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The effect of STEM activities on the scientific creativity of middle school students

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Abstract

Recently, potential effects of STEM activities on students in science education are among important research topics. Therefore, in this study, the effect of STEM activity practices on the scientific creativity of middle school students was investigated. The research sample consists of 98 (experimental group = 50 students, control group = 48 students) eighth grade students studying at a state secondary school in the 2018-2019 academic year. The research is a pre-test post-test control group quasi-experimental design. While teaching with STEM activities was applied to the experimental group, the content of the science implementations course curriculum was applied to the control group. During the implementation process, the groups were not affected by each other and the lesson times were treated equally in all groups. The data of the study were obtained with the "Scientific Creativity Test" and evaluated with the t-test. When the research results are examined; It was determined that there was a significant increase in the scientific creativity test results of the experimental group compared to the control group, and according to these results, it can be said that the STEM activity practices in the study contributed to the scientific creativity of the students. However, when the scientific creativity test fluency, flexibility and originality sub-scores of the experimental and control groups were evaluated, it can be said that the results differed significantly in favor of the experimental group.

Keywords: STEM, science education, scientific creativity, middle school students

1. Introduction

The world is constantly in a multifaceted change and development with the effect of globalization. In line with these changes, social needs differ and individuals with different skills are needed to respond to em. Among these skills determined as 21st century skills; skills such as creativity, critical thinking, communication, problem solving, collaboration, flexibility, self-management, and social skills (Gürol, 1995; Kylonen, 2012; Partnership for 21st Century Skills, 2014). Today, these skills are seen as an important factor in lifelong learning (Dede, 2010; Trilling & Fadel, 2009). One of the innovative approaches that support individuals to acquire these skills and adapt to today's conditions is STEM

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education. In our country, STEM education is given under the name of engineering design skills in the science textbook of the "Ministry of National Education" (MEB, 2018b). STEM education combines the disciplines of "science, technology, engineering and mathematics" and offers a holistic learning-teaching environment through interdisciplinary relationships (Bybee, 2010; Smith & Karr-Kidwell, 2000). It also includes a design-oriented learning process with an innovative perspective (Baran, Canbazoğlu-Bilici, & Mesutoğlu, 2015; Gonzalez & Kuenzi, 2012; Temel, 2012; Thomas, 2014). Critical thinking and creativity are at the core of STEM activities. Students contribute to the development of their own problem-solving skills by offering different solutions to the problems they encounter in daily life through STEM activities in classrooms (Ceylan, 2014; Pekbay, 2017; Wang, 2012). At the same time, these activities improve students' creativity by positively affecting their high-level thinking and critical thinking skills (Chesloff, 2013; Çavaş, Bulut, Holbrook, & Rannikmae, 2013; Hartzler, 2000; Morrison, 2006; Niess, 2005).

In the literature, creativity is expressed as the ability to be aware of different and original situations and facts (Andreasen, 2009). Creativity includes the process of producing new and different products by producing solutions to existing problems (Gardner, 1997; McWilliams, 2009; Plucker, Beghetto, & Dow, 2004). Wallas (1926) mentions four phases in the creative process: preparation, incubation, enlightenment of thought and verification of results. In the preparation phase, which is the first phase of creativity, the individual defines the problem and tries to find solutions. Reveals new syntheses and ideas for the problem in the incubation phase. In the enlightenment phase, it produces a solution to the problem, and in the verification of the final phase, the solutions to the problem are verified and the deficiencies are eliminated.

The creativity of individuals can also be expressed as the ability to create original products at the end of a process or process (Doğan, 2011; Öztürk, 2004; Paulus, 2000; Sak, 2009; Simon, 1996; Torrance, 1968; Yenilmez & Yolcu, 2007). However, if this skill is trying to find a solution to a scientific problem in a process with certain limits, it is scientific creativity (Liang, 2002; Lin, Hu, Adey, & Shen, 2003). Scientific creativity is to make an original production in a field of science, mathematics, technology or science or to have a scientific skill in the related field (Rawat, 2010). Aktamış and Ergin (2007) defined scientific creativity as the problem-solving steps used while producing an original product or developing an existing product. Hu and Adey (2002) emphasize that it is a process involving the use of scientific knowledge in the process of solving scientific problems. Therefore, as a result of scientific creativity, a technical product or scientific phenomenon created with scientific knowledge should be presented (Amabile, 1983; Aslan, 1994; Atasoy, Kadayıfçı, & Akkuş, 2007; Hu & Adey, 2002; San, 1993; Yavuz, 1989). In addition, individuals should use scientific methods together with innovative solutions while producing a solution to a scientific problem (Harlen, 2004; Medaor, 2003).

The creativity model in science was proposed by Hu and Adey (2002), in which scientific creativity is defined and its criteria are determined. This model consists of three dimensions: creative process, creative character and creative product. The creative process dimension of the model consists of divergent thinking and imagination. Divergent thinking is the ability to generate various answers in the solution of the problem from a multi-faceted perspective. Dreaming, which is the most important feature of creativity, is to design a mental environment or phenomenon with known objects and ideas (Hu & Adey, 2002; LeBoutiller & Marks, 2003). Whether a thought is a product of creative thinking or not can be understood by evaluating the dimensions of fluency, flexibility and originality that define the character of thoughts (Hu & Adey, 2002). Fluency; being able to generate more than one idea, flexibility; producing different ideas with the same stimulus; Originality includes producing new and original ideas (Guilford, 1986; Hu & Adey, 2002; Torrance & Goff, 1989). Individuals; They express their ideas verbally or in different ways by producing a large number of fluency-sized ideas and offering rich solutions to the problem (Hu & Adey, 2002; Jaarsveldt, 2011). In the flexibility dimension, individuals can easily adapt to different situations or environments by evaluating the situation from different angles and producing unusual ideas (Hu & Adey, 2002; Kontaş, 2015), and by presenting an idea or product that has not been tried or produced before, in the dimension of originality. While searching for solutions, they take innovative initiatives and offer an original solution that has not been produced before (Hu & Adey, 2002; Jaarsveldt, 2011). In the creative product dimension of the creativity model in science, the products to be created as a result of creative thinking should be technical products. Scientific knowledge in these products should be revealed, should be related to a scientific fact and designed to solve a scientific problem (Hu & Adey, 2002; Karakuş, 2001; Üstündağ, 2014).

Scientific creativity is involved in engineering design processes in STEM implementations (Court, 1998; Howard, Culley, & Dekoninck, 2007). The ideas put forward with scientific creativity are important at the point of producing effective solutions to the problem in the engineering design process. The combination of scientific creativity and engineering design process contributes to individuals' creative thinking (Hacıoğlu, 2017). In STEM activities, engineering design processes support students' problem-solving skills and imagination skills, thereby improving their scientific creativity (Charyton, 2015; Havice, 2015; Samuels & Seymour, 2015). In fact, students are creative as they create original, new and different products in the implementation process of STEM activities (Charyton, 2015; Dugger, 2010; Larkin, 2015; Scott, 2009; Stohlmann, Moore & Roehring, 2012; Tunkham, Donpudsa, & Dornbundit, 2016; Zhou, 2010). In STEM activities; It is also extremely important for individuals to produce solutions to problems, to be creative, original and flexible, to evaluate events and situations with high-level thinking skills (Ceylan, 2014; Çakır, Yalçın, & Yalçın, 2019; Çiftçi, 2018; Gülan & Şahin, 2018; Kim et al., 2014; Lee & Lee, 2013; Pekbay, 2017; Suescun-Florez et al., 2013). Therefore, many interesting and important products presented in STEM activities were revealed at the end of the scientific creativity process (Chapman, 1978; Csikszentmihalyi, 1996; Rowe, 2007; Runco, 1988).

In today's teaching environments, students should be open to innovations with activities and performances that develop creative thinking skills. These activities will contribute to students' approach to events like scientists by using scientific creativity as much as possible in solving science-related problems (Kılıç & Tezel, 2012; Regis, Albertazzi, & Roletto, 1996).

Studies affecting the creativity of students with STEM education have recently been included in the literature (Ceylan, 2014; Cho & Lee, 2013; Çiftçi, 2018; Dong-Ju, Jin-Ho, & Su-Hong, 2016; Knezek, Christensen, Tyler-Wood, and Periathiruvadi. (2013; Pekbay, 2017; Ryu & Jae Lee, 2013; Siew, Amir, & Chong, 2015; Şentürk, 2017), researches on this topic have started relatively recently in our country and experimental studies that can explain the effects of STEM education on students with different examples are needed. Therefore, it is important to investigate the effect of STEM activities on students' scientific creativity and such studies will contribute to the literature.

Therefore, in this study, the effect of STEM activity practices conducted within the scope of science implementations course on students' scientific creativity was investigated. In this regard, the problem sentence of the research is "Does STEM activity practices have an effect on students' scientific creativity? determined as. It is thought that the results obtained from this research will guide program preparers and teachers regarding the applicability of STEM education in our country.

2. Method

2.1. Research Pattern

This study, which examines the effect of STEM activity practices on students' scientific creativity, is a control group pattern, one of the quantitative research designs, which is one of the quasi-experimental design types. In this study, the experimental and control groups were assigned randomly and they have equal probability of being found in the experimental and control groups (Çepni, 2014). Random assignment in the study; Groups were assigned randomly, considering that their effect on small groups was insignificant and would provide an advantage in terms of the generalizability of the results of the study and the availability of strong statistics in appropriate sample sizes (Büyüköztürk et al., 2019). Experimental and control groups assigned within the scope of the study; This experimental method was used because it was selected without interfering with the existing groups. In this research, implementations are made after the experimental and control groups are determined according to the previous plan (Fraenkel & Wallen, 1996). Quasi-experimental design is mostly used in educational research in which all variables cannot be controlled (Büyüköztürk, 2007).

2.2. Participants

The participants of the study consist of 98 eighth grade students in the last year of a state secondary school in the 2018-2019 academic year. Within the scope of the purpose of the research, the number of participants for statistical processes and analysis was tried to be kept wide with the design of the research (Büyüköztürk et al., 2019; Çepni, 2014). Six classes were determined for the research, and three classes were determined as experimental groups and three classes as control groups by random assignment from these classes (Table 1).

Table 1. Information about the participants in the Experimental and Control groups

Group	**Class**	**Gender**		**TOTAL (N)**	
		Female (N)	**Male (N)**		
Control	A	7	9	16	48
	B	7	10	17	
	C	7	8	15	
Experimental	D	9	10	19	50
	E	9	7	16	
	F	8	7	15	

In three classes in the control group; There are a total of 48 (21 girls and 27 boys) students. In the experimental group, there are a total of 50 (26 girls and 24 boys) students. For the equivalence of the groups, the academic achievement scores of the science course were compared with the 2017-2018 academic year general achievement score of the previous year and it was found that the groups were equivalent.

Within the scope of the study, the "Scientific Creativity Test", (BYT) scores of the experimental and control groups before the implementation, and their scores of flexibility, fluency and originality, which are the sub-scores of BYT, were compared, and whether there was a significant difference between the BYT pre-test scores of the groups. groups were evaluated by t-test analysis and the results are given in Table 2 and Table **3.**

Table 2. Scientific Creativity Test Pre-test Scores of the Experimental and Control Groups

Variable	**Groups**	**N**	**$\bar{x}$**	**S**	**sd**	**t**	**p**
BYT	Exp.	48	5.21	1.68	96	2.17	.03*
	Cont.	50	4.39	2.02			

*p<.05

According to Table 2, it is seen that there is a significant difference between the scientific creativity test pre-test scores of the experimental and control groups (t (96) = 2.169, p <.05). According to these results, it can be said that the groups were not equivalent in terms of scientific creativity pre-test scores before the implementation.

Creativity test of groups; Whether there is a significant difference between the flexibility, fluency and originality pre-test scores was compared with the t-test analysis for independent groups and the results are shown in Table 3.

Table 3. Flexibility, fluency and originality pre-test scores of the Experimental and Control Groups

Variables	**Groups**	**N**	**$\bar{x}$**	**S**	**sd**	**t**	**p**
Fluency	Cont.	48	1.39	.57	96	.73	.46*
	Exp.	50	1.29	.70			
Flexibility	Cont.	48	3.02	1.07	96	2.65	.01
	Exp.	50	2.39	1.25			
Originality	Cont.	48	1.72	.54	96	1.81	.07*
	Exp.	50	1.49	.66			

*p>.05

According to Table 3, it is seen that there is no significant difference between the fluency pre-test scores of the experimental and control groups (t (96) = .739, p> .05). According to these results, it can be said that the groups are equivalent in terms of fluency pre-test scores before the implementation. Similarly, it is seen that there is no significant difference between the originality pre-test scores of the experimental and control groups (t (96) = 1.812, p> .05). According to these results, it can be said that the groups are equivalent in terms of originality pre-test scores before the implementation. On the contrary, it is seen that there is a significant difference between the flexibility pretest scores of the experimental and control groups (t (96) = 2.651, p <.05). According to these results, it can be said that the groups were not equivalent in terms of flexibility pre-test scores before the implementation.

2.3. Data collection tool

The data in the study were obtained with the "Scientific Creativity Test". BYT was originally developed by Hu and Adey (2002), and adapted to Turkish by Kadayıfçı (2008). The original test was prepared in accordance with the dimensions of scientific creativity, was applied to 160 secondary school students and 35 science educators who were experts in their fields examined to ensure the content validity of the test. As a result of the factor analysis of the original test, it was calculated that it had one factor and its reliability was α = 0.89. The test, which was translated into Turkish by Kadayıfçı (2008), was applied to 57 students and its reliability was found to be α = 0.74. In this study, the reliability coefficient of the scale was found to be 0.87.

Scientific Creativity Test, scientific creativity structure model dimensions; It measures the product (science, technical product, science problem, science phenomenon), process (thinking, imagining) and character (originality, flexibility, fluency). The content of the questions in the test consisting of seven questions; first question = "different, unusual uses", second question = "discovering and finding the problem", third question = "product development", fourth question = "scientific imagination", fifth question = "problem solving", sixth question = It includes "science experiment" and the seventh question = "product design" (Kadayıfçı, 2008). Each question can correspond to more than one dimension in BYT. Scores according to the answers given to the test from the students; It was graded according to the sub-scores of flexibility, fluency and originality. Annex111 Fluency; being able to generate more than one idea, flexibility; producing different ideas with the same stimulus; Originality involves generating new and original ideas (Torrance & Goff, 1989).

In the scoring of BYT, firstly, the answers given by the students were determined as "raw ideas". From these data, "organized ideas" were obtained by combining the ideas that point to the same idea but expressed in different ways. While creating the student scores, the analysis was made as follows by considering the “organized ideas” (Kadayıfçı, 2008).

In the scoring of the questions, both researchers reached a consensus by evaluating the raw data and the organized ideas together and made a decision together. The criteria given in Table 4 below were taken into account for the scoring of the questions.

Table 4. Scoring Criteria of Scientific Creativity

Questions	Scoring Criteria
1, 2, 3, 4	1 point for each answer generated (fluency score) +1 point (flexibility score) for each different implementation suggested 2 points for each answer with less than 5% people, 1 point for 5% - 10% (originality score)
5	For each answer produced, 3 points for each answer found in less than 5% people, 2 points for the answer between 5% and 10%, 1 point (originality) found in more than 10% people.
6	The answer given is evaluated in three dimensions as means, method and implementation. Students of all dimensions are evaluated on 3 points (flexibility). 3 points for each answer found in less than 5% people, 2 points for 5-10%, 1 point for more than 10% (originality)
7	3 points of flexibility for each separate function of the machine, and additionally a originality score of 1 to 5 based on a comprehensive overall impression

2.4. Implementation Process

The implementation was carried out in the Science İmplementations course and two lesson hours per week, in a total of 6 weeks. İmplementations in the experimental and control groups were carried out by the researcher. While teaching with STEM activities to the experimental group, the teaching process was carried out with the control group students within the scope of the "Science İmplementations Course Teaching Program" (MEB, 2018a). The groups were not affected by each other, and the lesson times were treated equally in all groups. In the research, implementations to the experimental and control groups were made by the same researcher in order to eliminate the effect caused by practitioner difference.

Four activities determined by the researchers were conducted with the experimental group. The STEM activities carried out during the implementation process are given in Table 5. The activities were determined to cover the engineering design process after the literature review on STEM implementations. After the activities were examined by the researchers, the opinions of 5 science teachers working in secondary schools affiliated with the Ministry of National Education were taken. In line with the opinions of the teachers, the activities were rearranged by the researchers and the expert opinions were taken by the three experts in science education and the implementation activities were decided to cover the engineering design process (Table 5). The "Scientific Creativity Test" was administered to the experimental and control group students before and after the STEM activity implementations, and the process was completed in a total of six weeks.

Table 5. STEM Activities

Activities	STEM Area	*Activity Achievements
Let's make a telescope (Astronomy Land)		"Uses scientific methods." "He knows the structure of the telescope and what it does." "Understands the relationship between science, technology and engineering." "Realizes the usage areas of lenses in technology." "Realizes the historical change of the telescope with technological developments." "Prepares and presents a simple telescope design." "Redesigning a product with accessible materials, taking into account its mechanical design features." "It applies the stages of planning, prototyping, design, execution, quality control, which are the processes involved in the engineering project in the product development process." "In product design, geometry creates its design by taking into account the properties of shapes." "He / she calculates ratio and proportion in the process of designing the product." "Calculates the cost."
Let's measure air		"He develops a solution proposal for a problem he encounters in daily life and makes applications for the suggestion he develops." "Becomes aware of the environmental problem in its immediate surroundings and offers suggestions for its solution." "Understands the relationship between science, technology and engineering." "Recognizes the air pollution measurement tools and realizes the

pollution (TryEngineering, 2018)		historical change with technological developments." "Understands the relationship between science and technology." "Uses the engineering design process." "Designs air pollution measuring instrument." "Calculates and interprets arithmetic mean in the product design process." "Calculates product cost using four operations."
Lets' make a thermos (Science Fair Central, 2018)		"Classifies materials in terms of heat conduction." "Knows alternative thermal insulation materials." "It determines the selection criteria for the thermal insulation materials used around it." "It does research about ways to reach knowledge by adopting scientific process skills." "Knows the effects of changes in technology development on thermal insulation-transmission material diversity." "Understands the relationship between science and technology." "Makes original designs by using engineering steps for design problems faced in daily life." "Designs a thermos considering the thermal insulation." "He tests the thermos he designed." "While designing the product, it takes into account the volume and area properties." "It uses four operations with integers in the product design process and while calculating costs."
Lets' make a microscope (Science in School, 2012)		"Uses scientific methods in the process of creating scientific knowledge." "Understands the development of the microscope in the historical process." "Knows the function of the microscope." "Realizes the usage areas of lenses in technology." "Designs a microscope." "In the process of creating the product; planning, prototyping, testing the solution " "Creates the design by taking into account the properties of geometry shapes in product design." "Calculates the ratio and proportion in the product design process."

*(MoNE, 2018a; MoNE, 2018b)

After the preliminary information given to the experimental group students, the students carried out STEM activities by using the engineering design process steps. Achievements and activities within the scope of science applications lesson were made with the control group students. These activities do not cover the engineering design process. Activities in both groups were carried out in groups of 4-5 people in a collaborative learning environment (Coştu, Ünal, & Ayas, 2007; Genç & Şahin, 2015). In the applications, the activity materials were provided by the researchers and the researchers guided the student groups during the application process. In the STEM activity implementation process, the engineering design-based cycle stages of Hynes et al. (2011) were used Figure 1.

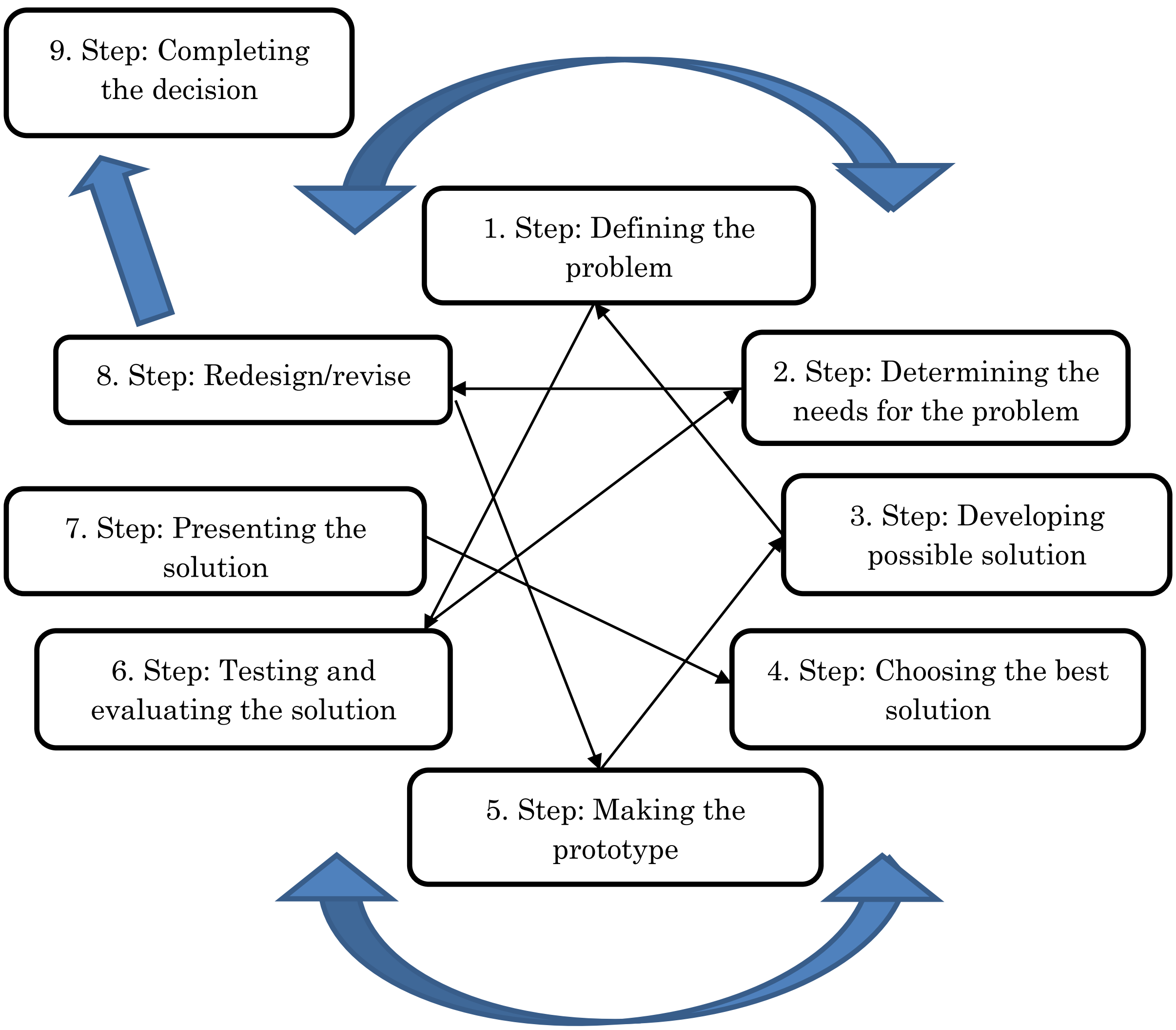

Figure 1. Engineering Design Process (Hynes vd., 2011)

Some design examples of the activities created by the students given in Photographs below.

1. Telescope Design

2. Air Filter Design

3. Microscope Design

4.Thermos Design

2.5. Data Analysis

The data collected from BYT, which is the data collection tool of the research, was analyzed with the SPSS 21 program. The normality assumptions of the collected data were tested before the analysis, and it was determined that the groups' pre-test and post-test data provided the normality assumptions. In order to determine whether the data obtained from the BYT scale of the groups showed normal distribution, the data were analyzed with the Shapiro-Wilks normality test. As a result of the analysis, the p value in the Shapiro-Wilks normality test of the data of the experimental and control groups was higher than .05. According to these results, it can be said that the scores of the tests show a normal distribution (Büyüköztürk, 2013). Independent groups t-test was used to test the difference between the experimental and control groups in terms of scientific creativity, flexibility, fluency and originality variables, and the pre-test and post-test data dependent groups t-test was used to test the differences within the groups. During the analysis of the data of the experimental and control groups; In order to interpret the post-test scores of the groups better, it was examined whether the difference between the post-test and pre-test scores of both groups, namely the achievements, was significant (Akdağ & Tok, 2010). The achievement scores of the experimental and control groups were compared to demonstrate the progress within themselves and to compare their differences. The level of significance in the findings of the study was accepted as .05 and evaluated. In addition, the effect size (eta squared = η2), which is a statistical value showing the size of the difference between the two groups, of the variable that we measure the difference between the two groups was calculated (Cohen, 1988). Effect size gives information about how much of the variance between test scores is due to the independent variable or group variable. The effect size was defined as small, medium and large as 0.01, 0.06 and 0.14, respectively (Büyüköztürk, 2013).

3. Findings

Within the scope of the study, the data regarding the scientific creativity of the experimental and control group students and the difference between the pre-test post-test scores were evaluated with the dependent groups t-test and the results are given in Table 7 and Table 8.

Table 7. The Scientific Creativity Test Pre-test Post-test Scores of the Experimental Group

Variable	**Measurement**	**N**	**$\bar{x}$**	**S**	**sd**	**t**	**p**
Scientific Creativity	Pre- test	50	4.39	2.02	49	-12.96	.00*
	Post-test	50	8.23	2.05			

*p<.05

When Table 7 is examined, it is seen that the difference between the scientific creativity pretest posttest mean scores of the experimental group is significant (t (49) = 12.96, p <.05). Since the scientific creativity test posttest average ($\bar{x}$ = 8.23) of the experimental group is higher than the pretest ($\bar{x}$ = 4.39), it can be said that this difference is in favor of the posttest averages.

Table 8. The Scientific Creativity Test Pre-test Post-test Scores of the Control Group

Variable	Measurement	N	$\bar{x}$	S	sd	t	p
Scientific Creativity	Pre-test	48	5.21	1.68	47	-5.03	.00*
	Post-test	48	6.52	1.99			

*p<.05

When Table 8 is examined, it is seen that the difference between the scientific creativity pre-test post-test mean scores of the control group is significant (t (47) = 5.03, p <.05). Since the scientific creativity test posttest mean ($\bar{x}$ = 6.52) of the control group is higher than the pretest ($\bar{x}$ = 5.21), it can be said that this difference is in favor of the posttest averages.

The significance level between the post-test-pre-test achievement scores obtained by the experimental group students who were applied with STEM activities and the control group students who conducted the implementations as predicted by the curriculum was examined by independent groups t-test, and the results are given in Table 9.

Table 9. Scientific Creativity Test Scores of the Experimental and Control Groups

Variable	Group	N	$\bar{x}$	S	sd	t	p
Scientific Creativity	Cont.	48	1.32	1.81	96	-6.37	.00*
	Exp.	50	3.84	2.10			

*p<.05

When Table 9 is examined, it is seen that the difference between the experimental and control group scientific creativity test achievement (post-test - pre-test) mean scores is significant (t (96) = 6.37, p <.05). Since the scientific creativity average of the control group ($\bar{x}$ = 1.32) is lower than the average of the experimental group ($\bar{x}$ = 3.84), it can be said that the scientific creativity of the experimental group increased more. In the study, the eta-square value of the scientific creativity variable was determined as 0.3. This value can be interpreted as a large effect size.

The findings of the experimental and control group students' scientific creativity, flexibility, fluency and originality sub-scores are given below. The data regarding the difference between the flexibility, fluency and specificity pre-test post-test scores of the experimental and control groups were evaluated with the dependent groups t-test and the results are given in Tables 10-11.

Table 10. Fluency, Flexibility and Specificity Pre-test Post-test Scores of the Experimental Group

Variables	Measurement	N	$\bar{x}$	S	sd	t	p
Fluency	Pre-test	50	1.22	.61	49	-9.55	.00*
	Post-test	50	2.44	.91			
Flexibility	Pre-test	50	2.39	1.25	49	-13.12	.00*
	Post-test	50	4.54	1.30			
Originality	Pre-test	50	1.49	.66	49	-12.50	.00*
	Post-test	50	2.87	.81			

*p<.05

When Table 10 is examined, when the fluency, flexibility and originality scores of the experimental group are evaluated; experimental group students' fluency (t (49) = 9.55, p <.05), flexibility (t (49) = 13.12, p <.05) and originality (t (49) = 12.50, p <.05) pre-test It is seen that the difference between the post-test mean scores is significant. Fluency post-test average of the experimental group ($\bar{x}$ = 2.44), pre-test ($\bar{x}$ = 1.22); elasticity post-test mean ($\bar{x}$ = 4.54), pre-test ($\bar{x}$ = 2.39); Since the specificity posttest mean ($\bar{x}$ = 2.87) is higher than the pretest ($\bar{x}$ = 1.49), it can be said that this difference is in favor of the posttest means.

Table 11. Fluency, Flexibility and Specificity Pre-test Post-test Scores of the Control Group

Variables	Measurement	N	$\bar{x}$	S	sd	t	p
Fluency	Pre-test	48	1.42	.55	47	-4.56	.00*
	Post-test	48	1.84	.66			
Flexibility	Pre-test	48	2.94	.91	47	-4.43	.00*
	Post-test	48	3.66	1.20			
Originality	Pre-test	48	1.69	.45	47	-5.01	.00*
	Post-test	48	2.17	.74			

*p<.05

When Table 11 is examined, when the fluency, flexibility and originality scores of the control group are evaluated; fluency (t (47) = 4.56, p <.05), flexibility (t (47) = 4.43, p <.05) and specificity (t (47) = 5.01, p <.05) pre-test post-test It is seen that the difference between the mean scores is significant. Fluency post-test mean of the control group ($\bar{x}$ =

1.84), pre-test ($\bar{x}$ = 1.42); elasticity post-test mean ($\bar{x}$ = 3.66), pre-test ($\bar{x}$ = 2.94); Since the specificity posttest mean ($\bar{x}$ = 2.17) is higher than the pretest ($\bar{x}$ = 1.69), it can be said that this difference is in favor of the posttest means.

The level of significance between the post-test-pre-test achievement scores obtained by the experimental group students who were applied with STEM activities and the control group students who made their applications as predicted by the curriculum was examined with the independent groups t-test. The results are given in Table 12 .

Table 12. Fluency, Flexibility and Specificity Reach Scores of Experimental and Control Groups

Variables	Measurement	N	$\bar{x}$	S	sd	t	p
Fluency	Pre-test	48	.47	.63	96	-4.76	.00*
	Post-test	50	1.22	.90			
Flexibility	Pre-test	48	.72	1.13	96	-6.17	.00*
	Post-test	50	2.15	1.16			
Originality	Pre-test	48	.48	.66	96	-6.15	.00*
	Post-test	50	1.38	.78			

*p<.05

When Table 12 is examined, it is seen that the difference between the fluency sub-dimension achievement (posttest - pre-test) mean scores of the experimental and control groups is significant ($t (96) = 4.76$, $p <.05$). Similarly, it is seen that the difference between the flexibility subscale achievement mean scores ($t (96) = 6.17$, $p <.05$) and the individuality subscale achievement mean scores ($t (96) = 6.15$, $p <.05$) is significant. According to Table 12, it can be said that these variables increased more in the experimental group, since the fluency, flexibility and specificity mean scores of the control group were lower than the averages of the experimental group. The eta-square value of the fluency variable in the study was 0.19; The eta-squared value of the elasticity variable was determined as 0.28 and the eta-square value of the specificity variable as 0.28. These values can be interpreted as a large effect size.

4. Discussion, Conclusion, and Recommendations

In the study, the effects of the applications made with STEM activities within the scope of science applications course on the fluency, flexibility and originality sub-scores of the scientific creativity and scientific creativity of the senior school students were examined. The scientific creativity findings of the students in this application carried out with a semi-experimental design are shown in Table 7-8-9; Scientific creativity test fluency, flexibility and originality findings are given in Table 10-11-12 and the results are discussed below.

When the findings of Table 9 are examined; When the scientific creativity test scores of the experimental and control groups are compared, it can be said that the results differ significantly in favor of the experimental group. In the study, the scientific creativity test, pre-test and post-test scores of the experimental and control group students were evaluated and given in Table 7 and Table 8. When the tables were examined, it was determined that the average scores of the scientific creativity test in the experimental and control groups increased in favor of the posttest. However, the experimental group's pre-test post-test mean scores were found to be higher and significantly higher than the control group (Table 3). Accordingly, it can be said that the STEM activity practices conducted with the experimental group students contribute more to the scientific creativity of the students.

Similarly, when the findings of Table 12 are examined; When the scientific creativity, fluency, flexibility and originality sub-scores of the experimental and control groups were evaluated, it can be said that the results differed significantly in favor of the experimental group. The fluency, flexibility and originality pre-test and post-test scores of the experimental and control group students were also evaluated and given in Table 10 and Table 11. When the tables were examined, it was determined that there was an increase in the mean scores of fluency, flexibility and specificity in the experimental and control groups in favor of the post-test. However, the experimental group's pre-test post-test mean scores were found to be higher and significantly higher than the control group (Table 12). Accordingly, it can be said that STEM activity practices with the experimental group students contribute more to the students' scientific creativity, fluency, flexibility and originality sub-scores.

In the results of the study; The reason why the experimental group scientific creativity and scientific creativity fluency, flexibility and originality sub-scores were higher than the control group, it is thought that the engineering design process steps were used in the STEM activities applied in the process. Associating the problem scenarios used in practice in these activities with daily life and creating a solution to an existing problem can be an important contribution. According to Mauffette, Kandlbinder, and Soucisse (2004), they stated that the scenarios used in learning environments and the problems in the scenarios establish a connection in drawing students' attention, determining the boundaries of the relevant subject and relating it to daily life. However, it can be said that students should be actively involved in the design process. In addition, the students revealed their mental designs and creative thoughts through drawings in the activities (Kadayıfçı, 2008). Discussing the features and functions of the design they created with their group friends, the students worked responsibly for each activity during the implementation process.

It can be said that the experimental group's taking active responsibility and making their own decisions by discussing while producing solutions to the problems encouraged the students to think creatively. In the activities, the students were constantly confronted with new situations, and therefore the students displayed an investigative and questioning attitude. Thus, it can be said that students' feelings of curiosity and discovery are activated (Kurtuluş, 2012). Students especially used their imaginations while drawing the activities and thought in more detail. It can be said that this situation contributes to their scientific creativity. In addition, the reason for the increase in the fluency, flexibility and originality scores of the experimental group students compared to the control group students may be due to the product design-oriented activities. However, it can be stated as a justification that students gain different perspectives to different events by constantly producing new and original products (Çepni, 2017).

For example, in the "Let's Make a Thermos" activity, students discussed about conductive and insulating materials and decided on the best solution for their designs. With the materials they chose, they created their own thermos in the way, size and feature they wanted. In another activity, "Let's Measure Air Pollution", students made drawings of their own instruments that measure air pollution and wanted to design a vehicle with different features and structure to determine the air pollution that exists around it. At the same time, students grasped the importance of environmental problems with this activity. In the "Let's Make a Telescope" activity, the students realized that a telescope could be made from accessible and simple materials and also made a cost calculation for the materials they used. While designing the telescope, they decided by discussing the working mechanism and how and according to what they would position the lenses in the design. In the "Let's Make a Microscope" activity, students drew, developed and tested their designs. Although the idea of making a microscope at the beginning was complicated for the students, at the end of the process, the groups designed creative and different microscopes.

In STEM activity processes, students; They related their experiences in daily life with their previous field knowledge. In the process of implementing the activities, they followed the changes in their ideas, interpreted different ideas, and came to a conclusion by discussing the correctness and applicability of their ideas. In addition, students' awareness of what they know and do not know has increased while evaluating different ideas in group work. Thus, this process contributed to the scientific creativity of the students. Studies in the literature also support the results of the study (Cho & Lee, 2013; Dong-Ju, Jin-Ho, & Su-Hong, 2016; Knezek, Christensen, Wood & Periathiruvadi, 2013; Pekbay, 2017; Ryu & Jae Lee, 2013 ; Siew, Amir, & Chong, 2015). For example, in the findings of the study conducted by Çiftçi (2018) with seventh grade students, it is stated that the STEM activities developed positively affect the scientific creativity levels of the students. Similarly, it has been determined that STEM activities integrated into the subject of acids and bases contribute positively to the creativity of students on the subject (Ceylan, 2014), and STEM activity practices associated with abstract concepts also improve students' scientific creativity (Şentürk, 2017).

Well-designed STEM activities; Since it offers an integrated curriculum by bringing different disciplines together, it supports students' learning different areas, creativity, development of problem solving skills and cooperative learning (Niess, 2005). In addition, it emphasizes that STEM applications also improve students' thinking skills (Siew, Amir, & Chong, 2015). In the study conducted by Eroğlu and Bektaş (2016), it is stated that STEM activities improve students' psychomotor skills, increase their creativity and motivate group work. In addition, STEM applications encourage students both to produce solutions to meet the needs of the age and to make logical deductions (Morrison, 2006).

The students who participated in the study worked like a scientist in the STEM activity implementation process, using scientific methods and techniques to find a solution to a problem, and even got ideas about how an invention could be. This practice positively affected the scientific creativity of the students, as the scientific methods and techniques were used in the STEM activities conducted in the study and the activities provided the students with the opportunity to associate their own field knowledge with daily life.

The study was limited to the activities carried out within the scope of the research and to middle school students where the application was made. Making similar studies with more students or with different sample groups will contribute to the field. The activities within the scope of this research were carried out in the classroom and the classroom environment was organized in accordance with the activities throughout the implementation process. However, it is another important factor that STEM activities can be implemented easily and that suitable environments should be arranged for students' group work. In this context, workshops or laboratories can be organized in schools for the implementation of STEM activities. Thus, environments can be provided for students to create their own designs and products.

Considering the results of the research; It is thought that there is a need for teaching environments where students can actively take part in the teaching process, where they can offer various solutions to the problems they encounter, use their imagination skills, make original and innovative designs and exhibit their creativity. In addition, it is extremely important to combine the activities in the teaching process with different disciplines and to apply them in relation to daily life.

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