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Research Article

Investigation of the effects of mathematics-centred STEM activities on students 'creative thinking skills and student opinions[1]

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Abstract

The aim of this study is to examine the effect of mathematics-centered STEM activities on students' creative thinking skills and to determine student views on this topic. In the research, quantitative and qualitative methods were used together. The quantitative part of the research consists of two groups of pre-test-post-test, the experimental-control group of quasi-experimental design, and the qualitative part of the case study design. The study, a province in the 2018-2019 academic year in the eastern Black Sea region of Turkiye was carried out with students in two different classes in the first semester of 6th grade who are studying in public schools. Torrance Creative Thinking Test (TCTT) was applied to the experimental and control groups at the beginning of the study. STEM activities prepared by the researcher were applied to the experimental group students for seven weeks, while the control group students were taught a course in accordance with the current curriculum. STEM activities prepared by the researcher were applied to the experimental group students for seven weeks, while the control group students were taught a course in accordance with the current curriculum. At the end of the term, TCTT was applied to the groups as a post-test and eight students who were selected voluntarily from the experimental group were interviewed. The data obtained from the TCTT were analyzed with a statistical program. It was concluded that the change in the pre-tests of the TCTT was found significant in the verbal category, while there was no significance in the change in the figural category. Content analysis was conducted for the interviews with the students and it was concluded that STEM activities contributed to the creative thinking of the students according to the students' opinions.

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Introduction

Due to the changes made in Turkiye and different countries about mathematics education, which is to show the need to have different skills that can be considered qualified individuals with evolving technology. So that the main goal of mathematics education is to help individuals solve problems they encounter in real life. When we consider mathematics as the solver of the problems of other professions (especially engineering), the concept of integration has emerged in order to provide multiple perspectives to problems. Integration has been compared to the formation of compounds in that it expresses the undivided state of a whole (Lederman & Niess, 1997). In this context, mathematics has to be intertwined with other disciplines in terms of problem solving. As a matter of fact, mathematical modeling has an important place in this regard. Mathematical modeling is related to daily life and has an interdisciplinary nature. In mathematical modeling, problems are chosen from daily life, but there is no transition

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between disciplines (Akay, 2018). However, many of the problems encountered in daily life do not consist of problems that can be solved with only one field / discipline knowledge. With the solutions of the methods found for these problems, it will be possible to know the information of different disciplines in order to increase the quality of the products produced more efficiently, and to use and blend this information creatively, with the joint work of experts from different disciplines (Aydeniz, 2017). In this respect, STEM stands out as a teaching approach in which science, technology, engineering and mathematics disciplines are applied together (Honey, Pearson, & Schweingru, 2014). Science, Technology, this approach created with the initials of the sub-disciplines of engineering and mathematics, as means that have been used in Turkiye include the abbreviation STEM. Science, Technology, this approach created with the initials of the sub-disciplines of engineering and mathematics, as means that have been used in Turkiye include the abbreviation STEM. Science, Technology, this approach created with the initials of the sub-disciplines of engineering and mathematics, as means that have been used in Turkiye include the abbreviation STEM. In today's rapidly changing and developing world, it is necessary for individuals to develop their creative thinking skills in order to progress in the fields of science and technology, and to continue people's lives. Mathematics-centered STEM activities prepared in this context consist of interdisciplinary lesson plans in which middle school 6th grade mathematics course outcomes are centered and the outcomes of other sub-disciplines are distributed according to this center. The problems chosen in this educational approach include the achievements of the students in mathematics and other sub-disciplines at the level of education. In the solution phase of the problems, because mathematics achievements were used predominantly, activities were created by placing mathematics discipline at the center. Students' need for logical thinking and problem solving skills has increased as a result of rapid progress in science and technology. It is known that mathematics, which is seen as a tool for thinking, increases the opportunities for individuals to find a job and, more importantly, the rate of enjoying their lives together with the opportunities it provides for their education (Ministry of Education, 2013). From this point of view, STEM can be considered as an educational approach that encourages students to think critically and at a high level, provides quality learning with an interdisciplinary education, provides the opportunity to transfer the learned knowledge to daily life, and supports and increases the skills used in daily life (Yıldırım & Altun, 2015). In this study, STEM activities were prepared by taking mathematics into the center and using mathematical modeling. The effects of the prepared activities on creative thinking skills, which are among the thinking skills that national education wants to gain, have been investigated. The research has been enriched with the opinions of the students. In the studies conducted, it is seen that the activities in the literature do not give intensity to mathematics achievements. The activities prepared are at the 6th grade student level of middle school and the modeling approach is taken as a basis for the mathematics discipline in the center. It has been realized that the discipline of mathematics in STEM education can be enriched by mathematical modeling (Akay, 2018). In addition, students' difficulties in solving daily life problems, introducing students to daily life problems in the 6th grade of secondary school, and contributing to students in this field were seen as a reason for the study. Problem solving, creativity and design skills are defined as basic skills in the STEM education approach of students. Using any of the problem solving methods provides a vital service to student success in the 21st century by contributing to students' critical and creative thinking skills (Cooper & Heaverlo, 2013). In addition, creative problem solving is the process of combining high-level thinking skills such as creative thinking, critical-thinking and analytical thinking (Lumsdaine & Lumsdaine, 1995). There is a transition between disciplines in solving creative problems, and different disciplines are solved by gathering around a problem. There is a transition between disciplines in solving creative problems, and different disciplines are solved by gathering around a problem. There is a transition between disciplines in solving creative problems, and different disciplines are solved by gathering around a problem. There is a transition between disciplines in solving creative problems, and different disciplines are solved by gathering around a problem. The process continues, just like the STEM education approach. The interdisciplinary approach enables students to connect with real life and contribute to problem solving, along with creative and critical thinking skills that are desired in the 21st century (Özkök, 2005). The process continues, just like the STEM education approach. The interdisciplinary approach enables students to connect with real life and contribute to problem solving, along with creative and critical thinking skills that are desired in the 21st century (Özkök, 2005). On the other hand, among the definitions of the term creativity, processes such as multidimensional thinking, testing the thought, and creating a product are mentioned. In this respect, it is understood that it is similar to the engineering design skills in the STEM education approach.

Problem of Study

In this study, the effect of math-centered STEM activities on students' creative thinking skills and student views were investigated. There are two sub problems of this study. These sub problems are as follows:

- Do math-centered STEM activities affect the creative thinking skills of middle school 6th grade students?
- What are the students' views on STEM and creative thinking?

Method

Research Model

In the research, quantitative and qualitative methods were used together. Quantitative findings are presented by enriching them with qualitative findings (Ekşi, Kılıç Memur, Sevgi Yalın, & Dinç, 2020). The quantitative part of the study consists of a semi-experimental design with two groups of pretest-posttest experimental-control groups. The quasi-experimental design should be used when conducting research on the effects of teaching materials in different classes or teaching methods. The quantitative part of the study consists of a semi-experimental design with two groups of pretest-posttest experimental-control groups. The quasi-experimental design should be used when conducting research on the effects of teaching materials in different classes or teaching methods. In this design, classes are not organized for any purpose related to education before the research, but are included in the examination as it is in their own terms. Two groups were formed randomly and activities in accordance with the STEM education approach, which is the independent variable of the study, were applied to one of the groups. Test measurements were made to the groups before and after the experiment. Two groups were formed randomly and activities in accordance with the STEM education approach, which is the independent variable of the study, were applied to one of the groups. Test measurements were made to the groups before and after the experiment. The qualitative part of the research consists of a case study design. The case study handled within the qualitative method is a type of study that allows one or more cases to be investigated in detail. In qualitative studies, all factors belonging to a situation are considered with a holistic approach and the level of influence of the group from the situation given in the research is emphasized (Yıldırım & Şimşek, 2016).

Participants

Research, a province in Turkiye's eastern Black Sea region, in the 2018-2019 academic year studying at the secondary school in the first semester of 6th grade students in public schools was conducted with two different classes. Students in the experimental and control groups that make up the study group study in public institutions. The institutions where students study are located in a medium-socio-economic environment. It was observed that the cognitive levels of the students in the experimental and control groups were different from each other. It was observed that the experimental group students had higher levels of cognitive and academic achievement compared to the control group students. The researcher reached this conclusion due to the fact that he conducted lessons and practices in both classes. Purposeful sampling method was used in the selection of students. The administrators in the institutions were informed about the subject and the necessary permissions were obtained from the Directorate of National Education in the province where the study was conducted.

Data Collection Tools

Torrance Creative Thinking Test was used to collect the data of the quantitative part of the study. In the qualitative part, a semi-structured interview form prepared by the researchers and arranged with expert opinion was used.

Torrance Creative Thinking Test

The creative thinking test developed by Torrance has an important place in the literature in that it can directly measure creativity (Aslan, 2001). In 1966, this test was developed as two basic tests, "verbal" and "figural" forms. TCTT Verbal A form consists of seven activities. These activities are in the form of asking questions, predicting causes, predicting results, product development, unusual uses (cardboard boxes), unusual questions, and suppose that. With the TCTT Verbal A form, the dimensions of fluency, originality and flexibility of creativity are measured. TCTT Figural A form consists of 3 activities. These activities are painting, painting completion and accuracy. TCTT figural form A consists of fluency, originality, enrichment (detailing), abstraction of titles, resistance to early closure sub-dimensions and creative forces list sub-dimensions. These tests, which are developed both figurally and verbally, allow application from preschool to higher education (Sungur, 1997). These forms of TCTT were adapted to Turkish by Aslan in 1999. He conducted linguistic equivalence, reliability and validity studies in order to create the adapted version of the test to Turkish.

Semi-Structured Interview Form

In this study, "Semi-structured Student Interview Form" prepared by the researcher was used in order to learn about the usability of mathematics-centered STEM activities in mathematics lessons and students' thoughts about creative thinking and STEM activities. In some parts of the form, depending on the flow of the interview, the flow of the

interview was determined with the sub-questions and the students detailed their answers. The interview questions were created by taking into account the concepts that constitute the theoretical framework of the research. Expert opinion was consulted for the applicability of the interview questions prepared. Volunteerism requirement was observed among the nineteen students in the sample group, and eight students who were willing to interview were interviewed who differed in their interest in STEM activities and their level of participation. Permission of the students was requested in order to record the interview. Before the interview, each student was informed about the purpose of this interview. The interview questions were asked sequentially as they were prepared in the form, and guidance was avoided in the answers given by the students. Eight of these questions in the interview form are also composed of open-ended questions and questions that will detail the answers to these questions. The first four questions are about views on math-centered STEM activities. The remaining four questions are those in which creative thinking, which forms the basis of the study, and the relationship between creativity and mathematics, and the relationship between mathematics-centered STEM activities and creative thinking are taken.

Data Analysis

In this section, the methods used in the analysis of qualitative and quantitative data are included.

Analysis of Quantitative Data

Testing the Normality Assumptions of Control Group Students' Findings

Torrance Creative Thinking Test Verbal-Figural Form-A normality tests of the data belonging to the control group were conducted in order to test the necessary assumptions before the ANCOVA test to determine whether there was a statistically significant difference between the pre-test and post-test. In addition, the findings of the Shapiro-Wilk test conducted for this purpose are given in Table 1.

Table 1

Results Obtained from Testing the Normality Assumptions of the Findings of the Control Group Students

Control Group Tests	N	Skewness	Kurtosis	Shapiro-Wilks
Verbal pre-test	19	.618	.913	.289
Figural post-test	19	.072	-.646	.865
Verbal pre-test	19	.216	-.342	.566
Figural post-test	19	-.670	.982	.657

In Table 1, it is seen that the significance values of verbal pre-test, verbal post-test, figural pre-test and figural post-tests are higher than ,05 at the end of the Shapiro-Wilks test made on the findings of the experimental group students, that is, the data are distributed normally. In order to check the normality assumption for the items, kurtosis (K) and skewness (S) coefficients were calculated and none of the items were -3 <K. <+3 and -10 < S < +10. It was observed that it did not exceed the values (Kline, 2005). From this point of view, it can be concluded that the pre-test and post-test data of the experimental group show normal distribution. For the data obtained from the TCTT to be scored, each student has a score sheet in verbal and figural sub-dimensions. In accordance with the criteria in this chart, the points obtained by the students from the activities are collected separately and the 3 types of points in the Verbal Form-A, which are the fluency, flexibility and originality scores, are calculated. For the Figural Form-A, there are sub-categories of fluency, originality, abstraction of titles, enrichment (detailing), resistance to early closure and creative forces list. The fluency, flexibility and originality dimensions of the students' responses to the Verbal-A form in the TCTT, benefiting from the principles in the TCTT Verbal-A instruction and assessment booklet, the researcher completed the calculation according to these 3 points type by scoring.

Analysis of Qualitative Data

In this part of research, semi-structured interview as a technique is used for the purpose of examining student opinions. Content analysis was used in the analysis of the data obtained from the interviews to determine the students' views on creative thinking and math-centered STEM activities. A wide variety of data sources, including textual data, visual stimuli (e.g. photographs/videos), and audio data can be involved in content analysis. Besides, the technique is highly flexible in terms of its empirical and theoretic aspect (Stemler, 2015). Content analysis is essentially a coding process. While coding is the process of transforming raw data into a standardized form, coding forces the researcher to make judgments about meanings (Kohlbacher, 2006). Each question asked to the students was collected under a common theme, and the answers given were categorized and divided into sub-categories. The obtained data are presented and interpreted in tables.

Validity and Reliability

The verbal and figural forms of TCTT were adapted to Turkish by Aslan in (1999). He conducted linguistic equivalence, reliability and validity studies, respectively, in order to create the adapted version of the test to Turkish. At all stages of the study, study groups were formed from individuals of different ages and education levels and data were collected randomly. For the adaptation study of the test, as in the original test, data were collected from students at different education levels such as pre-school, primary school (from 1st to 5th grade) high school and university students and individuals from different occupational groups. In order to ensure the reliability of the test, it is necessary to ensure that the information in the instruction is correctly understood by the individuals. For this reason, although the test was previously adapted to Turkish, the translation of the test was restarted with the work of two experts and researchers. Translation done with three different people, this form was translated into English by an English language expert. After the completion of these translations, the suitability of the test was decided with the original form and translation form comparisons. Then, the application of the tests, first in English and in Turkish with 15 days intervals, was carried out to a study group of 30 people who have a command of two languages (Aslan, 2001). In the reliability studies based on the data obtained as a result of these studies, test-retest and internal consistency calculations were made. Cronbach's alpha correlation coefficients varying between .89 and .86 for primary school, between .71 and .62 for secondary education, and between .68 and .81 for adults (Aslan, 1999). The reliability of the study was ensured by giving examples of the answers taken from the interview questions. In the process of developing the interview questions, interview questions were formed by taking into account the subject headings of the research. Expert opinion was sought in the preparation of these interview questions. The meeting was held after the necessary arrangements were made. During the interview, guiding the students was avoided and questions were asked to elaborate the answers given.

Researcher Role

The researcher is the one who implements the mathematics lessons of the control group and the STEM activities of the experimental group. The researcher received STEM training in the STEM workshop organized by Turkiye Ministry of National Education General Directorate of Innovation and Educational Technologies (YEĞİTEK) on STEM education and within the scope of the project named "Innovative Technology Applications in Mathematics Education" 4005 Scientific And Technological Research Institution Of Turkiye (TÜBİTAK) organized during the summer vacation. In the studies, the researcher takes the roles of participant, practitioner and observer. She carried out activities and lessons herself. The researcher was responsible for all the procedures related to the courses and activities for a term.

Practices/Procedure

In the STEM classroom, students develop different perspectives on the solution of daily life problems and provide supporting data. Students must always be active and productive. The study started by dividing the experimental group students into groups of 3-6 people. While forming the groups, student views were taken into account. The class is clustered to allow students to work in groups. Practices were carried out by considering the opinions of all individuals in the group regarding the daily life problem. At the end of the lesson, all groups were asked by their servers to present their products, and the groups were awarded points for each step. The research was conducted with students in two different classes who are studying in the 6th grade of secondary school in public schools in the first semester of the 2018-2019 academic year in a province located in the Eastern Black Sea Region of Turkiye.

Figure 1

An Example of Group Work of Making Juice Boxes with Less Cost

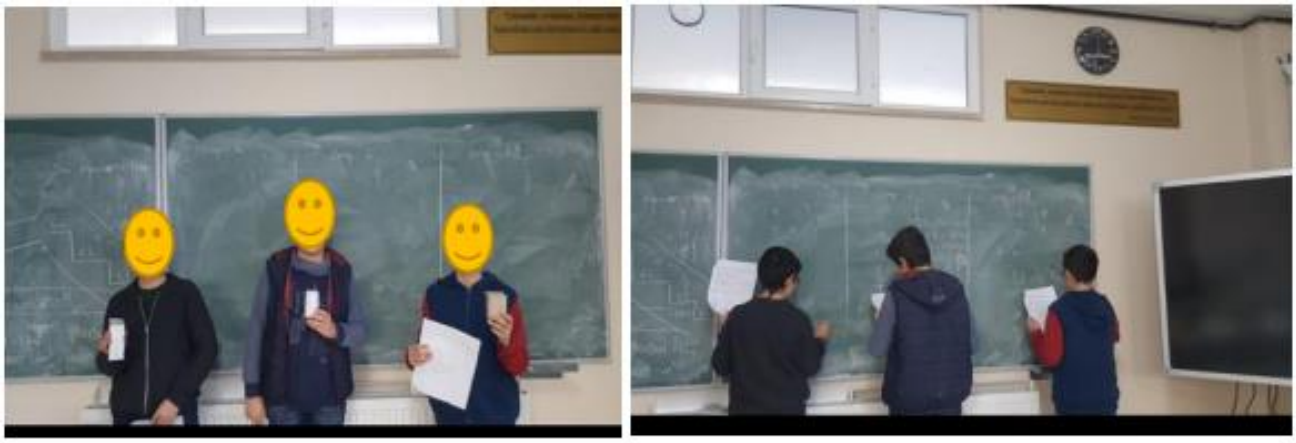


Figure 2
Example of STEM Student Presentation and Products

Findings

In this part, the statistical results and findings obtained from the research on the STEM activities of the experimental group and the pre-test post-tests of the TCTT experiment control groups applied to determine the effect of mathematics-centered STEM activities on the creative thinking skills of 6th grade students are included. In this section, the statistical results and findings obtained from the research on the STEM activities of the experimental group and the pre-test post-tests of the TCTT experiment control groups applied to determine the effect of mathematics-centered STEM activities on the creative thinking skills of 6th grade students are included. In this study conducted with quantitative and qualitative method research, quantitative and qualitative data were collected and interpreted together. First, the quantitative data part of the research was examined.

The Effect of STEM Activities on Students Creative Thinking Skills

In this section, score data of TCTT verbal / figural pre-test and verbal / figural post-test forms are presented.
Quantitative findings of control and experimental group students.
In this part, data regarding the scores of 38 students in the control and experimental groups obtained from the TCTT verbal / figural pre-test and verbal / figural post-test forms are presented.

Table 2
ANCOVA Test Results of the Control and Experimental Group Students' Pre-Test Post-Test Scores of TCTT Verbal-Figural Form A Sub-Dimensions

Tests	Group	N	$\bar{X}$ Pretest	$\bar{X}$ Posttest	$\bar{X}$ Corrected Posttest
Verbal Fluency Test	Control	19	51.89	68.32	70.81
	Experimental		59.00	121.58	118.16
Verbal Flexibility Test	Control	19	24.15	26.05	26.22
	Experimental		24.78	44.58	44.54
Verbal Originality Test	Control	19	25.94	31.42	31.46
	Experimental		26.10	69.11	69.04
Figural Fluency Test	Control	19	27.68	27.58	29.24
	Experimental		39.68	38.53	38.94
Figural Originality	Control	19	17.47	19.32	19.94
	Experimental		21.05	28.89	28.85
Abstraction Test of the Figural Titles	Control	19	5.05	5.11	5.78
	Experimental		10.78	11.37	10.73
Figural Enrichment Test	Control	19	16.26	15.32	15.41
	Experimental		17.10	17.95	17.96
Figural Early Closure Resistance Test	Control	19	6.84	7.47	8.06
	Experimental		9.89	11.58	11.93

As a result of STEM activities applied to develop students' skills related to verbal fluency sub-dimension, which is one of the sub-dimensions of TCTT, it is seen that the change made in relation to pre-test scores is significant ($F_{(1,36)}$= 12.450, p= .007, η2 = .198). With this finding, it can be said that the difference observed between the corrected

average scores of the students in the experimental and control groups is significant and the STEM activities applied in the experimental group are effective in increasing the verbal fluency scores of the students from the sub-dimensions of TCTT.

As a result of STEM activities applied to develop students' skills related to verbal flexibility sub-dimension, which is one of the sub-dimensions of TCTT, it is seen that there is no significant difference in the change in pre-test scores ($F_{(1,36)} = 1.891$, $p = .114$, $\eta 2 = .072$). With this finding, it can be concluded that the difference observed between the corrected average scores of the students in the experimental and control groups is not significant and that the STEM activities applied in the experimental group have no effect on the verbal flexibility scores of the sub-dimensions of the TCTT.

As a result of STEM activities applied to develop students' skills related to verbal originality sub-dimension, which is one of the sub-dimensions of TCTT, it is seen that the change made in relation to the pre-test scores is significant. ($F_{(1,36)} = 16.788$, $p = .019$, $\eta 2 = .151$). With this finding, it can be said that the difference observed between the corrected average scores of the students in the experimental and control groups is significant and the STEM activities applied in the experimental group are effective in increasing the verbal originality scores of the students from the sub-dimensions of TCTT.

As a result of STEM activities applied to develop students' skills related to the figural fluency sub-dimension of TCTT, it is seen that there is no significant difference in the change made in relation to the pre-test scores ($F_{(1,36)} = 14.397$, $p = .897$, $\eta 2 = .001$). With this finding, it can be concluded that the difference observed between the corrected average scores of the students in the experimental and control groups is not significant and that the STEM activities applied in the experimental group have no effect on the figural fluency scores of the sub-dimensions of the TCTT.

As a result of STEM activities applied to develop students' skills related to the figural originality sub-dimension of TCTT, it is seen that there is no significant difference in the change in pre-test scores. ($F_{(1,36)} = .194$, $p = .172$, $\eta 2 = .054$). With this finding, it can be concluded that the difference observed between the corrected average scores of the students in the experimental and control groups is not significant and that the STEM activities applied in the experimental group have no effect on the figural originality scores of the sub-dimensions of the TCTT.

It is seen that there is no significant difference in the change in the pre-test scores as a result of the STEM activities applied to develop the skills of the students related to the abstraction sub-dimension of the figural topics, which is one of the sub-dimensions of the TCTT ($F_{(1,36)} = .495$, $p = .135$, $\eta 2 = .065$). With this finding, it can be concluded that the difference observed between the corrected average scores of the students in the experimental and control groups is not significant, and the STEM activities applied in the experimental group have no effect on the abstraction scores of the figural headings from the sub-dimensions of the TCTT.

As a result of STEM activities applied to develop students' skills related to the figural enrichment sub-dimension, which is one of the sub-dimensions of TCTT, it is seen that there is no significant difference in the change in pre-test scores. ($F_{(1,36)} = 32.810$, $p = .790$, $\eta 2 = .002$). With this finding, it can be concluded that the difference observed between the corrected average scores of the students in the experimental and control groups is not significant, and the STEM activities applied in the experimental group have no effect on the figural enrichment scores of the sub-dimensions of the TCTT.

As a result of STEM activities applied to develop students' skills related to the figural early closure resistance sub-dimension of TCTT, it is seen that there is no significant difference in the change in pre-test scores. ($F_{(1,36)} = .223$, $p = .507$, $\eta 2 = .013$). With this finding, it can be concluded that the difference observed between the corrected average scores of the students in the experimental and control groups is not significant and that the STEM activities applied in the experimental group have no effect on the figural early closure scores of the sub-dimensions of TCTT.

Table 3

ANCOVA Test Results of the Pre-Test Post-Test Average Scores of the Control and Experimental Group Students from TCTT Verbal- Figural Form A

Tests	Group	N	$\bar{X}$ Pretest	$\bar{X}$ Posttest	$\bar{X}$ Corrected Posttest
Verbal Test	Control	19	34.00	41.92	42.81
	Experimental		36.63	78.42	77.08
Figural Test	Control	19	15.51	14.95	16.01
	Experimental		20.58	18.31	22.05

As a result of STEM activities applied to develop students' skills related to the verbal dimension of TCTT, it is seen that the change made in relation to the pre-test scores is significant. ($F_{(1,36)}$ =14.677, p=.007, η2=.192). With this finding, it can be said that the difference observed between the corrected average scores of the students in the experimental and control groups is significant and the STEM activities applied in the experimental group are effective in increasing the verbal dimension of the TCTT of the students.

As a result of the STEM activities applied to develop the skills of the students regarding the figural dimension of TCTT, it is seen that there is no significant difference in the change made in relation to the pre-test scores ($F_{(1,36)}$ 3.448, p=.461, η2=.016). With this finding, it can be concluded that the difference observed between the corrected average scores of the students in the experimental and control groups is not significant and that the STEM activities applied in the experimental group have no effect on increasing the students' scores in the figural dimension of TCTT.

Findings Regarding Students' Opinions on STEM

Below are the findings of the students' answers to the questions asked. First, the students were asked "What do you think about the mathematics-based STEM activities that the researcher used in the lessons throughout the semester? The question was asked. Information on students' views on this question is given in Table 4.

Table 4

Opinions on STEM

Theme	Category	Sub-category	P1	P2	P3	P4	P5	P6	P7	P8
STEM	Self-development	Self-development			+					
	Supporting Education	Educational		+		+		+		
		Increase in course success			+					
		Informative								+
		The suitability of the materials for the lesson	+							
	Developing a Positive Attitude	Fun			+		+			+
		Enjoyable		+						
	Creativity	Creativity in the foreground				+			+	
		The emergence of imagination							+	

From the findings obtained from Table 4, opinions about STEM activities are collected in four different categories: "Self-Development", "Supporting Education", "Developing a Positive Attitude" and "Creativity". The students mentioned that STEM activities improve them and the suitability of the materials used to the subject. Below are examples of these views.

Student view that mentions that STEM activities improve students themselves:

P_3: *"These activities improve me. It also improves my course performance. "*

Student opinion about the suitability of the materials used in STEM activities to the topics:

P_1: *"The materials we used in our activities were prone to the subjects we did. I think well about these*. "

Secondly, students were asked, "Do you think that math-centered STEM activities are useful in teaching mathematics lessons? Can you explain? " questions. Findings of this question are given in Table 5.

Table 5

Thoughts on the Effect of STEM Activities on Lesson Teaching

Theme	Category	Sub-category	P1	P2	P3	P4	P5	P6	P7	P8
Effect of STEM Activities on Lesson Teaching	Positive Attitude Development	Having fun	+							
		Learning with fun	+							
	Effective Learning	Active participation in the lesson							+	
		Accessing the teacher			+					
		Easy execution of the lesson								+
	Academic success	Gaining processing skills				+		+		
		Increasing of knowledgement					+			
	Creativity	Being Mind Opener		+				+		

From the findings obtained from Table 5, the opinions about the effect of STEM activities on teaching lessons are covered under the categories of "Positive Attitude Development", "Effective Learning", "Academic Success" and "Creativity". The students stated that these activities enabled them to participate in the lesson more effectively and that they learned different calculations. Some examples of these views are given below.

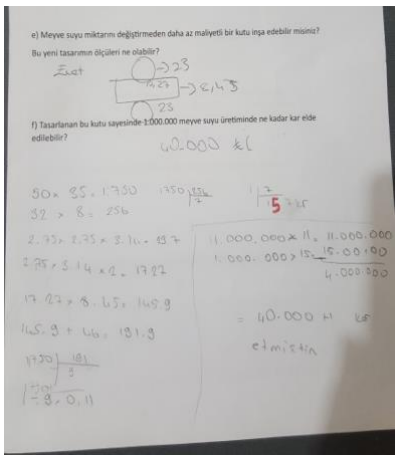
Student opinion stating that STEM activities make the lesson enjoyable:

P_1: *"Yes, I think. Because learning while having fun is a way to learn. That's why I like it. I think it is more beneficial to learn by having fun. "*

Opinion of the student stating that STEM activities provide processing skills:

P_4:*" Yes, I think. Because I'm developing processing skills. "*

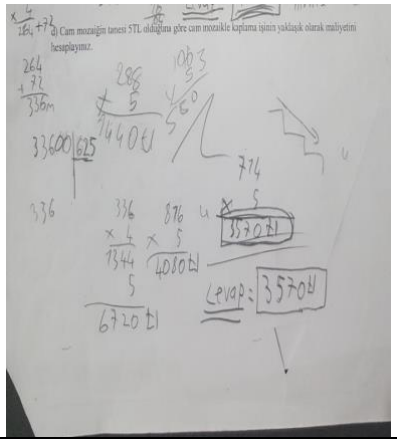
Based on the student views given as examples, it is seen that STEM activities contribute to the students' learning and processing skills by having fun throughout the activity. Figure 1 gives examples of students' processing skills.



e) Can you build a less costly box without changing the amount of juice?
What could be the dimensions of this new design?
-yes.

f) How much profit can be made in the production of 1,000,000 juices thanks to this designed box?

- Answer is 40.000 TL



d) Since the glass mosaic is 5TL each, the glass mosaic coating work is approximately calculate the cost.

- Answer is 3750 TL.

Figure 3

STEM Activities Student Worksheets Examples

As the third question to the students, "Do you think that the math-centered STEM activities used in the lessons during the semester have a positive or negative effect on your math exams? If your answer is positive, can you explain with the reasons? His questions were asked. The data for this question are given in Table 6.

Table 6

Opinions on the Effect of STEM Activities on Mathematics Exams

Theme	Category	Sub-category	P1	P2	P3	P4	P5	P6	P7	P8
Effect on Exam Success	Supporting Success	Making Learning Easy	+							
		Consolidation					+			
		Parallel to the school		+						
	Academic Success	Mark increasing			+	+				
		Gaining processing skills				+				
		Gaining processing speed						+		
	Developing Positive Attitude	Learning with Fun			+					
	Meaningful Learning	Easy understanding							+	
		Understanding the logic of the subject	+							
	Permanence	Ensuring persistence								+

From the findings obtained from Table 6, opinions about the effect of STEM activities on mathematics exams are gathered under the categories of "Supporting Success", "Academic Success", "Developing Positive Attitude", "Meaningful Learning" and " Permanence ". When the opinions of the students are examined, it is seen that STEM activities help to understand the logic of the subjects, and that they positively affect the mathematics exam success by gaining processing skills.

Below is an example of this view.

P_1: *"Yes, teacher. Because I can understand the new information we learn more easily thanks to STEM activities. I can understand its logic thanks to STEM activities. "*

P_4: *"While I had two mistakes, I started not to get any wrong. I gained process skills. "*

Fourth, the students asked, "Did you encounter any difficulties during the implementation of math-centered STEM activities?" "If your answer is yes, can you explain these difficulties?" questions were asked. The results obtained from these questions are given in Table 7 and Table 8.

Table 7

Opinions about Difficulties Encountered in Implementing STEM Activities

Category	Code	Frequency
Difficulties Encountered in STEM Activity Applications	Yes	4
	No	4

From the findings obtained from Table 7, four students stated that they encountered difficulties during the implementation of STEM activities, while four students stated that they did not encounter any difficulties. Views on the difficulties encountered are given in Table 8.

Table 8

Opinions on the Difficulties Encountered in the Implementation of STEM Activities

Theme	Category	Sub-category	P1	P2	P3	P4	P5	P6	P7	P8
Encountered Difficulties	Processing skill	Having difficulties while making operation			+	+				
	Lack of knowledge	Not knowing the subject		+						
	Ability to interpration	Unable to understand the problem								+

From the findings obtained from Table 8, opinions about the difficulties encountered in the implementation of STEM activities are collected under the categories of "Processing Skills", "Lack of Knowledge" and " Ability to interpration ". When the opinions of the students were examined, they stated that they had difficulty in the procedures during the activities, they did not have a command of the subject and they could not understand the problem.

The opinion of one of the students regarding the compensation of the difficulty he/she encountered is given below.

P_3*: "Teacher, I was having problems with the procedures. While operating. Sometimes it happens, but I handle it with the help of my group friends and you. "*

Based on the student opinion given, it can be concluded that group work in STEM activities is beneficial for students.

Fifthly, students were asked "What is creative thinking for you? What does a thought need to be creative? " The opinions obtained from the questions are given in Table 9.

Table 9

Thoughts on the Definition of Creative Thinking

Theme	**Category**	**Sub-category**	**P1**	**P2**	**P3**	**P4**	**P5**	**P6**	**P7**	**P8**
Creative Thinking	Understandability	Being clear							+	
	Productivity	Presenting a product				+		+		
	Originality	Thinking of the non-existent					+	+		
		Independence of information	+							
		Being undiscovered		+	+	+			+	
		Using different logic	+							
	Abstractness	Thinking differently					+			
		Using imagination		+					+	+

From the findings obtained from Table 9, opinions about the definition of creative thinking are grouped under the categories of "Understandability", "Productivity", "Originality" and " Abstractness ". They defined students' creative thinking as being independent of information and creating unexplored products. Examples of these views are given below.

P_1: *"It is necessary that the ways learned are different, for example it should not depend on only one subject. It should have a different logic. "*

P_6: *"To reveal something. It has to be different from the others. "*

P_2: *"The fact that he created it, that he did it, must have found it. Original so. Imagination is needed."*

In Figure 2, visuals of student products obtained with STEM activities are given.

Figure 2

Samples of Products Obtained in STEM Activities

Sixthly, "Do you think there is a relationship between creative thinking and mathematics? "If your answer is yes, can you explain what kind of relationship is between them?" questions were asked to the students. The data obtained from these questions are given in Table 10 and Table 11.

Table 10

Opinions on Creative Thinking and Mathematics Relationship

Category	Code	Frequency
Creative Thinking and Maths Relationship	Yes	5
	No	3

From the findings obtained from Table 10, five of the students stated that creative thinking is related to mathematics, and three of them stated that it is not. Findings about the relationship between creative thinking and mathematics lesson are given in Table 11.

Table 11

Opinions on Creative Thinking Mathematics Relationship

Theme	Category	Sub-category	P1	P2	P3	P4	P5	P6	P7	P8
	Supporting Creativity	Producing through math			+					
		Mathematical thinking				+				
	Multidimensional Thinking	Detailed thinking		+						
		Thinking of different ways	+							
		Thinking more					+			
	Understandability	Easier to understand	+							
	Supporting Teaching	Gaining processing skills			+					

From the findings obtained from Table 11, the opinions on the Relationship between Creative Thinking and Mathematics are grouped under the categories of "Supporting Creativity", "Multidimensional Thinking", "Understandability" and "Supporting Teaching". The students stated the relationship between creative thinking and mathematics as the need for mathematics for the product to be produced and as the mathematics lesson providing creative thinking.

P_4: *"Yes there is. Because mathematics enables creative thinking. "*

P_3: *"The new things we produce and do make it easier for us to do mathematics."*

Seventh, "Do you think there is a relationship between creative thinking and math-centered STEM activities?" And "If your answer is yes, can you explain what kind of a relationship between them? questions were asked to the students. The data obtained for these questions are given in Table 12 and Table 13.

Table 12

Opinions on the Relationship of Creative Thinking STEM Activities

Category	Code	Frequency
Creative Thinking and STEM Activities Relationship	Yes	6
	No	2

From the findings obtained from Table 12, six of the students stated that there was a relationship between Creative thinking and STEM activities, while two of them stated that they did not. Findings about the relationship between creative thinking and STEM activities are given in Table 13.

Table 13

Relationship Between Creative Thinking and STEM Activities

Theme	Category	Sub-category	P1	P2	P3	P4	P5	P6	P7	P8
Relationship Between Creative Thinking and STEM Activities	Product Oriented	Mathematical related product	+							
		Obtaining product			+					
	Originality	Producing non-existing						+		
		Thinking differently	+					+		
	The usefulness of mathematics	Using imagination								+
	Enabling thinking	Detailed thinking		+			+			

From the findings obtained from Table 13, opinions about the relationship between creative thinking and STEM activities are collected under the categories of "Product Oriented", "Originality", "The Usefulness of Mathematics" and "Enabling Thinking". Students stated the relationship between creative thinking and STEM activities as obtaining products through mathematics. Examples of these views are presented below.

P_1: *"We always do things related to mathematics in STEM activities. So because it's about math. Teacher, we are thinking and doing different things. "*

P_6: *"You had something done with fruit juice. There is creative thinking there. Different from others."*

Eighth and lastly, the students were asked, "Do you have any other opinions and suggestions about mathematics-centered STEM activities and creative thinking?" The question was asked. The data obtained from these questions are given in Table 14 and Table 15.

Table 14

Requested Opinions About Mathematics-Based STEM Activities and Creative Thinking

Category	Code	Frequency
Providing Opinion	Yes	2
	No	6

From the findings obtained from Table 14, two students provided additional views on mathematics-centered STEM activities and creative thinking, while six students did not provide any additional opinions. Data for additional opinions are given in Table 15.

Table 15

Additional Opinions Requested About Mathematics Based STEM Activities and Creative Thinking

Theme	Category	Sub-category	P1	P2	P3	P4	P5	P6	P7	P8
Additional Opinions	Generalize	Applying to all subjects	+							
	Focus on thinking	Detailed thinking		+						
	Fun	Being fun		+						

From the findings obtained from Table 15, the additional opinions students want to express about mathematics-centered STEM activities and creative thinking are grouped under the categories of " Generalize", "Focus on Thinking" and "Fun".

Examples of these views are given below.

P_2: *"It's fun and convenient for us to think about."*

P_1: *"It can be applied to other topics."*

Among these obtained findings, in the question asked to the students about the relationship between creative thinking and STEM activities, among the student answers, "producing the non-existent" and "thinking differently" views were combined under the category of originality. In this sub-dimension in the TCTT, the experimental group students made a significant difference in the posttests of both the figural originality and verbal originality dimensions compared to the control group students. It was observed that the answers given to the same question and additional opinions were gathered in the category of "detailed thinking" and led students to think. In the question asking about

the effect of STEM activities on the teaching of the lesson, the opinions of the students' "being mind opener" and "developing different ways" were combined under the creativity category. Similarly, among the responses of the students regarding the opinions about STEM, "creativity being at the forefront" and "emergence of imagination" were gathered under the creativity category. One of the skills expected from students in the literature for the STEM approach was the answer to "presenting a product" from student answers regarding the definition of creative thinking. Similar answers were given in the views on the relationship between STEM and creative thinking. These opinions; "Mathematical related product", "obtaining product", "producing what is not". It shows that the results obtained from the sub-dimensions of the TCTT and the students' views are similar, and that the qualitative and quantitative findings support each other. In the light of these data, it can be concluded that STEM activities encourage students to think creatively.

Conclusion and Discussion

Discussions of the Findings of the Results Obtained from the TCTT

Torrance Creative Thinking Test (TCTT) was applied to the experimental and control group students as a pre-test and post-test to obtain research data. According to the findings obtained from the TCTT Verbal Form-A and Figural Form-A booklets, it was concluded that the differentiation between the groups varies according to the sub-dimensions of the tests, and the change in the pre-test scores improved the verbal dimension of the experimental group students' creative thinking skills. In the figural category, it was concluded that there was no significant difference in the change in pre-test scores.

No significant difference was found in the change in the pre-test scores of the experimental and control groups in the verbal flexibility category within the sub-dimensions of the TCTT Verbal Form-A. A significant difference was found in favor of the experimental group in the change of pre-test scores in the fluency category, which is another related dimension of the verbal form. Similarly, a significant difference was obtained in favor of the experimental group in the change of pre-test scores in the originality category of the verbal form.

No significant difference was found in the change in the pre-test scores of the experimental and control groups in the fluency category, which is one of the sub-dimensions of the TCTT Figural Form-A. In the figural originality sub-dimension, there was no significant difference in the change in the pre-test scores of the experimental and control groups in the category.

No significant difference was found in the change in the pre-test scores of the experimental and control groups in the sub-category of the abstraction of figural titles, another dimension.

No significant difference was found in the change in the pre-test scores of the experimental and control groups in the figural enrichment subcategory.

There was no significant difference in the change in the pre-test scores of the experimental and control groups in the subcategory of resistance to figural early closure.

According to the obtained quantitative findings, it can be concluded that math-centered STEM activities are more effective in providing creative thinking skills, especially in the verbal sub-categories of TCTT, than the lessons taught with the current curriculum. According to Bakırcı and Kutlu (2018), they stated that with the STEM approach, students will learn by doing knowledge and experience, and develop their inquiry and creative skills. In the figural subcategories of the experimental group students, the score increase was higher than the control group students, but it was concluded that it was not enough to make a difference. It is thought that this situation may be due to the fact that providing creative thinking skills requires a long process and the research process is limited to one teaching period. Özerbaş (2011) stated that creativity is not a phenomenon that can change in a very short time.

Students' Views on STEM Education

At the end of the research, interviews were conducted with 8 students from the experimental group on a voluntary basis using a semi-structured interview form. The form of the interview consists of math-centered STEM activities and questions about creative thinking. In the first question, "What do you think about the math-centered STEM activities that the researcher used in lessons throughout the semester?" The question was asked. The students mentioned that STEM activities improve themselves and the suitability of the materials used to the subject. According to Akgündüz and Özçelik (2017), they concluded that students' skills to integrate mathematical operations into the product creation stage and their ability to use materials efficiently increased after such activities. A similar study demonstrated an increase in student scores in the posttests. It also demonstrates that STEM-based modules and activities are effective in increasing STEM understanding and mastery. (Zahidi, ve diğerleri, 2021)

In the second question, do you think that Mathematics-centered STEM activities are beneficial for students in teaching mathematics lessons? Can you explain? "The question has been asked. It was concluded that these activities enabled the students to participate in the lesson more effectively and learned different calculations. As a matter of fact, Gülhan and Şahin (2018) that STEM education approach affected students' attitudes regarding this result; Karakaya and Avgın (2016); Yamak, Bulut and Dündar (2014) reached their conclusion. Uğraş (2018) concluded that STEM activities increase students' motivation.

In the third question to the students, "Do you think that the math-centered STEM activities used in the lessons throughout the semester have a positive or negative effect on your math exams? If your answer is positive, can you explain with the reasons? His questions were asked. When the opinions of the students were examined, it was concluded that STEM activities helped to understand the logic of the subjects, and positively affected the mathematics exam success by gaining processing skills. A similar result to this finding has been obtained with the studies conducted. Gülhan and Şahin (2018) and Yıldırım and Altun (2015) stated that STEM activities increase academic success. Another study tried to determine the effects of the STEM curriculum on middle school students and found that students who received STEM education had significantly higher science and mathematics achievement scores than students who received traditional education. (Anita & Shepherd , 2016)

In the fourth question, "Did you encounter any difficulties during the implementation of math-centered STEM activities?" "If your answer is yes, can you explain these difficulties?" questions were asked. Four students stated that they encountered difficulties during the implementation of STEM activities, while four students stated that they did not encounter any difficulties. It was concluded that these difficulties were difficulty in processing during the activities, not being able to master the subject and not understanding the problem. Alıcı (2018) stated in his study that the difficulties students encounter during the implementation of the activities are lack of knowledge, difficulty using materials, and difficulty in mathematical operations.

The fifth question asked "What is creative thinking for you? What does a thought need to be creative? " questions were asked. It was concluded that students defined creative thinking as being independent of information and creating unexplored products.

In the sixth question, "Do you think there is a relationship between creative thinking and mathematics? "If your answer is yes, can you explain what kind of relationship is between them?" questions were asked. To these questions, six of the students stated that creative thinking was related to mathematics, and two of them stated that it was not. It was concluded that the answers of the students who answered yes to this question stated the relationship between creative thinking and mathematics, the need for mathematics for the product to be produced, and the mathematics lesson as providing creative thinking.

In the seventh question, "Do you think there is a relationship between creative thinking and math-centered STEM activities?" And "If your answer is yes, can you explain what kind of relationship is between them?" questions were asked. Six of the students stated that there was a relationship between creative thinking and STEM activities, and two of them stated that they did not. From the answers of the students who answered yes to this question, it was concluded that the relationship between creative thinking and STEM activities was to obtain products through mathematics. According to Akgündüz and Akpınar (2018), it was determined that STEM applications enable students to acquire 21st century skills such as creativity, critical thinking, collaboration and communication. In parallel with the findings, STEM activities include processes such as prototyping, generating possible solutions, and defining the problem.

Eighth and lastly, the students were asked, "Do you have any other opinions and suggestions about mathematics-centered STEM activities and creative thinking?" The question was asked. Two students suggested and added to this question. In these opinions, it was concluded that the students found STEM activities useful, had fun during the activity and wanted it to be applied in more subjects. Similar to this result, Eroğlu and Bektaş (2016) stated that STEM education should be expanded. It was also revealed in the sources that the students found STEM activities fun and their motivation increased.

As a result of the interviews with the students, it was concluded that math-centered STEM activities were beneficial for them and they were effective in developing their creative aspects. The fact that STEM activities and creative thinking skills have a place in the literature, product creation and product design process, supported the research. In addition, it has been concluded that student views support quantitative data.

According to the findings obtained from the quantitative and qualitative data, it was concluded that math-centered STEM activities contribute to the creative thinking skills of the students.

Recommendations

- It is in the literature that creative thinking skills can be improved. However, since this process is long, more time can be allocated for STEM activities.
- Based on the data obtained from the study, creating an activity for more gains can be presented as a suggestion.

It has been observed that the students' presentation of the product they have created contributed to both their communication skills and their in-depth handling of the problem, and this can be offered as a recommendation for the implementation of STEM activities.

Limitations of the Research

Application in the first semester of the 2018- 2019 academic year in the mathematics course the findings of the study; Secondary School 6th Grade students, The quantitative study group of the research consisted of 19 experimental and 19 control groups.38 students in total, the qualitative study group consisted of 8 volunteer students selected from the experimental group. It is limited to activities performed for 7 weeks and two hours a week.

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