluency. Besides, STEM involves skills such as adaptability, problem-solving, critical thinking, creative thinking, and design thinking (Bybee, 2013; Prinsley and Baranyai, 2015). STEM abilities "include, but are more extensive than, the knowledge and skills associated with the individual STEM disciplines" (Murphy et al., 2018, p. 3). It is evident that STEM makes learning environments applicable through diverse activities within related disciplines.

With all this information, in the 21st century, students are expected to obtain new knowledge and use it in new situations and problems (Wagner, 2008). There are many 21st century skills to be acquired by students. These skills are *adaptability, complex communication skills/social skills, non-routine problem-solving, self-management/self-development,* and *systems thinking* (NRC, 2010). In this regard, reviewing and renewing existing education systems should be required according to these skills (Gül and Taşar, 2020). In this respect, the main goal of STEM is to enable students to gain knowledge and skills required by the 21st century and to create learning environments to use them (Bybee, 2013; Sanders, 2009). According to Portz (2015), STEM aims to integrate vital issues in industry with real-life applications.

As a result of literature review, general characteristics of STEM education are as follows:

Providing learning through the use of interdisciplinary activities based on real-world learning (Peters-Burton et al., 2014); instructional activities are presented to motivate students to learn science and mathematics (Holmlund et al., 2018); gaining 21st century skills (Gravemeijer et al., 2017); collaboration with STEM professionals and use of modern technologies as part of in-class practices (Holmlund et al., 2018); training the students for global citizenry (Kennedy and Odell, 2014); and activities based on the engineering design process (Cantrell et al., 2006).

Arousing student motivation and interest in lessons organized using STEM activities is crucial in achieving positive outcomes. Therefore, students need to hold positive attitudes towards STEM and science course. Tezbaşaran (1996) defines the concept of attitude as a learned tendency to show positive or negative reactions to certain things, situations, institutions, concepts, or other people. At this point, the designs developed to achieve the learning outcomes are arranged in a way that develops positive attitudes in students. The STEM-based course design developed in this study was expected to develop students' attitudes toward STEM and the science course. Therefore, the results of the study were tested under an experimental design.

In this respect, the aim of this study was to determine whether there were statistically significant differences between the experimental and control group students' STEM attitudes and

Science Education International
33(4), 345-355
https://doi.org/10.33828/sei.v33.i4.1

their attitudes toward science course. Another aim of the study was to determine the experimental group students' opinions on STEM-based practices. The main research question and sub-research questions are as follows:

The main research question: What are the effects of using STEM activities in science classes on students' STEM attitudes and their attitudes toward science course?

Sub-research Questions

1. How is the difference between the pre-test and post-test STEM and science course attitude scores of the control group students statistically?
2. How is the difference between the pre-test and post-test STEM and science course attitude scores of the experimental group students statistically?
3. a. How is the difference between the pre-test STEM and science course attitude scores of the experimental and control group students statistically?
   b. How is the difference between the post-test STEM and science course attitude scores of the experimental and control group students statistically?
4. What are the opinions of the experimental group students on STEM activities and practices?

METHODOLOGY

General Background of Research

A quasi-experimental research design was employed in this research. Quasi-experimental studies include experimental and control groups. Pre-tests and post-tests are conducted in both groups, but the methods or activities to be tested are applied only to the experimental group (Creswell, 2003; Karasar, 2005). In this method, the participants are subjected to measurements related to the dependent variable before and after the experimental study.

In this study, two separate classes were determined as an experiment and a control group to assess the effectiveness of STEM practices and activities regarding the "light and sound" learning outcomes given in the "illumination and sound technologies" learning domain of Grade 4 (students aged 11–12) primary school science course. STEM activities and practices were carried out through group activities within the scope of the topic in the experimental group, whereas usual curricular content containing no STEM activities and practices was applied to the control group.

Research Group

A total of 64 Grade 4 students receiving education in a public school constituted the research group of the study. The school where the study was conducted is a local school located in a disadvantaged area, heavily inhabited by refugees from Syria. Of students in the study group, 32 students in a randomly selected class made up the experimental group, and 32 students in another randomly selected class made up the control group. As per their pre-test results and past year average academic year-end science course scores, the experimental and control groups were assumed to be of the same level as the initial conditions There were 24 students that were 11 years old and eight students that were 12 years old at the experimental group. At the control group, there were 23 students that were 11 and nine students that were 12. The experimental group consisted of 18 males and 14 females, the control group consisted of 16 males and 16 females.

All ethic permissions were obtained for research and all ethical rules were taken into consideration. Formal permissions were obtained from the institution. Before the study, permissions of students and their parents were obtained. Students are informed about the content of the study beforehand. At the attendance to the research, willingness was the principal.

Instruments and Procedures

STEM attitude test

The STEM attitude test developed by the Friday Institute in 2012 with the 4th and 5th grade students and adapted into Turkish by Gülhan and Şahin (2016) was used in the study. Friday Institute found that the test reliability values were between 0.84 and 0.86, but 0.92 in the adaptation study by Gülhan and Şahin (2016), and 0.84 in the present study. The 5-point Likert test consisted of four sub-dimensions, namely, Mathematics-Science-Engineering and Technology, 21st Century Skills, Your Future, and About Yourself. The attitude test undergone through piloting and reliability studies was administered as a pre-test and post-test in the experimental and control groups.

Science course attitude scale

Science course attitude scale developed for the 4th and 5th grade students by Kenar and Balcı (2012) was used in the research. The scale consists of 12 items. The reliability coefficient (Cronbach's alpha) of the scale was found to be 0.83.

Open-ended opinion form

To reveal opinion of students toward STEM activities and applications, a feedback form that consisted of one open-ended question was prepared. Two experts with one accord determined the open-ended question. Accordingly, the form was consisted of the question "What is your opinion toward STEM activities and applications?"

Data Analysis

SPSS statistical program was used in analyzing the collected data. To test the statistical significance of the collected data, the upper limit of the error margin was accepted as.05. In addition, the Shapiro–Wilk test was conducted to examine the normality of the data collected from the control and experimental groups. From parametric tests, independent and dependent samples t-tests were used to analyze the data, as the collected data satisfied the assumptions of the parametric tests. However, content analysis was performed in analyzing the qualitative data. The analyzed data were classified by dividing them into codes and categories. Before the data analysis, the data were tested for normality. In this study, the Shapiro–Wilk values were taken into account to test normality and descriptive

Science Education International
33(4), 345-355
https://doi.org/10.33828/sei.v33.i4.1

statistics and variability coefficient values were presented to support the normality test values. The normality test values are given in Table 1.

According to the data given in Table 1, the data relating to STEM and science course attitude scale comply with normal distribution (ρ > 0.05).

For the homogeneity of the group data, the variability coefficient values presented in Table 2 were taken into account, and the V value for each dataset was <20. According to Karaca (2008), the group is homogeneous when the V value is <20. Furthermore, close mean, median, and mode values are other factors that support normal distribution. Since the data showed a normal distribution according to the findings, it was decided to conduct parametric tests. To determine whether the control and experimental groups were equivalent in terms of the dependent variables before the study, an independent samples t-test was performed to compare their pretest scores. To perform this test, the homogeneity of variance was investigated.

Table 1: Normality test of distribution for science, technology, engineering, and mathematics attitude and science course attitude scale data

Attitude tests	Shapiro–Wilk		
	Statistic	df	Significance
STEM attitude	0.96	32	0.26
Science course attitude	0.94	32	0.07

*ρ>0.05. STEM: Science, technology, engineering, and mathematics

Table 3 includes findings regarding the homogeneity of the variances. According to Levene's test results, values of F = 0.003 (ρ > 0.05) were obtained for STEM attitude scale and F = 0.000 (ρ >.05) for science course attitude scale. These findings show a homogeneous distribution of variances. The independent samples t-test analyses yielded no significant differences between the mean pre-test scores of the control and experimental groups in STEM (t = 0.08, ρ > 0.05) and science course attitude (t = 0.49, ρ > 0.05) scales.

Reliability and Validity

Experimental design

Table 4 shows the Cronbach's alpha reliability values of STEM and science course attitude scales.

Validity and reliability are crucial elements in experimental studies. The reliability of the measurement tool used in the research is a critical element that supports the reliability of the experimental research. The reliability studies of STEM and science course attitude scales used in this research as quantitative data collection tools were performed. The scales were found to be within reliable ranges (α =.82 and α =.74). Another important factor that should be present in experimental studies is internal validity. Factors that may negatively affect the internal validity are subject loss, the environment where the data are collected, and the loss of quality of the data collection tool. No subject loss occurred in the study. To ensure the equivalence of groups from which the data were collected, attention was paid that the average science course academic scores of classes from the past year were similar and that they

Table 2: Descriptive statistics and variability coefficient values for ITAS data

Attitude tests	Experimental group					Control group				
	Mean	Median	Mode	SD	V	Mean	Median	Mode	SD	V
STEM attitude										
Pre	3.24	3.18	3.16	0.45	0.20	3.25	3.25	3.21	0.45	0.20
Post	4.15	4.14	3.40	0.41	0.17	3.60	3.61	3.50	0.36	0.13
Science course attitude										
Pre	2.46	2.62	2.67	0.52	0.17	2.52	2.66	2.67	0.53	0.18
Post	3.06	3.00	2.75	0.50	0.15	2.61	2.66	2.67	0.45	0.19

SD: Standard deviation, STEM: Science, technology, engineering, and mathematics

Table 3: Independent samples t-test and variance homogeneity of groups

Attitude tests	Group statistics			Independent samples test				
				Levene's test for equality of variances		t-test for equality of means		
	n	x̄	SD	F	Significance	t	df	Significance (two tailed)
Pre-test STEM attitude								
Control group	32	3.24	0.45	0.003	0.95	−0.08	62	0.92
Study group	32	3.25	0.45					
Pre-test science course attitude								
Control group	32	2.46	0.52	0.000	0.98	−0.49	62	0.62
Study group	32	2.52	0.53					

*ρ>0.05. SD: Standard deviation, STEM: Science, technology, engineering, and mathematics

Science Education International
33(4), 345-355
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Table 4: Cronbach's alpha coefficients

Attitude tests	Cronbach-alpha coefficient	The current Cronbach-alpha coefficient
STEM attitude	0.92	0.82
Science course attitude	0.83	0.74

STEM: Science, technology, engineering, and mathematics

were equivalent from a socioeconomic perspective. Another factor threatening internal reliability in the experimental study regarding STEM activities is the differences between the implementers. In this study, the lessons in the experimental and control groups were conducted under the control and guidance of the researcher. This way, validity threats arising from practitioner differences were eliminated.

Qualitative design

The accuracy and validity of the results are more important in qualitative studies than their replicability (Topkaya, 2006). For the content and face validity of the qualitative measurement tool used in this research, two academicians were consulted. Afterward, the opinions of five Grade 4 students were obtained after they read the open-ended question. After assuming that the open-ended question was understandable, it was decided to administer it. Formulating a valid study in qualitative research is possible by minimizing bias (Roberts and Priest, 2006). To minimize bias, two coders analyzed the responses provided to the open-ended question and divided the findings into codes and categories. To determine the intercoder reliability of findings obtained from the open-ended question, the Miles-Huberman coder reliability formula was used (Miles and Huberman, 1994). As a result of applying the coder reliability formula, the agreement between the two coders was.94, indicating the reliability of the coding process.

Procedures

Procedures performed in the experiment group

To organize the activities, 12 learning outcomes about "light and sound" under the "illumination and sound technologies" learning domain in Grade 4 science course Learning areas and learning outcomes are shown in Table 5.

The experimental group students prepared and conducted a total of 21 h of STEM activities for science course learning outcomes for 3 weeks. The experimental group students were divided into five groups to prepare STEM activities. Each group prepared three activities regarding the learning outcomes. In these groups, attention was paid to ensure that each student took active participation in line with the principles of the cooperative working method. The activities conducted in the experimental group are given in detail in Table 6.

Observations were made throughout the applications. The lessons and activities in both groups were carried by the same researcher.

Table 5: Learning outcomes on "Light and Sound" given in the "Illumination and Sound Technologies" learning domain in science course

Learning outcomes	Topics and concepts	Duration (h)
Illumination technologies Compares the illumination tools used in the past and present Creates designs regarding illumination tools that could be used in the future	Importance of illumination technologies and tools from the past to present	5
Convenient Illumination Investigates about convenient lighting Discusses the cost-effective utilization of illumination tools in terms of family and country economy	Convenient illumination and its importance, cost-effective utilization of illumination tools	3
Light pollution Inquires the causes of light pollution Describes the negative effects of light pollution on natural life and observing celestial bodies Generates solutions to reduce light pollution	Light pollution and its negative effects, things that should be done to prevent light pollution	5
Sound technologies from past to present Compares sound technologies used in the past and present Investigates the positive and negative effects of technological tools with loud noise	Technologies used in changing the sound level, technologies that improve our hearing ability, voice recording technologies	3
Sound pollution Investigates the causes of sound pollution Describes the negative effects of sound pollution on human health and environment Generates solutions to reduce sound pollution	Sound pollution and its negative effects, things that should be done to prevent sound pollution	5

Procedures performed in the control group

Usual course contents were applied to the control group with no additional intervention. Course content of the control group was consisted of experiment, observation, and class discussion activities based on mostly learning outcomes. However, experiment and observation activities of the control group were not designed appropriate to STEM principles. For example, about light pollution, students were requested to set mechanisms related to light sources that give light at different size and perspectives, and to determine the appropriate ones and report them, and finally to present them. Here, integration of technology, engineering, and mathematics was ignored.

RESULTS

This section presents findings regarding the sub-research questions.

Science Education International
33(4), 345-355
https://doi.org/10.33828/sei.v33.i4.1

Table 6: STEM activities organized in the experimental group and procedures

Science	Technology	Engineering	Mathematics
Activity: Angle and distance in light			
Procedure: There is a world globe model at the fixed end of a 2 m long rail system and a light source (lamp) with an adjustable height at the other end that can be moved closer to and away from the globe. The view angle of the head of the light source can be adjusted toward the globe. Illumination states are observed on the globe by changing the proximity of the light to the globe and its contact angles with the globe. In this activity, the effects of the distance from the light source and the contact angle of the light on objects were observed			
STEM dimensions			
Science	**Technology**	**Engineering**	**Mathematics**
Light intensity Illumination Electrical circuit Current	Electrical system Circuit system	Rail system design	Angle Distance
Activity: Megaphone experiment			
Procedure: Different megaphones with a length of 50 cm and a mouth diameter of 30, 20, and 10 cm were designed from cardboard. In this activity, it was observed the mouth width of the megaphone and the material it is made of affect the loudness of the sound radiated out by giving equal volumes to the megaphones			
STEM dimensions			
Science	**Technology**	**Engineering**	**Mathematics**
Sound Sound intensity Sound transmission	Material used in making megaphone and its effects	Megaphone design	Cylinder Diameter Radius Distance Circle
Activity: Sound transmission and insulation experiment			
Procedure: Three box models of equal sizes were designed. The inside of the first of these boxes was covered with cardboard, the inside of the second with fabric, and the inside of the third with a metal material. The intensity of sound coming out from an alarm clock placed inside the boxes was measured. In this activity, the ambient elements that are effective in the transmission of sound and the materials used in sound insulation were observed			
STEM dimensions			
Science	**Technology**	**Engineering**	**Mathematics**
Sound insulation Specifications of materials used in sound insulation	Shape of the box Packing material of the box	Box design Insulation materials material science	Cube Thickness Size

STEM: Science, technology, engineering, and mathematics

Findings Regarding the First Sub-Research Question

In this sub-research question, it was examined whether there were statistically significant differences between students' pre-test and post-test STEM and science course attitude scores in the control group exposed to usual course content. In this respect, a dependent samples t-test analysis was performed to examine the difference between their attitude scores. Table 7 provides the dependent samples t-test analysis results concerning the differences between the pre-test and post-test attitude scores of the control group students.

Table 7: Comparing the pre-test and post-test scores of the control group for science, technology, engineering, and mathematics attitudes (dependent samples t-test analysis results)

Group	n	$\bar{x}$	SD	t	ρ
Control pre-test	32	3.25	0.45	−7.07	0.000
Control post-test	32	3.60	0.36	0.000	<0.05

SD: Standard deviation

According to the dependent samples t-test results in Table 7, there was a statistically significant difference between the pre-test and post-test STEM attitude scores of the control group students [$t(32) = -7.07$, $\rho < 0.05$].

According to the dependent samples t-test result in Table 8, there was a statistically non-significant difference between the pre-test and post-test science course attitude scores of the control group students' [$t(32) = -1.36$, $\rho > 0.05$].

Findings Regarding the Second Sub-Research Question

In this sub-research question, it was examined whether there were statistically significant differences between students' pre-test and post-test STEM and science course attitude scores in the experimental group exposed to the STEM method. In this respect, a dependent samples t-test analysis was performed to examine the difference between students' attitude scores in the experimental group. Table 9 presents the dependent samples t-test analysis results regarding the difference between students' pre-test and post-test scores in the experimental group.

According to the dependent samples t-test results in Table 9, there was a statistically significant difference between students' pre-test and post-test STEM attitude scores in the experimental group [$t(32) = 12.747$, $\rho < 0.05$].

According to the dependent samples t-test results in Table 10, there was a statistically significant difference between students' pre-test and post-test science course attitude scores in the experimental group [$t(32) = -6.828$, $\rho < 0.05$].

Findings Regarding the Third Sub-Research Question

In this sub-research question, it was examined whether there were statistically significant differences between the experimental and control group students' STEM and science course attitude pre-test scores. In this respect, an independent samples t-test analysis was conducted to examine the difference between the attitude scores of students in the experimental and control group. Table 9 and Table 12 provide the independent samples t-test analysis results.

According to the independent samples t-test results in Table 11, there was no statistically non-significant difference between the STEM attitude pre-test scores of the experimental and control groups [$t(32) = 0.89$, $\rho > 0.05$].

According to the independent samples t-test results in Table 12, there was a statistically non-significant difference between the science course attitude pre-test scores of the experimental and control groups [$t(32) = 0.49$, $\rho > 0.05$].

Science Education International
33(4), 345-355
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Table 8: Comparing the pre-test and post-test scores of the control group for science course attitudes (dependent samples t-test analysis results)

Group	n	x̄	SD	t	ρ
Control pre-test	32	2.52	0.53	−1.36	0.184
Control post-test	32	2.61	0.45	0.184	>0.05

SD: Standard deviation

Table 9: Comparing the pre-test and post-test scores of the experimental group for science, technology, engineering, and mathematics attitudes (dependent samples t-test analysis results)

Group	n	x̄	SD	t	ρ
Experiment pre-test	32	2.46	0.52	12.747	0.000
Experiment post-test	32	3.06	0.50	0.000	<0.05

SD: Standard deviation

Table 10: Comparing the pre-test and post-test scores of the experimental group for science course attitudes (dependent samples t-test analysis results)

Group	n	x̄	SD	t	ρ
Experiment pre-test	32	3.24	0.45	−6.828	0.000
Experiment post-test	32	4.15	0.41	0.000	<0.05

SD: Standard deviation

Table 11: Comparing the science, technology, engineering, and mathematics pre-test scores of the experimental and control groups (independent samples t-test analysis results)

Group	n	x̄	SD	t	ρ
Experiment pre-test	32	3.24	0.45	0.89	0.929
Control pre-test	32	3.25	0.45	0.929	>0.05

SD: Standard deviation

Table 12: Comparing the science course pre-test scores of the experimental and control groups (independent samples t-test analysis results)

Group	n	x̄	SD	t	ρ
Experiment pre-test	32	2.46	0.52	0.49	0.626
Control pre-test	32	2.52	0.53	0.626	>0.05

SD: Standard deviation

Findings Regarding the Fourth Sub-Research Question

In this sub-research question, it was examined whether there were statistically significant differences between the experimental and control group students' STEM and science course attitude post-test scores. In this respect, an independent samples t-test analysis was conducted to examine the difference between the attitude scores of students in the experimental and control group. Table 13 and Table 14 provide the independent samples t-test analysis results.

Table 13: Comparing the science, technology, engineering, and mathematics attitude post-test scores of the experimental and control groups (independent samples t-test analysis results)

Group	n	x̄	SD	t	ρ
Experiment pre-test	32	4.15	0.41	5.57	0.000
Control pre-test	32	3.60	0.36	0.000	<0.05

SD: Standard deviation

Table 14: Comparing the science course attitude post-test scores of the experimental and control groups (independent samples t-test analysis results)

Group	n	x̄	SD	t	ρ
Experiment post-test	32	3.06	0.50	3.76	0.000
Control post-test	32	2.61	0.45	0.000	<0.05

SD: Standard deviation

Table 15: Findings related to student opinions on science, technology, engineering, and mathematics practices

Theme number	Opinions on STEM activities and practices		
	Category	Codes	f (%)
1	Benefits	They are fun	15 (38.46)
2		They enable learning by doing	8 (20.51)
3		They teach how to set up an experiment	6 (15.39)
4		They bring in responsibility in the group	5 (12.82)
5		They facilitate learning	5 (12.82)
Total			39 (100)
1	Challenges	Setting and implementing an experiment setup is difficult	15 (39.48)
2		Group members have responsibilities	13 (34.21)
3		It is necessary to follow up and take notes	10 (34.21)
Total			38 (100)

STEM: Science, technology, engineering, and mathematics

According to the independent samples t-test results in Table 13, there was a statistically significant difference between the STEM attitude post-test scores of the experimental and control groups [$t(32) = 5.57$, $\rho < 0.05$].

According to the independent samples t-test results in Table 14, there was a statistically significant difference between the science course attitude post-test scores of the experimental and control groups [$t(32) = 3.76$, $\rho < 0.05$].

Findings Regarding the Fifth Sub-Research Question

In this sub-research question, it was aimed to determine students' opinions on STEM activities and practices implemented in the science course. In this respect, the question "What are your opinions on STEM activities and practices?" was directed to students. Students' opinions on STEM activities and practices were subjected to content analysis

Science Education International
33(4), 345-355
https://doi.org/10.33828/sei.v33.i4.1

and categorized under benefits and challenges. The resultant findings are given in Table 15.

DISCUSSION AND CONCLUSIONS

According to the results obtained relating to the first sub-research question of the study, there was a statistically significant difference between the pre-test and post-test scores of STEM attitudes of the control group students who were taught regular course contents. However, there was no statistically significant difference between their pre-test and post-test science course attitude scores. STEM activities were not conducted in the control group. In contrast, the course content was designed with experiment activities. Experimental setup is thought to increase STEM attitude scores in the period between the pre-test and post-test. No statistically significant difference was found between their pre-test and post-test science course attitude scores. It is thought that the experiment activities are insufficient to increase students' attitudes toward science and that these activities should be conducted with a structure in which students are active, such as teamwork and group activities. According to the results obtained within the scope of the second sub-research question, there was a statistically significant difference between the pre-test and post-test STEM attitude scores of students in the experimental group. Students stated that they had fun in STEM activities and enjoyed doing experiments together. Considering the results obtained, STEM activities organized in the experimental group have positively affected students' attitudes toward STEM. This result is because the STEM method applied in the experimental group positively affected students' attitudes in the period between the pre-test and post-test. Furthermore, there was a statistically significant difference between their pre-test and post-test science course attitude scores. There have been some other researches that reached same results at literature (Yamak et al., 2014; Naizer et al., 2014).

The STEM activities were organized in such a way that covered the sub-themes of "Illumination Technologies, Convenient Illumination, Light Pollution, Sound Technologies and Sound Pollution from the Past to Present" given in the theme of "Illumination and Sound" in the science course. It is thought that STEM activities organized based on science topics have positively affected their attitudes toward science. In this respect, their attitudes toward science positively increased by the end of the activities. According to the results obtained within the scope of the third sub-research question, no statistically significant difference was found between the STEM attitude pre-test scores of the experimental and control groups. As such, no statistically significant difference was found between science course attitude pre-test scores of the experimental and control groups. One could say that this situation is realized by ensuring the equivalence of the classes selected as the experimental and control groups. All students in the experimental and control groups were fourth graders. To ensure equivalence, attention was paid to ensuring that the academic achievement scores of classes in the previous year's science course were close. This may have led to no difference in their STEM and science course attitude scores. According to the result obtained in line with the fourth sub-research question, there was a statistically significant difference between the STEM attitude post-test scores of the experimental and control groups. This indicates that STEM activities and practices have positively affected student attitudes. In other words, STEM activities helped students develop positive attitudes toward STEM. Likewise, STEM activities positively affected students' attitudes toward science. At the end of the activities, it was observed that students' attitudes increased toward science. Conducting activities and practices through group work, students' being in constant communication and cooperation, conducting game-based activities, and organizing activities harmonized with digital and computer-based activities might be the factors that have developed positive attitudes in students. This shows that using the STEM method in science classes positively increases students' STEM attitudes and their attitudes toward science course.

In parallel with the conclusion reached in this study, many studies in the literature have concluded that the STEM method used in science classes increases students' attitude levels toward STEM (Ayaz et al., 2020; Aydın et al., 2017; Gülhan and Şahin, 2016; Keçeci et al., 2017; Irkıçatal, 2016; Mahoney, 2009; Yıldırım and Türk, 2018) and science course (Doğanay, 2018; Gazibeyoğlu, 2018; Guzey et al., 2016; Gülhan and Şahin, 2016; Şimşek, 2019). In contrast, some studies concluded that STEM activities had no positive effect on STEM attitudes (Ching et al., 2019; Conrad et al., 2018; Cosentino, 2008; Kong and Huo, 2014; Kong et al., 2014; Leonard et al., 2016; Yildirim and Selvi, 2017). Considering the fifth sub-research question of the study, students' opinions on STEM practices were examined. According to the results obtained, students' opinions were categorized under the benefits and challenges of STEM activities. The opinions under the two categories were divided into codes considering their similarities. According to this, under the benefits of STEM activities, students stated that they "are fun, they enable learning by doing, teach how to set up an experiment, bring in responsibility in the group, and facilitate learning." Under the challenges, they stated that "setting and implementing an experiment setup is difficult, group members have responsibilities, and it is necessary to follow up and take notes." According to these findings, it was concluded that students evaluated STEM activities positively, but needed support in experiment setups.

Similar to this study, Keçeci et al. (2017) found that practices that were fun saw many students repeating the activities together with their families at home. Eroğlu and Bektaş (2016) examined teachers' views on STEM and reported that the activities were entertaining and enjoyable for students. According to another finding reached in our study, the 21st century skills of students increase at the end of the STEM activities. Similarly, Aydin and Karsli (2019) revealed that STEM activities contribute to students' 21st century skills such as cooperation, critical thinking, problem-solving, creativity,

Science Education International
33(4), 345-355
https://doi.org/10.33828/sei.v33.i4.1

and self-confidence. It is seen in the study that students express positive views on their STEM interests and motivations. Likewise, Pekbay (2017) concluded that STEM activities positively developed students' interest in STEM. Consistent with the result of this study, several studies in the literature have found that students had a positive description of STEM activities (Bindis, 2020; Dönmez, 2017; Kulyk, 2020; Öztürk, 2019; Şimşek, 2019; Yildirim and Selvi, 2017).

Recommendations

- Course designs based on STEM activities and practices significantly increase students' attitudes toward STEM and science course. Therefore, it is recommended to use STEM activities and practices in science courses.
- Informing students about design and content before STEM activities were suggested.
- STEM activities were organized with group work and a design in which students were active. It is recommended to ensure that students are active in the preparation, implementation, and evaluation stages of STEM activities.
- It is recommended to make use of digital content, web 2 tools, and so forth in STEM activities and organize STEM activities and practices with blended learning practices in some circumstances.
- It is recommended that students prepare and present reports as a group to the class at the end of STEM activities.
- In this study, STEM activities were organized based on the learning outcomes related to science course. Therefore, it is also recommended to prepare and implement STEM activities in different courses.
- While designing courses with STEM activities, time of the activities was suggested to be long enough to students do all activities completely and reach outcomes.
- It is suggested that teachers must attend courses about STEM activities.

Ethical Statement

An official application was made to the school where the research was conducted for ethical permissions. The necessary permission has been obtained with the approval of the directorate of national education. For the research, student parents were also informed and volunteering permission and participation permission were obtained.

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