The Effect of Scientific Toy Design Activities Based on the Engineering Design Process on Secondary School Students' Scientific Creativity

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Abstract: Toys used as a play tool have an important role in the development of children. For this reason, it is necessary to offer children the opportunity to design their own toys. Scientific toys can be used in science lessons to encourage creativity and to teach science concepts and scientific inquiry. With the integrated STEM Education and specifically Engineering Design Process, children can have the ability to design their toys according to their own creativity, while at the same time they can gain many skills through scientific studies. The integration of these designs into education will contribute to the development of engineering skills perceptions and scientific creativity. This study aims to examine the effect of scientific toy design activities based on engineering design process on the scientific creativity of middle school students' and their views on scientific toy design activities. The research conducted for this purpose was carried out over a 9-week period. The study group consists of 40 middle school 7th grade students. The research was carried out with a single group pre-test post-test experimental design method. "Scientific Creativity Test" was used to collect the data. Data were analysed using quantitative and qualitative analysis techniques. As a result of the research, it was determined that the scientific creativity of middle school students improved positively with scientific toy design activities based on the engineering design process.

Keywords: STEM education, Engineering Design Process, Scientific creativity, Scientific toy design

1. Introduction

21st Century developments have greatly affected countries economically, technologically, and culturally, and in terms of innovation (ITEA, 2007; NRC, 2012). This effect lays the groundwork for a competitive environment and encourages countries to introduce appropriate planning leading to change. In such a context, the skills that individuals should have should be suitable for meeting the needs of the period in which they live, and for meeting the new needs that may arise in the future. Academic knowledge and skills are important and necessary for individuals, but it is thought that such these alone will not be sufficient for individuals in the new age. The skills that will be able to meet these needs are expressed as 21st Century skills (Jerald, 2009). In this respect, it is important for students to acquire the skills of the twenty-first century in order to have an idea about the importance of innovation, in order to allow them to operate as effective and active individuals in society (Ceylan, 2014).

Students need to acquire the skills required by this century in order to successfully adapt and to have a better quality of life. Schools have an important part to play in the acquisition of these skills and it is aimed that teachers work in harmony with innovations and develop their students' skills (KeDu, 2018). For this reason, it is important that science teaching environments in schools are designed in such a way that can improve the scientific development of children as much as possible. In this context, STEM education offers students the opportunity to gain 21st Century skills. It is emphasized that STEM education can help students gain the skills needed for the 21st Century by finding practical solutions to problems, designing products, involving them in effective participation by seeking solutions to real-life problems, engaging in high-level thinking, making active use of technology, developing communication skills, using scientific process skills, questioning, engaging in creative thinking, making observations, designing experiments and determining variables (Bybee, 2010; Morrison, 2006; Smith & Karr-Kidwell, 2000; Sahin, Ayar, Adıguzel, 2014; Wang, 2012; Yildirim, Altun, 2015).

Creativity, which is an important skill for the 21st Century, is defined as the ability to look at a situation from different perspectives, to find different and new ways compared with traditional ways, to go beyond existing boundaries with the knowledge so acquired, to be original and to systematically bring together things that seem unrelated to each other (Fox & Schirrmacher, 2014). In the literature, creativity in science subjects is expressed as 'scientific creativity' (Aktamis & Ergin, 2006; Demir 2014; Isler & Bilgin, 2002). According to Hu and Adey (2002), scientific creativity is defined as the ability to produce an original product, an intellectual property or the potential to incorporate an individual or community-centered value into a product. Similarly, Mohamed (2006) defined scientific creativity as scientific activities based on of approaching a problems in the scientific field based on the previous knowledge of the individual, developing theories in this direction, and creating new products with the use of original ideas.

Hu and Adey (2002) introduced the Scientific Creativity Model by examining scientific creativity in three dimensions: creative process, creative character and creative product. This model is shown in Figure 1.

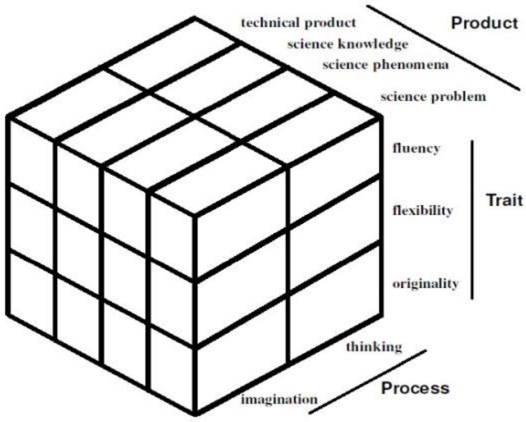

Fig. 1 Scientific Creativity Model (Hu ve Adey, 2002)

According to Hu and Adey (2002), the first dimension of the Scientific Creativity Model is the creative thinking process, while the third dimension is the creative product. The second dimension, creative thinking character, is defined within the framework of three characteristics: fluency, flexibility and originality. Of these, fluency covers all ideas that can provide a solution or answer to a problem situation. Flexibility can be defined as the ability to present different perspectives with regard to the problem, to handle it in different dimensions, to look from a different perspective. Originality can be defined as a situation in which the suggestions presented to the problem can be so specific that few people have previously thought of it.

According to the Scientific Creativity Model, scientific creativity should be based on science knowledge and skills. Establishing science experiments, dealing with problems scientifically, and producing solutions, are important components of scientific creativity. Not all students may be scientists, but each must have the ability to use creative thinking skills at a high level in their profession (Meador, 2003). For this reason, it is important to teach students creative thinking skills. Along with being able to think creatively, the basics of design-oriented thinking should also be taught (Salen, 2007). In this direction, in the present study, the effect of scientific toy design activities on middle school students' scientific creativity developed as a result of understanding the engineering design process, is examined.

In literature there are some studies which examine the use of toys in the classroom to teach science (Ekin, Cagiltay, & Karasu, 2018; Ihamaki & Heljakka, 2018; Samuelson, 2018; Thananuwong, 2015). Using toys in classroom improves students' design ability and creativity (Ming & Johnson, 2004) and also to teach them science concepts (Jarrett, Bulunuz, Jarrett, Bulunuz, 2020). Specifically, teaching science through toys children design by themselves is accepted an effected way to introduce children to scientific inquiry (Jarret, Jafi, 2019). Researchers emphasized that when children play with toys they can also engage in engineering design (Jarrett, Bulunuz, Jarrett, Bulunuz, 2020). The fact that students design their own toys in a scientific framework, and play games by assimilating the engineering design process, will their current developmental features and their future needs. In such an endeavor, engineering, which is an important part of STEM education, comes to the fore. It is thought that using scientific toy design activities based on the engineering design process in science lessons, will support students' creativity and meaningful learning, and provide motivation. Scientific toy design activities will contribute positively to the development of students' imagination, psychomotor skills, creative thinking skills, and problem solving skills (Ming & Johnson, 2004), and will provide the opportunity to develop the engineering design process in practice.

In the literature, it can be seen that there have been national and international studies which have examined the effect of engineering design process applications on students' scientific creativity. The results of the studies conducted with secondary school students, show that STEM applications contribute positively to the development of students' scientific creativity. These studies recommend the integration of the engineering dimension of STEM education with general school lessons (Ceylan, 2014; Cho, Lee, 2013; Ciftci, 2018; Knezek, Christensen, Wood, Periathiruvadi, 2013; Kurtulus, 2019; Senturk, 2017). However, engineering applications involving toy design are limited.

In the science curriculum in Turkey (MoNE, 2018), emphasis is placed on engineering applications and providing students with engineering skills as a result. In addition, it is emphasized that students have a need to develop other important skills such as problem solving and creative thinking. Considering the developmental characteristics of the students, their creative thinking skills can be developed when scientific toys are used in association with science lessons. In this context, in this study, it is planned to have students design scientific toys in science lessons. It is thought that by applying the engineering design process in the context of the STEM education approach, students can gain the skills targeted in the curriculum. It has been determined that studies in which scientific toy design and the engineering design process are used together, are limited in the literature. Consequently, the present study aims to examine the effect of scientific toy design activities based on the engineering design process on the scientific creativity of middle school students.

What are the effects of scientific toy design activities based on the engineering design process on the scientific creativity of middle school students? This problem is the focus of the study. The sub-problems developed in this direction are considered in the following section.

1. Do the scientific creativity skills of secondary school students' change after the scientific toy design activities based on the engineering design process compared to the pre-application?

1.1. Does the fluency dimension of the scientific creativity skills of secondary school students' change after the scientific toy design activities based on the engineering design process compared to the pre-implementation?

1.2. Does the originality dimension of the scientific creativity skills of secondary school students' change after the scientific toy design activities based on the engineering design process compared to the pre-application?

1.3. Does the flexibility dimension of the scientific creativity skills of secondary school students' change after the scientific toy design activities based on the engineering design process compared to the pre-application?

2. Method

2.1. Research Design

In this study, in which the scientific creativity and opinions of middle school students in line with the engineering design process applications were examined, a single group pre-test-post-test experimental design was used. In this design, which is expressed as a single-sample experimental design due to the lack of control group, the effect of the experimental process is tested with a study conducted on a single group (Christensen, Johnson, Turner, 2015, s.258; Buyukozturk, Cakmak, Akgun, Karadeniz, Demirel, 2012). Measuring procedures are applied to the same group with the same measurement tools as a pre-test before the application and as a post-test after the application. The difference between pre-test and post-test scores shows the effect of the application. When the results show that there is a statistically significant difference, it is accepted that the difference arises from the application (Basturk, 2014, p.37). This pattern is recommended for situations where an equalized comparison group cannot be reached (Christensen, Johnson, Turner, 2015, p. 259). In this study, a single group pre-test-post-test experimental design was preferred in line with the purpose of the study and because there was no comparison group.

2.2. Study Group

In the study, the research group consists of 7th grade students of a secondary school. The study group of the research consists of 40 students. Appropriate sampling technique was used in the selection of the study group of the study, due to the fact that the students should have prior knowledge about the application subject in order to be able to do the applications. The reason why 7th grade students are preferred is that, due to the spiral structure of the Science curriculum, students must have achieved the objectives of the relevant unit at the 5th grade and 6th grade before the application can be carried out. Another reason for choosing 7th grade students in the study group is the requirement for students to have psychomotor competencies to perform electrical applications.

2.3. Data Collection Tools

Scientific Creativity Test and open-ended question form were used as data collection tools in the study. While Scientific Creativity Test were applied as pre-test and post-test, open-ended question form was applied after the research.

In this study, the "Scientific Creativity Test" developed by Hu and Adey (2002) and adapted to Turkish by Kadayifci (2008) was used as a pre-test and post-test in this study. The Scientific Creativity Test consists of seven open-ended questions and three dimensions. The answers given to the questions of the test were evaluated in terms of fluency, originality and originality dimensions. The Scientific Creativity Test was applied to 160 students by Hu and Adey (2002), and content validity was ensured by taking the opinions of 35 science educators on the dimensions of scientific creativity. Factor analysis was performed for construct validity. It has been determined that the Scientific Creativity Test measures a main factor. Hu and Adey (2002) calculated the Cronbach Alpha reliability value of the test as 0.893. Kadayifci (2008), who translated the test into Turkish, applied it to 57 students and calculated the reliability of the Turkish-translated form of the test as 0.735. In the present study, the Cronbach Alpha internal consistency value of the Scientific Creativity Scale was calculated as 0.825.

2.4. Application Process

The scientific toy design activities based on the engineering design process were completed in 9 weeks. Applications are designed on the basis of 4 lessons per week. In the first week, a Scientific Creativity Test was applied as a pre-test. The students were then informed about the engineering design process stages. A pilot application was carried out in order to plan the activities that were to be implemented in the research process, and to provide students with preliminary information about the engineering design process. In the pilot application, an activity different from the seven activities in the course process was implemented. The application was carried out by the researcher with the aim of identifying important aspects such as how long would be needed for the activities, the selection and amount of materials needed, and the arrangement of the environment in which the activities would be implemented.

In the main study, from the second week onwards, scientific toy design activities were carried out in accordance with the course content. During the research, 7 activities were designed within the scope of the 7th grade "Electric Energy" unit (MoNE, 2013) and each activity was implemented over 4 lesson hours. The weekly lesson plan template that students can use in applications related to the engineering design process was prepared by the researcher, and the students were told how to use the plan in the first week. In the last week of the study, a post-test and open-ended question form was applied.

In this study, 7 different scientific toy design activities were used. Lesson plans relating to the activities to be implemented each week were prepared and presented to the students. The intention was that the students would encounter a different problem situation in each activity. Groups were formed and the distribution of tasks was carried out. The group members then shared their possible solutions with regard to solving the problem. Following discussion, the students made a decision as to the best solution to the problem under consideration. They then created a draft drawing of their design. Based on the drawing, the construction phase of the prototype was embarked on. For the prototype construction, the students selected the necessary materials from the materials' corner. After the construction of the prototype, each one was tested in front of all the students. The test phase was observed and noted by the group members and the success of the proposed solution was evaluated. In the lesson plan, the activity was completed with the question "What would you change if you had time to redo the design?". In addition, by asking questions with regard to the products produced by the groups, both the details of the design and the information to be gained were evaluated.

Sample of the lesson plan and scientific toys were attached in the appendices 1 and 2.

2.5. Data Analysis

The analysis of the data obtained from the scientific creativity test was carried out by using quantitative data analysis techniques. The data obtained from the students were evaluated individually and in line with the sub-dimensions of the test, taking into account individual percentages within the whole study group. The analysis of the scientific creativity test was calculated separately for each question. The questions and analyses in the test are as follows:

Question 1: "Write down the possible scientific uses of a piece of glass". In the analysis of this question, the student's fluency score, flexibility score and originality score were calculated.

Question 2: "If you had a spaceship to travel through space and go to a planet, what scientific questions would you wish to research"

Question 3: "Think of possible fixes that could make a regular bike more interesting, more useful and more beautiful".

Question 4: "Imagine that there was no gravity. Describe what kind of place the world would be".

The analysis of the first 4 questions were done in a similar way. The fluency, flexibility and originality scores were calculated for each of these questions. In the calculation of the fluency score, 1 point was given to each scientific answer provided by the student. In order to calculate the flexibility score, student's answers were categorized. The flexibility score for each question is obtained by counting the number of categorises or areas used in the answer and 1 point was given for each answer. In calculating the originality score, if the student's answer was seen in less than 5% of the answers of the other students, 2 points were given for each answer. If the answer of the student was seen in between 5% -10% of the answers of the other students, 1 point was given. If the student's answer was seen in more than 10% of the answers of the other students, 0 points were given.

Question 5: "Use possible methods to divide a square into four equal parts".

While calculating the fluency dimension and the originality dimension of this question, the flexibility score is not calculated. In the calculation of the fluency score, 1 point was given for each student's drawing. If the figures drawn by the students are seen in less than 5% of the other students' drawings, they were given 3 points for each answer, 2 points were given for 5-10%, and 1 point was given for more than 10%.

Question 6: "There are two kinds of napkins. How do you test which one is better?
Please write down the possible methods, tools you can use, along with the simple procedure".

In the scoring of this question, the flexibility score and originality score were calculated. Maximum 9 points were given for each method response given (3 points for instruments, 3 points for principles, 3 points for procedures). If an answer included two methods, a total of 18 points could be given. In addition to these scores, the methods specified as being in less than 5% of all answers were given 4 points, 2 points for between 5% -10% and 0 points for more than 10%. Originality is given a large number of points, as it is difficult for students to think of too many methods.

7. Question: "Please design an apple picking machine. Draw a picture, give a name and describe the function of each part".

In the scoring of this question, 3 points were given for each separate feature drawn on the apple machine. Additionally, an originality score of between 1 and 5 was given based on a comprehensive review.

SPSS (17.00) program was used to determine whether or not the data obtained from the scientific creativity test showed a normal distribution, and to compare the pre-test and post-test scores obtained. First of all, the normality of the distribution of the data obtained from the Scientific Creativity Test was examined. Due to the small sample size (<50), the Shapiro-Wilk test was used to check the normality of the distribution. If the distribution results were normal, a dependent (related) groups t-test was performed from the parametric tests, and the Wilcoxon test, one of the non-parametric tests, was applied when the distribution differed from the normal. The Shapiro-Wilk Test Results are presented in Table 1.

Table 1. Shapiro Wilk Test Results

	Fluency		Flexibility		Originality	
	Pre-test	Post-test	Pre-test	Post-test	Pre-test	Post-test
N	40	40	40	40	40	40
$\overline{X}$	11.57	16.80	13.05	19.05	20.70	28.52
p	.00*	.00*	.17	.68	.00*	.00*

*(p< .05)

According to Table (1), it is seen that the distribution is normal in the Flexibility score pre-test post-test data distributions (p> .05), while the distributions of Fluency and Originality scores pre-test-post-test data distributions differ from normal (p < .05).

2.6. Reliability and Validity

Reliability can be expressed as the consistency of the research process and the ability of the research to remain unchanged despite the possible effects of time, place and the researcher (Miles & Huberman, 2015). The reliability of the quantitative data in this study was calculated statistically. The agreement percentages for each question in the Scientific Creativity test were examined by comparing the two experts' coding, the agreement percentages were calculated and presented in Table 2. The agreement percentage for all the questions in scientific creativity test was calculated as 82.27.

Table 2. Agreement Percentages of Scientific Creativity Test

	Q1	Q2	Q3	Q4	Q5	Q6	Q7
Agreement %	79.4	81.4	85.1	83.6	82.2	86.0	78.2

In this study, various applications were made in order to minimize the variables that negatively affect the factors for internal validity, which is defined as the degree of explanation of the changes observed in the dependent variable with the independent variable (Creswell, 2013). In order to increase internal validity, measures can be taken in matters such as the participants being at a certain maturation stage, eliminating the effect of subject loss and pre-test effect (Buyukozturk, et al., 2012; Cresswell, 2013). In this study, the fact that the subjects are at a certain maturation stage was determined by selecting the students by considering their grade levels. In this direction, 7th grade students were selected due to the necessity to have the preliminary knowledge needed in the application process. In order to reduce the effect of participant loss, students were informed about the study before the application and full participation was ensured during the application process. Another effect to increase internal validity is that the participants in the group can remember the questions if the same test is repeated after the pre-test application. For this reason, a certain time must pass before the same test can be applied again. In this study, there is a 9-week period between pre-test and post-test.

3. Findings

3.1. Findings Related to Fluency Score

Findings regarding the fluency score are presented in the table (3).

Table 3. Fluency Score

	Q1	Q2	Q3	Q4	Q5
Pre test	85	88	64	65	83
Post test	138	163	96	114	84

When the pre-test post-test fluency scores of five questions are examined, it is seen that there is an increase in the post-test scores compared to the pre-test scores in all questions. The fluency score of the first question was calculated as 85 for the pre-test and 138 for the post-test. It is seen that the post-test fluency score has increased by 53 points compared to the pre-test score. Fluency scores of the second question, was calculated as 88 for the pre-test, while the post-test score was calculated as 163. When the pre-test and post-test results are compared, it is seen that there is 75 points increase in the post-test compared to the pre-test. Fluency scores of the third question were calculated as 64 points for the pre-test, while the post-test was calculated as 96 points. It is seen that the fluency score has increased by 32 points. The fluency score of the fourth question was calculated as 65 for the pre-test and 114 for the post-test. It is seen that the post-test fluency score has increased by 49 points compared to the pre-test score. The fluency scores of the fifth question were calculated as 83 points for the pre-test, while the post-test was calculated as 84 points. It is seen that there is 1 point increase in fluency score. Sample of the student answers regarding the fluency score are presented in figure 2.1 and figure 2.2.

Sand watch
Solar collector glass

Fig. 2.1 Q1-pretest (S12)

Telescope lens
Microscope lens
Glass to protect special tools
Glass for storing special liquids

Fig. 2.2 Q1-posttest (S12)

3.2. Findings Related to Originality Score

Originality scores of middle school students were analysed separately for each question. Findings regarding originality score are presented in table (4).

Table 4. Originality Scores

	Q1	Q2	Q3	Q4	Q5	Q6	Q7
Pre test	81	83	64	137	10	44	97
Post test	131	192	138	138	16	68	139

As seen in Table (4), the originality scores increased in the post-test compared to the pre-test. In the originality score calculated by taking into account the percentages of the fluency scores of the first question, the pre-test score was calculated as 81, while the post-test score was calculated as 131. It was determined that the originality score of the first question increased by 50 points in the last case. The originality pre-test score of the second question was calculated as 83, while the post-test score was calculated as 192. It is seen that there is 109 points increase in originality scores. When the originality scores are compared, it is seen that the highest increase is in the second question. The originality pre-test score of the third question was found 64 points and the post-test score was found 138. It is seen that there is an increase of 74 points between the originality scores. While the originality pre-test score of the fourth question was calculated as 137, the post-test score was calculated as 138. It was determined that there is a 1 point increase in the originality score of the fourth question in the last case. The originality pre-test score of the fifth question was calculated as 10 points, and the post-test score as 16. When the originality scores are examined, it is seen that there is 6 points increase. While the originality pre-test score of the sixth question was calculated as 44, the post-test score was calculated as 68. It was found that the originality score of the sixth question increased by 12 points. The originality pre-test score of the seventh question was calculated as 97 points, while the post-test score was calculated as 139. When the originality scores are examined, it is seen that there is an increase of 42 points. Sample student answers regarding originality score are presented in figure 2.3 and figure 2.4.

It becomes harder for us to drink
It's hard for us to move
It's hard to go to the toilet
It's hard to take a bath

Fig. 2.3 Q4- pre-test (S1)

Without gravity we would have a hard time taking a bath
We couldn't move freely
We had trouble drinking water
We had trouble eating
The world would be a dangerous place because nothing would be on the ground

Fig 2.4 Q4 –post-test (S1)

3.3. Findings Related to Flexibility Score

Findings regarding the Scientific Creativity Test flexibility score are given in Table (5). In the fifth question, while the fluency and originality scores are determined, the flexibility dimension is not determined. For this reason, the fifth question was not included in the table.

Table 5. Flexibility Scores

	Q1	Q2	Q3	Q4	Q6	Q7
Pre test	7	4	16	10	310	297
Post test	36	13	48	29	350	432

As can be seen in Table (5), in all six questions for which the flexibility score was calculated, there was an increase in the post-test scores when compared to the pre-test scores. Flexibility score of the first question was calculated as 7 for the pre-test and 36 for the post-test (Table 5). It is seen that the flexibility score has increased by 29 points. For the flexibility scores, the answers given by the students are categorized. The categories created in order to calculate the flexibility score of the first question are given in Table (6).

Table 6. Categories Created For The First Question

Category No	Category
E1	Use for storage (preservation)
E2	Use for designing an experiment

E3	Use for innovation
E4	General use
E5	Use for Physics, Chemistry and Biology
E6	Use for mathematical purposes

Flexibility score of the second question was calculated as 4 for the pre-test and 13 for the post-test. It is seen that the flexibility score has increased by 9 points (Table 5). The categories created in order to calculate the flexibility score of the second question are given in Table (7).

Table 7. Categories Created For The Second Question

Category No	Category
E1	Formation of the planet / universe / world
E2	The geographic structure and atmosphere of the planet
E3	General characteristics of the planet (star, sky visible? ...)
E4	Science and science-related events / technology on the planet
E5	Comparisons - Difference / Similarity (As Planet, Earth and Human)
E6	Life and characteristics of living creatures on the planetdöngü/oksijen/bitki/
E7	Climate and natural events on the planet (season, day and night)
E8	Social life on the planet
E9	Energy sources on the planet
E10	Off-planetary questions

Flexibility score of the third question was calculated as 16 for the pre-test and 48 for the post-test. It is seen that the flexibility score has increased by 32 points (Table 5). The categories created in order to calculate the flexibility score of the third question are given in Table (8).

Table 8. Categories Created For The Third Question

Category No	Category
E1	Aesthetic
E2	Energy-saving
E3	Security
E4	Innovative view
E5	Usefulness

Flexibility score of the fourth question was calculated as 10 for the pre-test and 29 for the post-test. It is seen that the flexibility score has increased by 19 points (Table 5). The categories created in order to calculate the flexibility score of the fourth question are given in Table (9).

Table 9. Categories Created For The Fourth Question

Category No	Category
E1	Living and life (biological)
E2	Transportation
E3	Health
E4	Nature and natural phenomena
E5	Life in general and social sense
E6	Inventions / technology
E7	Scientific view

Flexibility score is not calculated for the fifth question.

Flexibility score of the sixth question was calculated as 310 for the pre-test and 350 for the post-test. It is seen that the flexibility score has increased by 40 points (Table 5). The categories created in order to calculate the flexibility score of the sixth question are given in Table (10). In line with student answers, more categories were created in the post-test compared to the pre-test.

Table 10. Categories Created For The Sixth Question

Categories Created for Pre-Test		Categories Created for Post-Test	
No	Category	No	Category
E1	Reaction to different chemicals	E1	Reaction to different chemicals
E2	Weight / Thickness / Fold / Fold	E2	Weight / Thickness / Fold / Fold
E3	Soaking / Water absorption time /	E3	Stain / Water cleaning / Drying
E4	Tear / Durability	E4	Soaking / Water absorption time /
E5	Combustion	E5	Tear / Durability
E6	Feel / Softness / Touch Dokunma	E6	Combustion
E7	Length	E7	Drying time
E8	Physical appereance	E8	Feel / Softness / Touch
E9	Light transmittance	E9	Color
		E10	Pattern
		E11	Length
		E12	Physical appereance
		E13	Light transmittance
		E14	Brand / Price
		E15	Flexibility

Flexibility score of the seventh question was calculated as 297 for the pre-test and 432 for the post-test. It is seen that the flexibility score has increased by 135 points (Table 5).

3.4. Findings Regarding the Comparison of Scientific Creativity Pre-test Post-test Scores

Results of the correlated group t test performed to determine whether there is a difference between flexibility dimension pre-test and post test scores of the students' are given in table 11.

Table 11. Flexibility Dimension- Results of Correlated Group t Test

Gruplar	*N*	$\bar{x}$	*ss*	$Sh_{\bar{x}}$	*t* Test		
					t	*Sd*	*p*
Pre test	40	13.05	5.57	.88	-4.74	39	.00*
Post test	40	19.05	6.63	1.03			

(*p<0,05) (η2 = 0,98)

According to the related group t test analysis results, a statistically significant difference was found between the flexibility scores of the students before and after the application. Considering the pre-test and post-test average scores, this difference is in favor of the post-test. According to this result, it can be said that the applications of scientific toy design activities based on the engineering design process have a positive effect on the "Flexibility" scores of the students.

Results of wilcoxon signed ranks analysis performed to determine whether there is a difference between the fluency dimension of pre-test and post-test scores and the originality dimension of pre-test-post-test scores are given in table 12.

Table 12. Fluency and Originality Dimensions-Results of Wilcoxon Signed Ranks Analysis

Dimension	Groups	N	$\bar{x}_{sira}$	$\sum_{sira}$	z	p
Fluency	Negative ranks	4	18.25	73.00	-4.32	.00*
	Positive ranks	34	19.65	668.00		
	Ties	2				
	Total	40				
Dimension	Groups	N	$\bar{x}_{sira}$	$\sum_{sira}$	z	p
Originality	Negative ranks	12	13.92	167.00	-3.26	.00*
	Positive ranks	28	23.32	653.00		
	Ties	0				
	Total	40				

($\eta_F^2 = 0.683$; $\eta_O^2 = 0.51$)

Analysis results showed that there are statistically significant differences between the fluency pre-test and post-test scores and the originality pre-test and post-test scores of the students (Z_F: -4.32; Z_O: -3.26; $p < .05$). Considering the mean ranks and totals of the difference scores, it is understood that the differences found are in favor of the positive ranks, that is, the post-test. According to these results, it can be said that the application has a positive effect on the fluency and originality dimensions of the scientific creativity test.

4. Discussion and Conclusion

Creative thinking is one of the 21st Century's most important skills that needs to be developed on the part of students to allow them to adapt in future years. In the Ministry of National Education (MoNE, 2018) Science Curriculum, it can be seen that creative thinking skills, accepted among the life skills that individuals should have, is of great importance. It is also emphasized that creative thinking skills help students to find solutions to the problems they encounter (Demir, 2014; Kadayifci, 2008; Pekbay, 2017).

As a result of the current study, it has been determined that the creative thinking skills of the students involved developed. Similar results have been found in other studies. The creativity of 8th grade students was examined in a study in which the science, technology, engineering and mathematics approaches based on acids and bases in the middle school science course. As a result of the experimental research conducted with the control group, a pre-test-post-test approach was applied, and it was stated that the creativity skills of the students in the experimental group had increased (Ceylan, 2014). In studies evaluating the effect of the engineering design process and STEM education on creative thinking skills, it is seen that creativity skills can be developed (Erdogan et al., 2013; Eroglu, 2018; Knezek et al., 2013; Lawanto et al., 2013).

The scientific creativity test consists of three dimensions: fluency, originality and flexibility. Within the scope of the scientific creativity test, fluency is defined as the total number of ideas that can form an appropriate answer to a problem situation (Kadayifci, 2008). The fluency dimension of the scientific creativity test was examined with the use of the first five questions. The fluency score is calculated by giving one point to each answer considered valid (Hu & Adey, 2002). As a result of the research, it was determined that there was an increase in the fluency score as measured by the post-test. In this context, it can be said that scientific toy design activities based on the engineering design process contribute to the development of the fluency dimension of scientific creativity in students. Similarly, in studies in which STEM-based applications were carried out with regard to secondary school students, it was found that fluency scores of the experimental group increased after the application (Kurtulus, 2019; Senturk, 2017). At the same time, it has been determined that such applications are effective with regard to the creativity of students in advanced classes. As a result of a study investigating the effect of STEM applications on the scientific creativity of 9th grade students, it was determined that fluency scores increased (Eroglu, 2018).

Within the scope of the scientific creativity test, originality is defined as one of the characteristics that individuals with creative thinking skills should have (Kırısoglu, 2002). The "originality" dimension is based on the ability of individuals to present rare and unique answers, in contrast to the majority (Demir, 2014; Hu & Adey, 2002). Being able to produce unique products on the basis of these original ideas is closely related to the dimension of originality. In line with these definitions, it is important for students to develop original ideas. Accordingly, in the present study, whether or not the originality dimension of the scientific creativity test changed depending on the scientific toy design activities based on the engineering design process engaged in by students was analysed. The originality dimension was calculated for all questions in the pre-test and the post-test, and it was found that the originality scores of all questions increased after the application. Similarly, in a study examining the effect of STEM activities on the scientific creativity of 7th grade students in a science class, it was found that the originality scores as measured by the scientific creativity test increased (Senturk, 2017). When the results are evaluated, it can be said that the STEM activities applied in the studies positively affect the development of original ideas.

Flexibility is the ability to produce a number of different perspectives and different approaches (Hu & Adey, 2002). One of the important skills needed in the 21st Century is to be able to think flexibly (Kelesoglu & Kalayci, 2017; Eroglu, 2018; Wagner, 2008). The International Technology and Engineering Association (ITEA) (2007) reported that STEM education contributes to students' flexible thinking. In the present study, the flexibility dimension of the scientific creativity test was calculated for 6 questions. In the first 5 questions, the number of categories determined as a result of pre-test and post-test analysis did not change. However, as a result of the analysis of the 6th question, 9 categories were created in the pre-test, and 15 categories were created in the post-test. As a result of the post-test analysis of this question, the increase in the number of categories showed that scientific toy design activities contributed to the flexibility dimension on the part of the students.

In all questions for which flexibility scores were calculated, it was found that there was an increase in the post-test scores. Similarly, in a study in which STEM applications were performed with 7th grade students, it was found that the flexibility scores increased (Senturk, 2017). Consequently, it has been determined that the engineering design process applications improve flexible thinking on the part of students, and therefore contribute positively to the development of creative thinking skills.

It is understood from the results obtained from the research that the scientific creativity of the students improved positively as a result of scientific toy design activities based on the engineering design process. There are similar studies in the literature emphasizing that the engineering design process and STEM education contribute positively to scientific creativity (Eroglu, 2018; Ciftci, 2018; Gulhan, 2016; Ozcelik, Akgunduz, 2018; Senturk, 2017). In a study examining the effects of STEM-based activities on the scientific creativity of 7th grade students, it was concluded that the scientific creativity levels of students increased (Ciftci, 2018). In another study, Ozcelik and Akgunduz (2018) examined gifted students with regard to STEM education. The activities used in the research were prepared in accordance with the engineering design process, and it was determined that STEM education improved the students' creativity. Lawanto et al. (2013) also stated that the engineering design process improves students' creative thinking skills, while Morrison (2006) stated that STEM education contributes to students being individuals who can make creative designs by recognizing global needs. The researchers emphasized that teaching and learning become more successful when students learn through doing in the classroom, and when they encounter the challenge themselves (Rahmat, Leng & Mashudi, 2021). In addition, students develop important skills when authentic and multidisciplinary pedagogical design is implemented (Hawari & Noor, 2020).

According to the current research results, scientific toy design activities based on the engineering design process contribute positively to the scientific creativity of middle school students. It is observed that there is a positive increase in students in terms of the fluency, originality and flexibility sub-dimensions of the scientific creativity test. When the results obtained from the current study and the results of the studies in the literature are evaluated, it can be suggested that scientific toy design activities based on the engineering design process in science courses can contribute to the creative thinking skills of the students involved. The development of scientific creative thinking skills will also transform students into individuals who can think differently in the 21st Century and will be effective in allowing them to adapt better to the age they live in.

The results of this study has an importance in terms of science teacher training program. To implement scientific toy design activities in the science lessons, science teachers need to have some skill, such as implementing engineering design process in the classroom and also creativity. Research on science teachers' implementation of engineering design activities are getting increase in literature, but studies related with scientific toy design based on engineering design process was so limited. Therefore, science teachers' training programmes should include such of these activities to increase preservice science teachers' knowledge, self-confidence related design based process and also their creativity.

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Appendices

1. Lesson Plan

Lesson:	**Subject**
Grade:	**Duration**

Group name:
Group leader: ....
Researchers: ....
note writers: ....
Material providers: ....
Practitioners: ....
....

1. Learning Outcomes

2. Problem and limitations:

3. Developing Possible Solutions

a. Possible solutions

b. The Most Appropriate Solution Proposal:

Drawing

Explanation

4. Materials :

5. Prototype Construction Stages:

6. Changes Made in Draft Drawing During Prototype Construction

The changes that have been made

What is the reason for the change made?

6. Prototipin Test Edilme Aşaması:

Testing Observation Notes:

Results:

Did your solution suggestion to the problem work??

( )Yes ( ) No

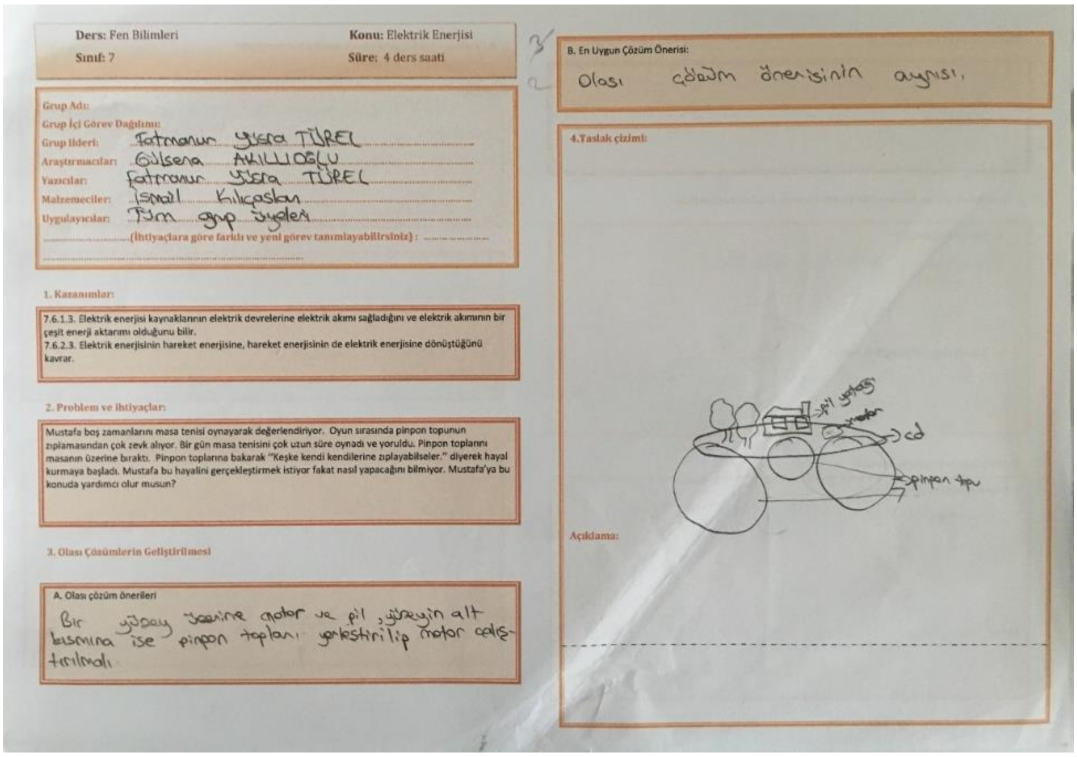
Why?

What stage of the design process do you enjoy the most??

Why?

What would you change if you had time to redo the design??

2.Sample of Lesson Plan



Ders: Fen Bilimleri **Konu:** Elektrik Enerjisi
Sınıf: 7 **Süre:** 4 ders saati

Grup Adı:
Grup İçi Görev Dağılımı:
Grup lideri: Fatmanur Yüsra TÜREL
Araştırmacılar: Gülsena AKILLIOĞLU
Yazıcılar: Fatmanur Yüsra TÜREL
Malzemeciler: İsmail Kılıçaslan
Uygulayıcılar: Tüm grup üyeleri
(İhtiyaçlara göre farklı ve yeni görev tanımlayabilirsiniz) :

1. Kazanımlar:

7.6.1.3. Elektrik enerjisi kaynaklarının elektrik devrelerine elektrik akımı sağladığını ve elektrik akımının bir çeşit enerji aktarımı olduğunu bilir.
7.6.2.3. Elektrik enerjisinin hareket enerjisine, hareket enerjisinin de elektrik enerjisine dönüştüğünü kavrar.

2. Problem ve İhtiyaçlar:

Mustafa boş zamanlarını masa tenisi oynayarak değerlendiriyor. Oyun sırasında pinpon topunun zıplamasından çok zevk alıyor. Bir gün masa tenisini çok uzun süre oynadı ve yoruldu. Pinpon toplarını masanın üzerine bıraktı. Pinpon toplarına bakarak "Keşke kendi kendilerine zıplayabilseler." diyerek hayal kurmaya başladı. Mustafa bu hayalini gerçekleştirmek istiyor fakat nasıl yapacağını bilmiyor. Mustafa'ya bu konuda yardımcı olur musun?

3. Olası Çözümlerin Geliştirilmesi

A. Olası çözüm önerileri

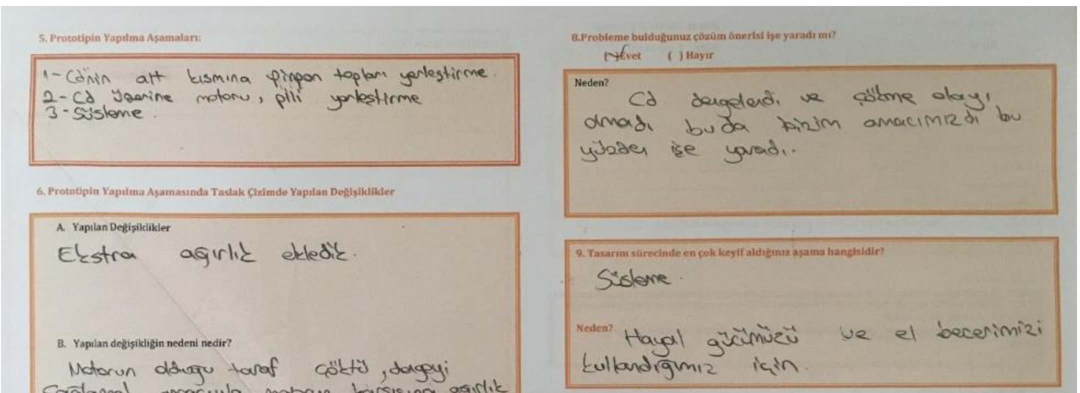
Bir yüzey üzerine motor ve pil, yüzeyin alt kısmına ise pinpon topları yerleştirilip motor çalıştırılmalı.

B. En Uygun Çözüm Önerisi:

Olası çözüm önerisinin aynısı.

4.Taslak çizimi:

Açıklama:



5. Prototipin Yapılma Aşamaları:

1- Cd'nin alt kısmına pinpon topları yerleştirme.
2- Cd üzerine motoru, pili yerleştirme
3- Süsleme.

6. Prototipin Yapılma Aşamasında Taslak Çizimde Yapılan Değişiklikler

A. Yapılan Değişiklikler

Ekstra ağırlık ekledik.

B. Yapılan değişikliğin nedeni nedir?

Motorun döndüğü taraf çöktü, dengeyi sağlamak amacıyla motorun karşısına ağırlık

8.Probleme bulduğunuz çözüm önerisi işe yaradı mı?

(X) Evet ( ) Hayır

Neden?

Cd dengelendi ve çökme olayı olmadı bu da bizim amacımızdı bu yüzden işe yaradı.

9. Tasarım sürecinde en çok keyif aldığınız aşama hangisidir?

Süsleme.

Neden? Hayal gücümüzü ve el becerimizi kullandığımız için.

3.Sample Photos of the Toys